The Effectiveness of Peer Instruction (PI) in Enhancing Pre-service Teachers' Understanding of Electromagnetism I in a Nigerian College of Education

A full thesis submitted in fulfilment of the requirement for the degree Doctor of Philosophy

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DECLARATION BY CANDIDATE

I AINA JACOB KOLA, hereby declare that this treatise/dissertation/thesis, **"The Effectiveness of Peer Instruction (PI) in Enhancing Pre-service Teachers' Understanding of Electromagnetism I in a Nigerian College of Education"** is my own work; that it has not been submitted before for any examinations or degree purposes, in another University or for another qualification.

AINA JACOB KOLA

SIGNED: ………………………………….. **DATE:**

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My sincere and unequal appreciation goes to my Almighty God, who made my journey through school a possibility. I would not have been able to go to school if not for the mercy of God upon my life. Since I started in primary one, God has been keeping and endowed me with wisdom to cope in school. There are many of my classmate who had died while many are not able to go through to this level: allowing me to this level is by the mercy of God. I am not better than those who could not, may His name be exalted.

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God bless you all.

DEDICATION

I dedicate this work to the Almighty God for His abundant grace upon my life. If not for His grace that is abundant in my life, I am not worthy of attending the four walls of the school not to talk of studying for a doctoral degree. God is good to me from my first day in the school until now that I am compiling this doctoral thesis. To God, only be the glory. By today I am proud that I belong to Jesus the only begotten Son of God.

"But by the grace of God I am what I am: and his grace which was bestowed upon me was not in vain… "

1 Corinthian 15:10

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ABBREVIATIONS

AAPT:	American Association of Physics Teacher
AL:	Authentic Learning
ANCOVA:	Analysis of Covariance
C:	Capacitance
CA:	Correct Answer
CAI:	Computer Aided Instruction
CCT:	Constructive Controversy Theory
CESAC:	Comparative Education Study Adaptation Centre
CGPA:	Cumulative Grade Point Aggregate
DAIM:	Dialogical Argumentation Instructional Model
ERS:	Electronic Response System
EMF:	Electromotive Force
EPA:	Electromagnetism Physics Assessment
FME:	Federal Ministry of Education
FRN:	Federal Republic of Nigeria
GW:	Gigawatt
I:	Current
ICT:	Information Communication and Technology
IT:	Information Technology
ILO:	International Labour Organization
JAMB:	Joint Admission Board Examinations
JSS:	Junior Secondary School
KV:	Kilovolt
KWH:	Kilowatt per Hour
MW:	Megawatt
NCCE:	National Commission for Colleges of Education
NCE:	Nigerian Certificate in Education
NECO:	National Examination Council
ND:	No Date
NPE:	National Policy on Education
NSSSP:	Nigerian Secondary School Science Project
PBL:	Project Base Learning

PCC:	Piaget Cognitive Constructivism
PCK:	Pedagogical Content Knowledge
PD:	Potential Difference
PI:	Peer Instruction
PIDAIM	Peer Instruction Dialogical Argumentation Instructional Model
PIDAQ:	Peer Instruction Dialogical Argumentation Questionnaire
R:	Resistance
RCCB:	Residual Current Circuit Breaker
SCT:	Social Constructivism Theory
STAN:	Science Teacher Association of Nigeria
SSP:	Senior Secondary Physics
SSS:	Senior Secondary School
TW:	Terawatt
US:	United States
V:	Volt
VSC:	Vygotsky Social Constructivism
W:	Watt
WAEC:	West African Examination Council
WASSCE:	West African Senior School Certificate Examination

ABSTRACT

This research study investigated the effectiveness of Peer Instruction (PI) in enhancing pre-service teachers' understanding of Electromagnetism I in a Nigerian college of education. PI as a research-based pedagogy was invented for the teaching of introductory science courses to large classes. Lectures in PI is made of short presentations on the main points, each followed by short conceptual questions known as ConcepTest, posed in a multiple-choice format, on the subject under discussion. Electromagnetism is a branch of Physics where students perform poorly at Colleges of Education in Nigeria. Electromagnetism I covers electrostatics, magnetostatics, current electricity, electrolysis, and capacitance. Each of these themes has different topics under it. Most students studying Electromagnetism I, cannot relate or connect what they learned in the classroom to real-world situations because they often learn by memorization (rote learning). Therefore, there is a lack of what is called an Authentic Learning (AL) experience. The study purposively sampled 52 pre-service Physics teachers from a selected College of Education in a Nigerian state. The sample is mainly all the first-year students of Physics who enrolled for Electromagnetism I in this college. The research questions addressed are: What is the pre-service science teachers' understanding of Electromagnetism I before and after peer instruction intervention? Is there any gender difference in academic performance in Electromagnetism I of the pre-service science teachers who participated in the Peer Instruction intervention? Does the use of Peer Instruction enhance the pre-service science teachers Authentic Learning experiences associated with Electromagnetism I? The study is a pre-post-test quasi-experimental design. The research instruments employed to collect data were Electromagnetism Physics Assessment (EPA), Peer Instruction Dialogical Argumentation Questionnaire (PIDAQ) and semi-structured interviews. Data collected from experimental design and interviews were analyzed using the descriptive statistics, t-test, and ANCOVA. The study integrated DAIM into the PI purposely to investigate how students learn when PI is employed in science class. The outcome of the analysis revealed that the students' knowledge of Electromagnetism I before and after the intervention was weak. However, the result reveals significant improvement in the students' understanding after the intervention. The results indicated that there was a significant difference between male and female student's performance after the PI intervention. Also, the result shows that students' understanding was enhanced when a Dialogical Argumentation Instructional Model (DAIM) was used. The emergence of peer instruction dialogical

argumentation model (PIDAM) and peer instruction authentic learning framework for learning electromagnetism are novels in this study.

Some implications of the study provide relevant information for use by science education policy-makers, teacher education programmes, teacher educators, pre-service teachers, and in-service teachers. The study concludes with some recommendations for all stakeholders in education and also makes suggestions for further areas of research on socio-scientific-cultural issues.

Keywords: Peer instruction, electromagnetism, academic performance, authentic learning, rote learning, ConcepTest, teaching pedagogy, dialogical argumentation, misconception.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Studies show that methods of teaching may be one of the causes of students' poor academic performance in Physics courses (Wanbugu, Chiangeiywo & Ndirit, 2013). Malcolm, Hestenes, and Swackhamer (1994) observed that the effectiveness of Physics instruction is very dependent on the pedagogical expertise of the teacher. The teacher is expected to involve students in active learning stimulated inquiry (McCarthy & Anderson, 2000). However, research studies show that the traditional lecture approach still dominates teaching in most post-secondary schools (Deslauriers, Schelew & Wieman, 2011).

Watkins and Mazur (2013) also attributed failure in science to poor pedagogy. Crouch, Watkins, Fagen, and Mazur (2007) affirmed that courses taught in traditional ways do little to improve students' understanding of the central concepts of Physics. Research shows that commonly used teaching methods such as the traditional lecture method do not help the students acquire sufficient functional understanding of Physics (Bernhard et al., 2007). Rote learning is a typical experience for most students in Physics (Fagen, 2003).

Studies have shown that students' academic performance in Physics in Nigerian schools is usually bad. The poor performance is at all levels of education which include secondary schools. Stephen (2010) observed that the poor performance of the students in Physics, both at secondary and post-secondary schools in Nigeria is of concern to everybody. Students' dwindling performances in Physics in public examinations are given stakeholders in education a severe burden in Nigerians (Folashade & Akinbobola, 2009; Dupe, 2013). Opinions differ about these students' academic performance based on the student's gender. There are gender differences in Physics performance among colleges of education students (Alao & Abubakar, 2010; Aina & Akintunde, 2013). Stephen (2010) and Victoria (2011) posited that male students performed better in Physics than female students in secondary school. Crouch, Watkins, Fagen, and Mazur (2007) observed that there is no gender gap in conceptual understanding of introductory Physics among university students when taught through an interactive pedagogy.

Most research findings, however, refer to poor student's performance in Physics without identifying the specific aspects of Physics that students struggle to understand. Some of these aspects have been identified as current electricity and electrostatics (Engelhart & Beichner, 2003; Guisasola, Zubimendi & Zuza 2010) which will be grouped under the topic of

Electromagnetism I for this study based on the Physics curriculum offered in Nigeria by the National Commission for Colleges of Education (NCCE, 2008).

The National Commission for Colleges of Education (NCCE) has the responsibility of coordinating the programmes of Colleges of Education in Nigeria. Students admitted into the Physics programme are those who have completed their secondary school education and passed Physics at credit level. The Nigerian secondary education structure considered a student's score between 50% and 100% as a pass with credit; between 40% and 49% as a pass and below 40% as a fail (WAEC, 2004). The students on this programme are awarded a Nigerian Certificate in Education (NCE) after completing three years of intensive training.

A student may perform better in optics and modern Physics, but not in electronic Physics. Results are computed and compiled as an overall score, which means the overall cumulative grade point average (CGPA) of such a student may be weak because of low marks in electronics Physics. It is therefore incorrect to generalize the statement that the student is weak in Physics. This study focused on the teaching and learning of Electromagnetism I as an area that seemingly presents conceptual challenges (Jackman, 1999).

1.2 Contextual Background

Science teaching and learning in Nigeria can be dated back to the time of informal education in 1842 (Ojebiyi & Fasakin, 2014). Teaching and learning of science at this period were conducted through storytelling and by role play (Aina & Adedo, 2013). This was non-formal and non-certified regarding competencies and took place at various stages of a child's life. The knowledge was presumed to be static, and the pedagogic techniques used were mainly memorization and the strict imitation of adults' behaviour (Okoro, 2011). During this time, there was no specific method of teaching because teaching and learning were done outside the four walls of any classroom. There was no particular science curriculum. Abdullahi (1982) is of the view that the period between 4000 and 3000 B.C no meaningful teaching and learning of science occurred.

The colonial period is another era in the history of the Nigerian educational system where the Nigerian colonial master- the British, brought education in with religion. The Christian Missionary trained people to serve as an interpreter for a while preaching to the indigenous population. British colonial education aimed to train clerks for interpretation of language, administration, and commercial activities. British colonial education, therefore, intruded into what the Nigerians regarded as foreign ideologies, culture, and values (Okoro, 2011).

The introduction of science into the Nigerian educational system was as general science (Abdullahi, 1982). The general science curriculum was designed to reflect the desire and aspiration of the British government. The curricula of schools during the colonial era was not synchronized and balanced with the needs and aspirations of the people (Sulaiman, 2012). The wishes of the British were to produce the clerks required for the growing administration and expanding commercial enterprises in Nigeria. Also, to give their support to the Missionaries who provided education to further the religious purposes of the colonizer. The primary intention of the missionaries was evangelization and Christianization of the heathen Africans (Oyeleke & Akinyeye, 2013, p.74). This objective was pursued zealously by missionaries' organizations such as the CMS, Wesleyan, the Catholic Mission, Baptist and the Church of Scotland.

Science education was not seen as a significant part of the country's education system because the motives of the missionaries were mainly for the evangelization and production of clerks that could assist them in their commercial enterprise (Ojebiyi & Sunday, 2014). Thus, the motive of the missionaries was not to develop Nigerian citizens as scientists.

The science content was based on the British environment, and all textbooks used clear examples from the British environment in England and not Nigeria. The British have the belief that Africans are biologically inferior to the Europeans, therefore, cannot be taught the specialized vocabulary of science and its mode of inquiry (Ojebiyi & Fasakin, 2014). It was apparent that the British were not willing to lose control over the nation because of the discovery of petroleum and its benefit to their expansionism programme of colonization. The European nations used their strong powers to introduce a Western Education which was foreign to the African countries to exploit the Continent (Suleiman, 2012). The colonialism is a means by which the European nations have direct political control over the Africa countries, to protect their economic interest in an exploitative way. Thus, colonialism is not only a system of exploitation but also a means to repatriate the profits to the metropolis. Therefore, the discovery of petroleum in Nigeria afforded the European this unique advantage. They deceived Nigerians to provide the right education through which the nation could train indigenous engineers and skilled workers for oil exploration. Teaching and learning in schools were tailored towards teaching and mastery of the specific subject and students ability were identified by their capacity to memorize and reproduce facts for passing examinations from these subjects (Okoro, 2011). Therefore, the British objective of science teaching at this period was not to produce Nigerian doctors, lecturers or engineers.

The content of science involved learning about the environment, plants, animals and non-living things. The science curriculum was modelled on British syllabi, with content and activities in science that did not align with Nigerian students' experience and culturally inappropriate (Ogunmade, 2005). There was nothing called Biology, Chemistry and Physics but General Science with the emphasis on personal hygiene and environmental sanitation.

For instance, the concept of the Melting point in the science curriculum was foreign to the students in Nigerian schools because the majority of the students had not come across the ice. Nigeria climate is not a cold one that formed ice; also, not many households can afford a refrigerator. The General Science contents were foreign to both Nigerian students and teachers. British authors wrote in English and not in the Nigerian vernacular and illustrations and examples were based on phenomena relevant to the British environment. Given this scenario, teaching and learning science was by reading directly from the textbook and pupils relied on rote learning and memorization. The Nigerian pupil was denied skills and practice on how to solve local home-based real-world problems. According to Adeyemo (2010), no vital science was taught in Nigerian schools from 1842 to 1960, the colonial era before independence. After Nigerian independence in 1960 between 1969 and 1975 curriculum, workshops and conferences coming up. These workshops and conferences evolved into a science curriculum for both the primary and post-primary school as contained presently in the National Policy on Education (NPE) (FRN, 2004).

Before 1960, the schools in Nigeria depended heavily on the staff of expatriate teachers and Missionaries. A significant number of these expatriates had no teaching qualifications (Akindutire & Ekundayo, 2012). There was an increase in pupil enrolment resulting in more schools being established immediately after the independence. In 1952 and 1957 both the West African Examination Council (WAEC) and the Science Teacher Association of Nigeria (STAN) were respectively inaugurated which brought remarkable changes in the country's science education. The 1968 collaboration between STAN, the Ministry of Education and Comparative Education Study and Adaptation Centre (CESAC) brought about the introduction of Biology, Chemistry and Physics into schools in Nigeria (Aina & Adedo, 2013). However, there remained a serious problem of a shortage of qualified teachers. Also, the Ashby Commission report of 1960 indicated an inadequate supply of teachers in Nigerian schools (Akindutire & Ekundayo, 2012). The Commission, therefore, recommended the training of more teachers for secondary education. It also recommends the establishment of more universities and institutions for training more qualified teachers.

Before the Ashby Commission report in 1960, the highest level of the professionally qualified teacher in Nigeria was Grade 1. This commission report recommended two years of Advance Teacher's College programme underwritten by the Institutes of Education of Universities (Afe, 2006). The Advanced Teacher's College programme was later developed to three years of Nigerian Certificate in Education (NCE). This category of teachers (NCE teacher) forms the sample for this study.

As part of the attempts to develop science education in Nigeria, between 1970 and 1972, CESAC established the Nigerian Secondary School Science Project (NSSSP). The NSSSP according to Awolola (2004), was up to 1978 trial-tested, and in 1980 published the first revised edition of the project instructional materials and integrated into the secondary school system.

Before the development of NSSSP Physics, the curriculum development conference of 1969 sponsored by CESAC had identified some problems of Physics teaching and learning in Nigeria. The conference participants observed that teaching of Physics was theoretical, abstract and uninteresting. According to Awolola, the participants also observed that Physics teachers were not adequately qualified both in content and methodology to teach Physics. Furthermore, the few qualified teachers could not give their best because they were overloaded with work.

The evolvement, implementation, and evaluation of the NSSSP yielded encouraging results. These resulted in the organization of science content at the secondary school level. The NSSSP was developed for Biology, Chemistry, and Physics.

According to Akindutire and Ekundayo (2012), teacher education is a veritable tool for educational development. The National Policy on Education (NPE) states that teacher education will always be given a respectable status in all educational planning. Therefore, NPE emphasized that all teachers in the nation's educational institutions from pre-primary to the university would be professionally trained.

The objectives of the NPE were:

- To produce highly motivated, conscientious and efficient classroom teachers for all levels of our education system;
- To encourage further, the spirit of inquiry and creativity in teachers;
- To help teachers to fit into the social life of the community and society at large and to enhance their commitment to national objectives;

- To provide teachers with the intellectual and professional background adequate for their assignment and to make them adaptable to any changing situation, not only in the life of their country but the full world; and
- To enhance teachers' commitment to the teaching profession (FRN, 2004).

According to Omosewo (2009), Physics was introduced in Nigerian secondary schools at the senior level because of the immediate perception of its numerous advantages:

- to provide a basic literacy in Physics for functional living in society;
- to acquire basic concepts and principles of Physics as a preparation for further studies;
- to acquire essential scientific skills and attitudes as a preparation for the technological application of Physics; and
- to stimulate and enhance creativity (Federal Ministry of Education, 185, p.5).

Nigeria is yet to achieve self-reliance as a nation because of the many challenges emanated from poor Physics education. Some of these difficulties are insufficiently qualified teachers, inadequate laboratory equipment, and inadequate teaching methods. These challenges are discussed in detail in the literature review section. A nation which develops its Physics education appropriately may have solutions for most of these difficulties (Omosewo, 2009).

Students can continue their Physics education career in Nigeria beyond secondary school by either proceeding to a university or a college of education. However, research studies show that Physics classrooms are predominantly factual: this implies that Physics students are reduced to passive participants in the classroom (Owolabi, Akintoye & Adeyemo, 2011). In the same vein Sheriff, Maina and Umar (2011) contended that teaching of Physics in Nigerian schools was characterized by the traditional didactic method. The authors stressed further that this method promotes merely more rote learning and memorization, which hardly develops a conceptual understanding of the subject matter.

In an attempt to develop Nigerian education after independence, teacher training institutions were established. The primary objective is to train qualified teachers for the growing Nigerian economy. The College of Education in Nigeria is one such teacher training institution established to train teachers for the primary and the junior secondary schools. The prescribed courses for students in the college are those required to be taught in primary school and junior secondary school. However, some courses like Physics offered at this college are not directly taught in the junior secondary school but is relevant for teaching and learning in integrated science. Integrated Science is teaching science in a way to present scientific ideas as a unified whole (Ajao, 1996). It is a subject that comprises of Biology, Chemistry, Physics and partly any other science-related subject. Integrated Science is an amalgamated course designed to show unity, wholeness, and interrelationship of the distinctions that make up science (Daudu, 1984). Integrated Science syllabus is merely a collection of topics from single disciplines in science (Abba, 2000). Integrated Science provides students with a sound basis for further science education studies (Oludipe, 2012).

Research studies indicate that the quality of NCE teachers currently produced by the Colleges of Education is not encouraging at all (Akinbote, 2007; Aina, 2014). The poor quality of these teachers is due to many factors like an unsatisfactory method of teaching as well as admission policy (Akinbote, 2007; Aina, Olanipekun & Garuba, 2015). This situation is worrisome because NCE is the minimum qualification a teacher can possess in Nigerian schools (Ibidapo-Obe, 2006; Akinbote, 2007; Akindutire & Ekundayo, 2012). It has been observed that Nigerian students performed poorly in Physics (Aigbomian, 1994; Uguanyi, 1994). The reasons for the poor performance may also be traced to the type of teacher teaching the subject such as poorly qualified NCE teachers as mentioned above.

Aiyelabegan (2003) queried the attitude of the teachers and the students to Physics teaching and learning as one of the factors contributing to poor performance. For Akanbi (2003), poor performance in Physics may be due to some fundamental reasons, which could be caused by a shortage of science teachers in quality and quantity, inadequate laboratory equipment, and facilities. Onah and Ugwu, (2010) viewed students' poor academic performance as due to teacher qualification, school location, and student's interest among many others. Schools in urban cities do have qualified Physics teachers with access to modern learning resources, such as computers, laboratories, and science equipment: this contributed to better performance than their counterparts in rural areas. Mekonnen (2014) argued that the student's background and environment are two important factors contributing to a student's poor performance in Physics.

The limiting factors mentioned above are crucial to Physics students' academic performance. For instance, many students who came from uneducated backgrounds may not perform as well in Physics as those who came from an educated background. The teaching pedagogy is essential to learning in science irrespective of the students' background. It is on this basis that the current study is considering peer instruction by incorporating the DAIM to make it an innovation.

1.3. The PI and the Incorporation of the DAIM (PI-DAIM)

The use of PI involves the instructor starting with a brief presentation or summary of the material to teach. After that, the instructor poses a ConcepTest and asks students to think about the question and related concepts. A ConcepTest is a conceptual question that is presented with one correct answer and other incorrect answers in a multiple-choice format (Pilzer, 2007). The instructor then allows 1–2 minutes for students to think and come up with a definite answer. This may be through clickers, flashcards, a simple raising of hands, or writing down the answer on a piece of paper. This study made use of flashcards.

The instructor may revisit the concepts using a lecture or try a different ConcepTest if there are too few correct responses from the students. If the majority of the students' responses are correct, the instructor will then give a brief explanation and move on to the next topic or ConcepTest. In a situation where 30–70% of the students answer the concepts correctly, the instructor asks the students to turn to their neighbours and discuss their answers. The students talk in pairs or small groups and are encouraged to find someone with a different answer. The teacher moves around the room to encourage productive discussions and guide student thinking. After several minutes, the students answer the same concepts the second time, and the instructor then explains the correct answer. The instructor can pose other related ConcepTest questions or proceed to a different topic or concept depending on the student's answers.

The conceptual framework of Peer Instruction (PI) integrated with a Dialogical Argumentation Instructional Model (DAIM) which positions argumentation around selected scenarios involving Electromagnetism I located in Authentic Learning (AL) experiences of the participants is applied. Figure 1.1 below shows the conceptual framework of the Peer Instruction process.

The PI as teaching pedagogy is different from other interactive teaching engagement because of the ConcepTest (Crouch, Watkins, Fagen & Mazur, 2007). Many scholars confused the PI with being cooperative teaching strategy while some take it to be a form of inquiry learning. PI may have some of the features of but it is not the same with others because of the ConcepTest and the 'convince your neighbour' section (Mazur, 1997; Crouch et al., 2007). The literature review section in Chapter Two is clear about the differences between the PI and other teaching strategies in science.

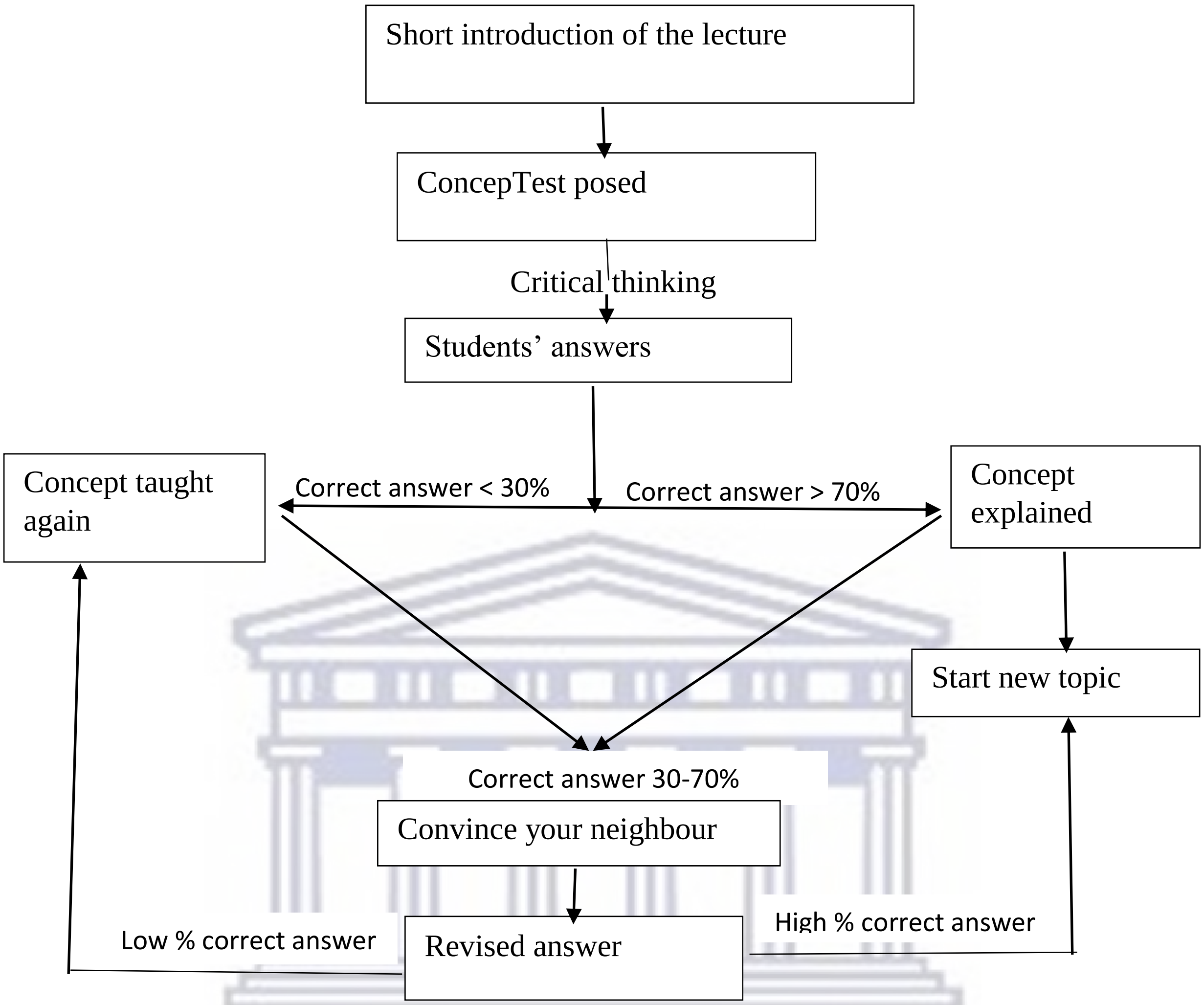


Figure 1.1 Conceptual Framework of Peer Instruction (PI)

The figure is a flowchart of the process of peer instruction in science class that was adopted for this study.

There are concerns about how students learn during peer discussions. Some said not much is known about the dynamics of the peer discussion before students register their answers (James, 2006). Porter, Lee, Simon, and Zingaro (2011) were worried about whether a student indeed learned or just copied the correct answer in their groups. This concern was addressed by merging PI with a Dialogical Argumentation Instructional Model (DAIM) as suggested for triangulation consolidation in this study (Angaama, 2012; Langenhoven, 2014).

According to Angaama (2012), dialogical argumentation involves learners holding to claims in the science class based on evidence while other learners are free to question the claims or the evidence through presenting counterclaims or even rebuttals. A dialogical argumentation-based classroom is an environment where learners are provided with the opportunity to express their views freely. In this way, dialogical argumentation allows students to construct what may be called Authentic Learning (AL) knowledge and to participate in a socio-cultural milieu of classroom interactive discursive dialogue focussed on conceptual-contextual issues. In this case, students do not accept any scientific information given by the teacher unless such information is subjected to an argument-based classroom interrogation before reaching what may be called harmonious understanding or cognitive harmonization.

Both Peer Instruction and Dialogical Argumentation are two different models with similar pedagogies for scaffolding conceptual understanding in the socio-cultural environment in which authentic science teaching and learning may occur. PI and DAIM have dynamic instructional similarities that this study explored. Both frameworks address active and cooperative student-centred learning strategies. Therefore, the Dialogical Argumentation Instructional Model (DAIM) merged with PI examines how students' correct answers may improve if supported by peer discussion under the banner of convincing your neighbour. The significance of this study alludes to the lack of studies in PI focussed on the contribution that peer dialogue may have on the learning process since most PI studies provide quantitative percentages of correct answers after peer discussion with a scarcity of paradigm shifts if any in conceptual understanding.

Immediately after the first voting in PI, pre-service science students formed different opinions in their mind regarding the concept under discussion. When peer discussion began, each student started to convince his or her neighbour regarding the opinion already formed in mind through argumentation. It has been observed that the first answer students gave help with more arguments and ideas being presented during the discussion and the students are more likely to come to a consensual understanding or agreement (Nielson et al., 2012).

Dialogical Argumentation is placed in an instructional modelled framework to create cognitive teaching and learning spaces whereby Peer Instruction can best be appreciated as illustrated by the adapted model in Figure 2 below. The students' understanding is further strengthened through group discussion and group leader presentation to the entire class before the final revised answer is decided upon. During the group leader's presentation, other class members who had voted different answers can query the group answer through dialogical argument and may result in a consensus or alternative perspectives. The model shows that after the revised final answer, the next step is a new or revised concept. The students' understanding of the concept has consequently developed and is usually regarded as highly acceptable by the group. The facilitator is now at liberty to decide if repetition of teaching should continue or whether the signals and responses allow for moving more rapidly to the next topic or concept.

A model, as illustrated below, is used in this study to synchronize PI, DAIM and Authentic Learning (AL). In the same manner that dialogical argumentation instruction shares some similarities with PI, authentic learning and PI also have similarities. Due to these similarities, pre-service science teachers taught with PI should be able to apply classroom experience of Electromagnetism I to real-world problems.

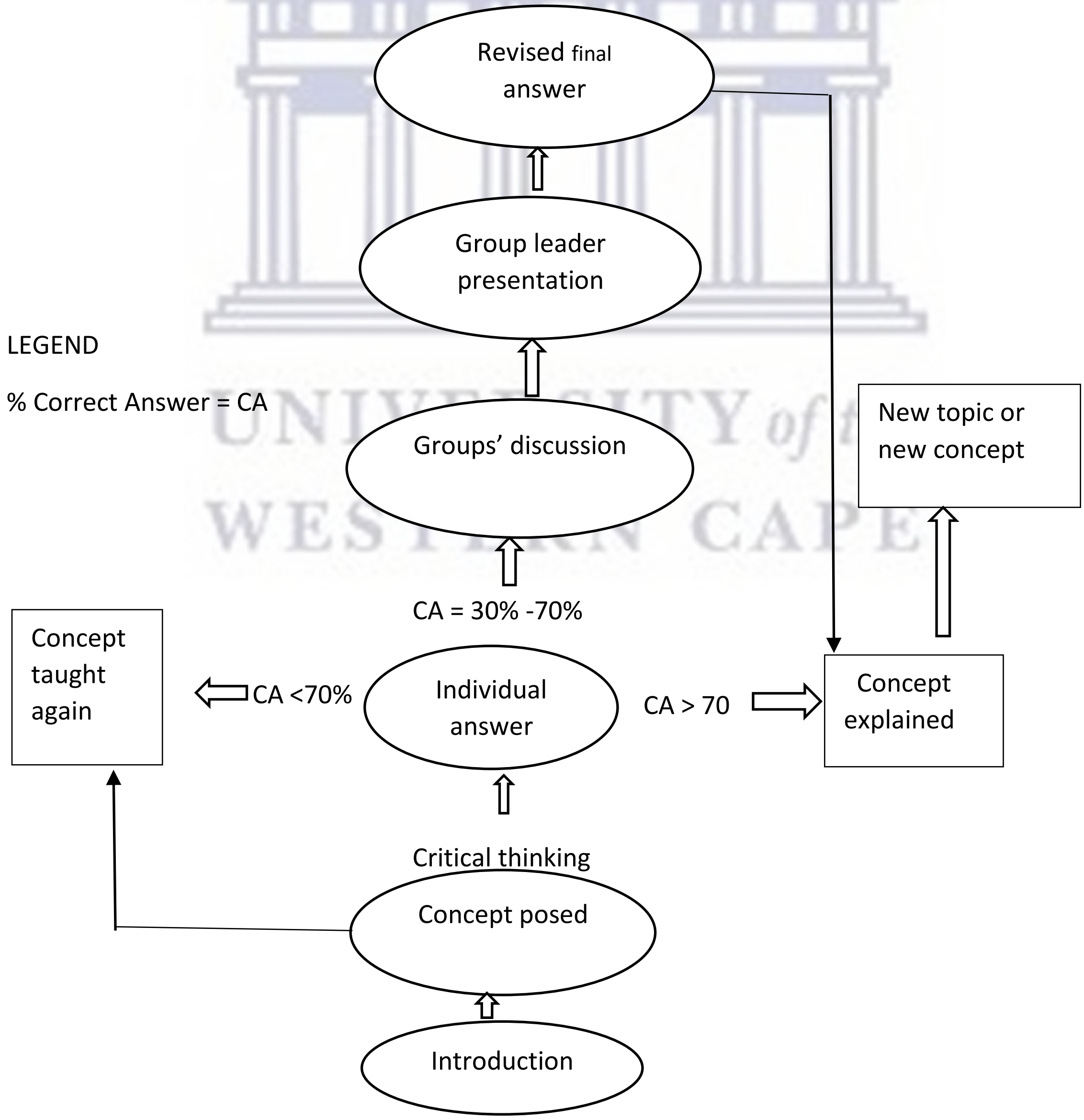


Figure 1.2 Posited Peer Instruction Dialogical Argumentation Model (PIDAM)

The figure is a model that explains the procedure of PI, the integration to DAIM, and how learning takes place in peer instruction. The model is one of the significant contributions of the study to knowledge.

The assumption that students would be able to apply the instructional model to understand real-life situations in the Nigerian context is problematic since the traditional lecture method currently employed is positivist in nature and favours rote learning and regurgitation of memory knowledge rather than conceptual understanding. Figure 1.3 below explicates this dilemma visually.

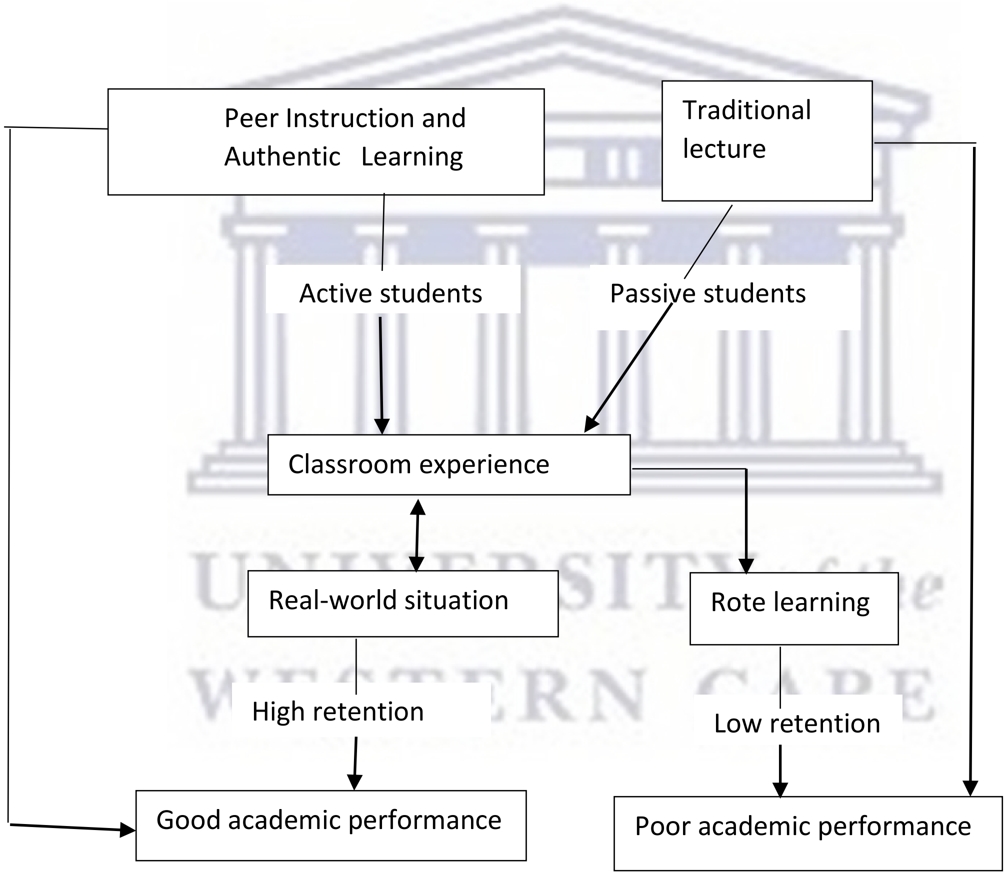


Figure 1.3 Conceptual framework of authentic learning and PI

The figure explains the peer instruction authentic learning framework in science learning. The framework is essential as it indicates the evolvement of higher retention and excellent academic performance

Herrington (2000) identified nine elements of authentic learning as a learning context, learning activities, expert performance, multiple roles and perspectives, collaboration, reflection, articulation, coaching and scaffolding, and authentic assessment. A close study of the process of PI reveals that six of these elements are equally essential in the PI class. Learning context is very relevant to PI because the interpersonal interaction is very high. Collaboration, multiple roles, and perspectives are critical because students collaborate to discuss different concepts. The teacher in PI does not act as an authority but guides the students where coaching and scaffolding become necessary. PI and authentic learning share the goal of equipping a pre-service science teacher with abilities to link classroom experience to real-world problems. This is very important because according to Herrington (2000), knowledge should not be inert. Since this might not be the first research conducted on this subject, it is imperative to make an extensive review of relevant literature.

1.4 Problem statement

As entrenched in the National Policy on Education, the principal objective of teaching physics in Nigerian schools is to ensure that students acquire the skills of science (Adeyemo, 2012). According to Jegede and Adebayo (2013), the philosophy is to provide fundamental physics literacy to function in modern society and acquire critical scientific skills for technological development. To achieve the stated objectives require teachers who are sound in subject content knowledge and teaching pedagogy (Wanbugu et al., 2013; Adeyemo, 2012). Therefore, NCCE recommended the teaching methods that make students active learners in any physics class (NCCE, 2008). Electromagnetism is a branch of Physics in the Nigerian Physics education programme. The learning of electromagnetism is compulsory for all students in Nigeria colleges of education. Students learn Electromagnetism I in year one; Electromagnetism II in year two and Electromagnetism III in year three. According to NCCE (2008), a student must register and pass Electromagnetism I without which the student cannot register for Electromagnetism II or III. Research indicates that many students found Physics to be difficult, tedious and irrelevant (Mekonnen, 2014) due to poor pedagogy and lack of support for teachers among other (Aiyelabegan, 2003; Ahtee & Johnston, 2006). Studies also indicate that there are gender gaps in physics education, particularly, the academic performance due to teaching pedagogy (Victoria, 2011; Limprecht, Janko and Gläser-Zikuda, 2013). Gender gaps in learning have been a global debate for an extended period (Koul, Lerdpornkulrat & Poondej, 2016; Moore, Combs & Slate, 2012; Murphy & Whitelegg, 2006). Therefore, the result is poor academic performance particularly in electromagnetism at a higher level of education (Bertrand, 2007; Akanbi, Omosewo, Abdulraheem, and Ojediran, 2017). To address these lingering problems of Physics in Nigerian schools is the purpose of this study. Instructions in most Physics classes today is based on the traditional lecture method, and this has been impacting student’s academic performance negatively (Deslauriers, Schelew & Wieman, 2011; Rodrigues & Oliveira, 2008). Given the above problems, this study is investigating the effectiveness of peer instruction in enhancing students’ learning of Electromagnetism I. In other to achieve this goal, the dialogical argumentation instructional model was integrated into the peer instruction. The reason for the integration was to investigate how students learn in peer instruction.

1.5 Rationale for the Study

Peer Instruction (PI) is a research-based pedagogy developed and widely used in universities for undergraduate students in some developed countries. The current study is incorporating DAIM into PI as a new area of knowledge different from the PI studies in many other countries. The rationale for the incorporation is to strengthen the perceived weak areas of the PI as criticised by some scholars (James, 2006; Porter, Lee, Simon, and Zingaro, 2011). One of these areas is that the PI does not improve learning, but students only copied the more knowledgeable students during the lesson in the PI class (James, 2006).This teaching and learning method is believed to increase the conceptual understanding of the sciences. The study aims at incorporating DAIM into PI to investigate the effectiveness of it in enhancing pre-service teachers understanding of Electromagnetism I. Electromagnetism I is a vital branch of Physics because of its usefulness in many areas of human life. Application of Electromagnetism I is implemented in health, agriculture, electronics, communication, and others. It is the bedrock of Information and Communication Technology (ICT) transmission. Electromagnetism offered in the Nigerian Colleges of Education is divided into Electromagnetism I, II, and III. The introductory one which is the Electromagnetism I was investigated in this study.

For instance, the application of Faraday and Lenz’s laws of electromagnetism is applicable in every home and offices. To apply the tenants of electromagnetism to real-life problems require innovative pedagogy of an interactive and learner-centred nature rather than rote memorization of factual information for examination purposes.

Physics educators realized that many students learned little Physics from traditional lectures (Crouch & Mazur, 2001; Aina, 2013). In the same vein, Rosenberg et al. (2006) posited that many Physics teachers believed that students understood their teaching, not knowing that the pedagogy used frustrated the students' understanding.

Research studies show that teachers’ pedagogy may be a critical factor to be considered in the teaching and learning of Physics courses. PI become a widely known pedagogy used, in science and mathematics and has been immensely successful (Butchart, Handfield & Restall, 2009). A survey by Fagen (2003) shows that the USA, Canada, Australia, Belgium, Spain, and Sweden are some of the countries which had implemented PI in their schools. In light of this, some countries have adopted PI to teach other subjects as well. However, many countries have not been using PI, especially in developing countries in Africa. The reason for not using PI in many developing nations of Africa is unknown to this study. Nonetheless, according to Smith et al., (2009), PI can be useful for understanding difficult concepts.

Given the points above, PI with the incorporation of DAIM was used to teach Electromagnetism I and to assess its effectiveness in enhancing conceptual understanding. The above rationale, therefore, justifies the choice of Electromagnetism I as a focus for this study.

1.6 Purpose of the Study

The main thrust of this research is to investigate the effectiveness of the Peer Instruction (PI) pedagogy for the teaching of Electromagnetism I to pre-service science teachers at a Nigerian College of Education. The relationship between subject content knowledge, application, and authentic learning was also explored. In pursuit of this purpose, the following three research questions were framed.

1.7 Research Questions

1. Does the incorporating of DAIM into PI intervention have an impact on the pre-service physics teachers' understanding of electromagnetism I?

2. Is there any gender impact of PIDAIM on the pre-service science teacher in the learning of electromagnetism I?

3. Is there a correlation between authentic learning classroom and the constructivist classroom based on the students' academic performance of electromagnetism I?

1.8 Theoretical Framework

Teaching and learning theories are critical to educational research as the term is used commonly in papers, books, and theses (Tellings, 2012). Leedy and Ormrod (2005) defined the theory as an organized body of concepts and principles intended to explain a particular phenomenon. The theory has many roles in educational research. Tellings (2012, p.4) posits that theory provides predictions and explanations as well as guidelines for actions and behaviour. The theory provides a defence against unscientific approaches to a problem, an issue or a theme. In the view of Johnson and Christensen (2007), the theory is a blueprint to tell us how and why certain observed phenomena in education functions. The underpinning theories for this study are Social Constructivism Theory (SCT) and Constructive Controversy Theory (CCT) of learning.

1.8.1 Social Constructivism Theory (SCT). Constructivism emphasizes the importance of the knowledge, beliefs, and skills that an individual brings to the experience of learning (Garbett, 2011, p.37). Vygotsky, a proponent of social constructivism, argued that learning is a social and collaborative activity by which people constructs meaning as they interact with one another (Schreiber & Valle, 2013). Students created ideas through interaction with the teacher and other students.

Interaction is very crucial to students' learning. Educause Learning Initiative (2005) argued that successful learning is closely linked to interaction. This author identifies different types of interaction models. Learning is a process of interaction through which the learners develop their understandings by assembling facts, experiences, and practices.

According to Kim (2001), individuals create meaning through their interactions with each other and with the environment where they live. Meaningful learning could only take place when students are engaged in social activities. Social constructivism believes that both the situation in which learning occurs and the social contexts that the learners bring to the classroom are critical.

Andrews (2012), says social constructivism is concerned with the nature of knowledge and how to create it. According to Powell and Kalina (2010), collaboration and social interaction are incorporated into social constructivism. This theory relies on the social interaction of students in the classroom, along with the critical thinking process.

Creating a more robust understanding of learning requires cooperative learning. These authors argued that social learning is an integral part of creating a social constructivist classroom. The theory holds that students have so much to offer one another by not only working one-on-one with the teacher but also with other students. Bredo (1994) concurred that if the environment and social relationships among groups of students change, apparently the tasks of each student may also change, resulting in better understandings of a concept.

1.8.2 Constructive Controversy Theory (CCT). The constructive controversy theory involves deliberative discussions aimed at creative problem solving (Johnson, Johnson & Tjosvold, 2000). Students must be right collaborators and follow the norms of cooperation and the laws of rational argumentation. Students are strongly motivated to produce solutions and display high-level reasoning, and more significant mastery and retention of new knowledge gained. They generate high quality and creative solutions.

Constructive controversy exists when one person’s idea, conclusions, and opinions are not compatible with another person's ideas, conclusion and opinion, but the two seek to reach a consensus on the solution to the problem or the course of action to take in a situation (Johnson & Johnson, 2003). Constructive controversy is never a debate, nor is it an individualistic approach to a controversial issue. It is a procedure for cooperative learning where individuals with different, conflicting views agree on the best position based on evidence and reasoning (Johnson & Johnson, 2007). According to Daniels and Cajander (2010), constructive controversy builds on the basis that discussions and controversies may create a good starting point in an attempt to understand a complex problem. Students will improve their innovative and constructive thinking skills to find solutions to complex and challenging problems. Similarly, Smith (2013, p.9) thinks that the ultimate goal of constructive controversy theory is when one person’s ideas, information, conclusions, theories, or opinions are incompatible with those of another, and the two seek to reach an agreement.

Numerous theories of learning in education could be considered for this study, but Social Constructivism and Constructive Controversy theories were considered the most appropriate for this study. These theories are active learning theories that positioned pre-service science teachers at the centre of teaching and learning. Both theories considered pre-service science teachers’ interactions through dialogue very important and that constructive argumentation help them develop critical thinking abilities. Constructive Controversy theory when triangulated with PI and a Dialogical Argumentation Instructional Model (DAIM) is a unique pedagogy for science teaching and learning in an argumentation paradigm leading to achieving consensus amidst conflicting views and competing opinions.

1.9 Significance of the Study

This study may be uniquely significant for three main reasons.

- First and foremost is the knowledge gained through an authentic learning experience for students in Electromagnetism I.
- Secondly, immediate responsive feedback is essential for reflections on the teaching and learning; thus, using the PI and DAIM in a dialogical framework to get immediate students to feedback.
- Thirdly, the study enables pre-service science teachers to identify learners’ misconception of certain Electromagnetism I concepts. However, the study is significant in many other areas as well, which are discussed in the literature chapter.

Further areas of significance for consideration are indicated as:

1. The introduction of PI and DAIM in Physics classes in Nigerian schools could make students more active and efficient in the class, which may result in obtaining better grades.
2. This study is significant because PI and DAIM allow students to reflect both *in* and *on* learning. Reflection is one of the essential elements of authentic learning.
3. This study is significant because it shows how the teacher could help students to generate fresh perspectives on an issue or topic through scaffolding and interactive coaching.
4. This study is significant because it exposed alternative conceptions held by students on concepts evident in Electromagnetism I.

1.10 Delimitation of the Study

The study used a purposive sample of fifty-two student teachers enrolled for the Nigerian Certificate in Education (NCE) intending to qualify as science teachers to teach at primary and Junior Secondary School (JSS) level. These student teachers had acquired content knowledge in their Senior Secondary School (SSS) by studying Physics from SSS 1 to SSS 3. They studied Physics for three years in secondary schools before their enrolment in a college of education. An entrance qualification required by these students to study Physics for three years in a college of education is a pass in the two national examinations. These examinations are the West African Examination Council (WAEC) and Joint Admission Matriculation Examinations (JAMB). These students needed to obtain five credits in WAEC; the five credits include English Language, Mathematics, and Physics plus any other two science subjects. The students also needed to score 150 and above in the JAMB. The total mark obtainable in JAMB is 400 because students must enrol for four subjects in JAMB including Physics and the Use of English.

1.11 Limitation of the Study

The sample for this study is made of fifty-two students who enrolled in NCE 1 in the 2014/2015 academic session. The sample is made up of thirty males and twenty-two females. These students study subject combinations such as physics/biology, physics/chemistry, physics/computer science, physics/integrated science and physics/mathematics. Therefore, the finding cannot be generalized to other subject combinations in the school of science. Since this is just a college of education among so many in the country, the finding cannot also be generalized as representative of all other colleges of education. Nevertheless, the results of the study may speak to researchers who may wish to carry out similar research in other colleges of education.

The number of hours spent on teaching using PI within the eight weeks of the intervention may not be adequate to assess these students. However, with the help of the research assistants, the assessment made within this period can be relied upon for this thesis.

Another limitation is the fact that Peer Instruction (PI) and Dialogical Argumentation Instructional Model are entirely new to both students and research assistants.

Besides, there is a limitation of the power supply in the college. The researcher made use of a private electrical generator for the period of the intervention. Managing the class also was another limitation at the start of the intervention because of the newness of the programme but the students later adjusted to the programme.

The official language of instruction in Nigerian schools is English; however, there are language problems in some schools. Many of the students had the issue of a proper understanding of English. This study was not exempted from this problem because many of these students came from a poor background where they cherish their local dialect over and above English.

Despite these limitations, the findings of this study are hoped to be useful in promoting the effective teaching and learning of Electromagnetism I to future prospective pre-service Physics teachers in a Nigerian College of Education.

1.12 Operational Definition of Terms

For understanding, some operational terms are briefly explained in this section.

Ashby Commission: The Ashby Commission was set up in April 1959, with the mandate to conduct an investigation into Nigeria's needs in the field of higher education over the next 20 years. This was informed mainly by the workforce needed at independence to replace expatriate officials. The commission submitted its report in September 1960, a month before independence. The report was titled 'Investment in Education' (Adeyemo, 2000).

Comparative Education Study Adaptation Centre (CESAC): The center was established by the Nigerian government for the development of education. The centre sponsored the science curriculum development conference of 1969 (Ogunmade, 2005).

ConcepTest: Conceptests are short conceptual questions, typically posed in a multiple-choice format, on the subject being discussed. ConcepTests are designed to expose students' difficulties with the material, and to give students a chance to explore essential concepts; they should not primarily test cleverness or memory (Crouch, Watkins, Fagen & Mazur, 2007).

Social Constructivism Theory: The theory Emphasis that learning is a social and collaborative activity where people create meaning through their interactions with one another (Schreiber & Valle, 2013).

Constructive Controversy Theory: The Constructive controversy is one of the concepts that primarily falls within the discipline of social psychology, but in practice, there is no discipline in which it does not find a mention or application (Scheid, 2010). When one person's ideas, information, conclusions, theories, or opinions are incompatible with those of another, and the two seek to reach an agreement (Smith, 2013). The constructive controversy involves deliberative discussions aimed at creative problem solving (Johnson, Johnson & Tjosvold, 2000).

Peer Instruction (PI): It is a research-based pedagogy for teaching sizeable introductory science courses (Fagen & Mazur, 2003). It is a method created to help make lessons more interactive and to get students intellectually engaged in classroom activities.

Dialogical Argumentation Instructional Model (DAIM): Dialogical Argumentation Instructional Model is a pedagogical instructional framework or model developed to assist teachers in scaffolding learning spaces for dialogical argumentation to take place to reach cognitive harmonization around controversial/contestable socio-scientific-cultural topics (Langenhoven, 2009 as cited in Langenhoven, 2014).

Authentic learning: It is learning by doing where students are actively involved in the learning process. It is an inquiry method of learning. This is a process of asking meaningful questions, finding information, drawing conclusions, and reflecting on possible solutions (Milson, 2002).

Flashcards*:* Flashcards are an easy, low-tech way to gather student answers. These cards are made of different colours or number to indicate answers to the ConcepTest (Rosenberg, Lorenzo & Mazur, 2006).

Joint Admission Board Examinations (JAMB): It is a Nigerian entrance examination board for tertiary-level institutions. The board conducts entrance examinations for prospective undergraduates into Nigerian universities. The board is also charged with the responsibility to administer similar examinations for applicants to Nigerian public and private monotechnics, polytechnics, and colleges of education. (FRN, 2004).

Junior Secondary School (JSS): This is a lower level of secondary schools in Nigeria. This comprises of the first three classes in Nigerian secondary school. There are JSS1, JSS2, and JSS3 (Gusau, 2008).

National Commission for Colleges of Education (NCCE): This is a body set up by the government of Nigeria to coordinate both public and private colleges of education in the country. All the academic programme of Nigerian colleges of education are under the supervision of NCCE. The awards of NCE to qualified students are also done by this Commission (NCCE, 2008). The establishment of the commission was a resultant effect of the utmost importance accorded to quality teacher education by the Federal Government of Nigeria. Since its inception, the Commission has continuously pursued goals of quality assurance in teacher education. The pride of the commission is based on the fundamental philosophy in the National Policy on Education (NAPE), which states that "no education can rise above the quality of its teachers."

Nigerian Certificate in Education (NCE): This is the certificate issued to any student who has completed his or her three years academic programme in any college of education in Nigeria. The body charged with the responsibilities of coordinating and awarding this certificate is the National Commission for Colleges of Education (NCCE, 2008)

National Policy on Education (NPE): The National Policy on Education in Nigeria is an important document that had attractive plans for the Educational System of the country. The National Policy on Education launched in 1997 and had been revised to provide enough theoretical frameworks for actualizing self-reliance through education in Nigeria (Amaele, 2004).

The **National Examination Council (NECO):** It is an examination body in Nigeria that conducts the Senior Secondary Certificate Examination and the General Certificate in Education in June/July and December/January respectively (Oluwatayo, 2007)

Nigerian Secondary Schools Science Project (NSSSP) was set up by the Science Teacher Association of Nigeria to develop syllabuses for biology, chemistry, and physics suitable for the senior secondary schools (Awolola, 2004).

Pre-service teacher: These are post-secondary school students who registered in any private or public colleges of education. These are students who have no teaching experience because they are admitted directly from Senior Secondary Schools (SSS). FRN, 2004).

Senior Secondary School (SSS): This is the higher level of secondary education in the Nigerian educational system. This level is divided into three levels which are SSS1, SSS2, and SSS3 (FRN, 2004).

Science Teacher Association of Nigeria (STAN) is a professional body of science teachers established for the development of the science curriculum (Fareo, 2013).

The West African Examinations Council (**WAEC**): This is an examination board that conducts the West African Senior School Certificate Examination and a University entry examination in West African countries. The council established in 1952 had contributed to education in Anglophonic countries of West Africa (Ghana, Nigeria, Sierra Leone, Liberia, and The Gambia), with the number of examinations they have coordinated, and certificates they have issued. They also formed an endowment fund, to contribute to the education in West Africa, through lectures, and aid to those who cannot afford education (Oluwatayo, 2007).

The **West African Senior School Certificate Examination (WASSCE)** is a type of standardized test in West Africa. It is administered by the West African Examinations Council. It is only offered to candidates residing in Anglophone West African countries. The academic school-leaving qualification awarded upon successful completion of the exams is the West African Senior School Certificate (FRN, 2004).

1.13 Overview of Chapters

This section looked at the summary of the chapters

Chapter One: Introduction

This chapter focuses on the rationale for carrying out this research with pre-service Physics teachers located at a College of Education, Nigeria. The peer instruction (PI) integrated with the dialogical argumentation instruction in Nigerian schools is a real innovation in education. Besides, identifying some elements of authentic learning in Electromagnetism I using PI could be a breakthrough in Physics education in Nigeria. The chapter gave a detail historical perspective of the development of Physics education in Nigeria before and after the country independence in 1960. The thrust of the chapter is the background to the study, problem statement, and the rationale for the study, the purpose of the study, research questions, theoretical framework, conceptual framework, and significance of the study.

Chapter Two: Literature Review.

In this chapter, a literature review is undertaken to (or “intending to”) search for literature focusing on critical areas. The areas are Nigerian Certificate in Education (NCE) curriculum, Students’ academic performance, Conceptual understanding, Misconception in Science and Pedagogy of teaching. Others include Authentic learning, Peer Instruction, Critical thinking, and the dialogical argumentation. The conceptual framework of this study is drawn based on the Social Constructivism Theory (SCT) and Constructive Controversy Theory (CCT). Papers related to topics listed above which have been presented at conferences and published in journals are also reviewed.

Chapter Three: Methodology.

The chapter considers the processes of data collection. This was done through classroom experimentation of the Peer Instruction (PI). The whole class was randomly divided into control and experimental groups. The experimentation took eight weeks of instructions for the groups. Instruments used for the data gathering are Electromagnetism Physics Assessment (EPA), Peer Instruction Dialogical Argumentation Questionnaire (PIDAQ) and Semi-structured Interviews.

Chapter Four: Results and Findings.

The chapter shows how the data generated for this study were presented and discussed. The findings and discussion were considered with references to the reviewed literature in Chapter Two. This was done to interpret the peer instruction procedure and the dialogical argumentation strategy amongst the pre-service Physics teachers.

Chapter Five: Recommendations and Conclusion.

This chapter presents a summary of the significant findings, the implication of the study for the government policy on education, pre-service teacher, and the teacher training programme. The study recommends that the modified peer instruction model be further tested in more schools before its full implementation. The general conclusion is drawn points to the role that the model plays in creating teaching and learning moments whereby students can engage in dialogue around contextual and conceptual aspects related to the scientific discipline and selected topics for better understanding.

CHAPTER TWO: LITERATURE REVIEW

A literature review is undertaken to (or “intending to”) search for literature focusing on critical areas such as policy arguments for and against peer Instruction and to identify any areas that require further investigation.

2.1 Introduction

The literature available about the research topic shall be reviewed as follows: Conceptual understanding and problem-solving skills, Physics academic performance according to gender, Authentic learning, Pedagogy of teaching science, Objective and content of the NCE Physics curriculum, Challenges of Physics Education in Nigeria, Misconceptions, The process of PI, Critical thinking and Dialogical Argumentation.

2.2 Conceptual Understanding and Problem-solving Skills in Physics

Physics students should be able to learn concepts in Physics and apply it (Mazur, 1997). Conceptual knowledge is essential for generation and selection of appropriate procedures in solving a problem (Rittle-Johnson, Seigler&Alibali, 2001). Conceptual understanding enables students to explain a phenomenon differently in various situations. (Viennot, 2009). Rittle-Johnson, Seigler, and Alibali (2001) said that through conceptual understanding, students could be guided to choose among the alternative procedures. This could be true as many procedures exist for solving Physics problems.

The students need to have a conceptual understanding, instead of the memorisation of the facts, because according to Vosniadou (2007), students cannot depend on memorisation only if they are going to learn and understand the advanced scientific concepts. The learning contents should be meaningful to the students as regards to the knowledge they had before (Venville & Damson, 2010). The constructivism theory guided the study because the students’ previous knowledge must connect with the new knowledge to give room for what Liang (2016) termed as conceptual change. Baser (2006), science educators called the conceptual change modification of students’ alternative conceptions.

Physics teachers are not expected to be in haste introducing new topics to students, however, utilized quality time to identify students’ previous experience of the intended topics. Research study shows that students often come to the Physics classroom with informal knowledge (Liang, 2016). Physics students come to classes with different types of concepts’ explanations, scientific interpretations, and terminologies (Dykstra, Boyle& Monarch, 1992) that are due to everyday experience and language (Baser, 2006). These are not in agreement with the scientific views and are not easy to change (Ronen & Eliahu, 2000; Savinainen, Scott &Viiri, 2004), thus making the learning of similar scientific concepts and explanations difficult (Duschl & Gitomer, 1991; Windschitl & Andre, 1998). These simple ideas, interpretations, explanations, and learning difficulties are regarded as misconceptions by Physics education researchers (Eryilmaz, 2002; Tsai, 2003; Wyrembeck, 2005), some call it alternative conception (Periago & Bohigas, 2005).

Conceptual understanding is critical in Physics that researchers attributed the poor academic performance to students' insufficient conceptual understanding. According to Jackman (1999), the problem of learning in Physics education is due to the lecture method used by professors. Jackman said students build their knowledge on the foundation of underlying conceptual Physics, and they should be well-grounded in it.

According to Gok (2011), Peer Instruction (PI) increases student conceptual learning and academic performance on problem-solving questions. Gok further argued that it is possible through PI to improve student conceptual learning and problem-solve in Physics courses. Lasry, Mazur, and Watkins (2008) observed that students taught with peer instruction demonstrate better conceptual learning and similar problem-solving skills than the students taught with the lecture method. The use of interactive engagement strategies like peer instruction can be an effective way of increasing conceptual and problem-solving test in Physics courses (Hake 1998; Watkins & Mazur, 2013).

For Crouch and Mazur (2001) peer instruction increased both conceptual understanding and problem-solving skill. Crouch, Watkins, Fagen, and Mazur (2007) asserted that peer instruction increased student mastery of conceptual understanding and problem-solving. The debate on an understanding of conceptual and problem-solving Physics using the PI required caution because PI is mostly applied to the conceptual Physics in many kinds of literature.

The two most important educational goals are to promote retention and to promote transfer (Mayer, 2002). The ability to remember what was learned at a later time in the same way as it was presented during instruction is retention. According to Mayer, transfer referred to the ability to use learned materials to solve new problems, answer new questions, or facilitate learning the new subject matter. Based on the submission of Mayer, there is a need for a student to possess problem-solving skill so that he or she could solve problems in new situations.

Problem-solving needs the trying of different methods to obtain a result and get rid of the unsuccessful ones (Senduran & Amman, 2015). Meaningful learning could only occur when students can build the knowledge and cognitive processes needed for successful problem-solving. Problem-solving is when students' device a way of achieving a goal that one previously has never been reached; this implies, figuring out how a situation can be changed from its given state into a goal state (Mayer, 1992).

According to Rosenberg, Lorenzo, and Mazur (2006), the problem-solving skill requires logical reasoning as well as mathematical skill. For Gok, problem-solving skill is a mental process that involves discovering, analyzing and solving problems. Problem-solving is a phenomenon utilised for obtaining the right answer what unknown or a decision that might have to some constraints.

Many Physics courses involve using equations and formulae to solve mathematical problems. Therefore Physics student should be well taught in addressing mathematical problems. Olusola and Rotimi (2012) put it that calculation makes Physics difficult for students to learn because of the inability to solve Physics equation correctly using the appropriate formula. Quantitative problem-solving is an essential aspect of science courses (Crouch & Mazur, 2001). The proper understanding of mathematics is an added advantage for the sound knowledge of Physics, as some believed that mathematics is closely related to Physics (Awodun & Ojo, 2013).

Situations requiring problem-solving skill are ill-defined (Herrington, Reeve & Oliver, 2010). There is no problem statement, and there is some ambiguity in the information given. Students should be able to define the problem on their own (Mourtos, Okamoto & Rhee, 2004). It is an essential area of learning in Physics that many neophyte Physics teachers are ignorant of and mostly dread. Once the steps to the solution are already given in detail to the student, all needed for them is to memorize the steps to be recalled in the later time. In this way, the students have not learned much; and no knowledge has been constructed which points to a mere mathematical manipulation of formulae.

Problem-solving is not the same as textbook exercise solving (Mourtos et al., 2004). Many people often made a mistake of confusing problem-solving with textbook exercise solving. Table 2.2 below adopted from Mourtos, Okamoto, and Rhee (2004) shows some differences between problem-solving and textbook exercise solving.

Table 2.1

Differences between Problem- Solving and Textbook Exercise Solving

	Problem-Solving	Exercise Solving
1	Involves a process used to obtain the best answer to an unknown, subject to some constraints.	Involves a process to obtain the only the right answer for the data were given.
2	The situation is ill-defined. There is no problem statement moreover, there is some ambiguity in the information is given. Students must define the problem themselves Assumptions must be made regarding what is known and what needs to be found.	The situation is well defined. There is an explicit problem a statement with all the necessary information (known and unknown).
3	The context of the problem is brand new (i.e., the student has never encountered this the situation before).	The student has encountered similar exercises in books, in class or in homework
4	There is no explicit statement in the problem, that tells the student what knowledge / technique /skill to use in order to solve the problem	Exercises often prescribe assumptions to be made, principles to be used and sometimes they even give hints
5	There may be more than one valid approach	There is usually one the approach that gives the right answer

6	The algorithm for solving the the problem is unclear	A usual method is to recall familiar solutions from previously solved exercises
7	Integration of knowledge from a variety of subjects may be necessary to address all aspects of the problem	Exercises involve one subject and in many cases only one topic from this subject
8	Requires reliable oral / written communication skills to convey the essence of the problem and present the results	Communication skills are not essential, as most of the solution involves math and sketches

Adopted from Mourtos, Okamoto & Rhee (2004)

The major highlight of the table is to show that problem-solving skill requires an in-depth students' understanding rather than depending on solving an exercise in a book.

Senduran and Amman (2015) note that problem-solving is a skill that should be learned and obtained because it is multidirectional that combines intelligence with other skills. Conceptual understanding and problem-solving skills are crucial to the teaching and learning of Physics otherwise, the problem of an alternative conception called misconception could be a severe barrier to learning (Rosenberg, Lorenzo, and Mazur, 2006).

2.3 Physics Academic Performance according to Gender

Physics is crucial to the scientific and technological development of all nations (Agommuoh & Ifeanacho). The application of Physics is evident in many fields like engineering, medicine, communication, information technology, and many others. Physics, a foundation of science, and technology is a tool on which the scientific and technological advancement of many products directly depends on (Olufunke, 2012).

However, as essential and relevant Physics is to the world, technology students' academic performance is not okay and is a source of concern to Physics educators and researchers (Dupe, 2013). The literature reviewed points to the reality that students' academic performance is not encouraging even in developed nations. Physics has many problems in our institutions of learning among which are poor academic performance in both external and internal examinations (Alao & Abubakar, 2010). Scholars like Ramos, Dolipas, and Villamor (2013) believed that Physics is hard to teach and harder to comprehend. This submission might be valid depending on the teacher's approach to the teaching of the subject. However, personal experience indicates that many students and parents concurred that Physics is hard to study.

The teaching of Physics and students' academic performance at the secondary school level has been the concern of government and parents in Nigeria (Onah & Ugwu, 2010). There is evidence of a mass students' failure in the National Examination Council (NECO) and West African Senior School Certificate Examination (WASSCE) in Physics in Nigeria (Erinosho, 2013). Erinosho explains further that slightly over 30% of students who registered for Physics passed at credit level as against 40% in Biology and Chemistry annually.

Stephen (2010) observed the poor academic performance in Physics is a global affair not peculiar only to the Nigerian post-primary schools which have been a source of concern for everyone. Although enormous resources are committed to education by the government at a higher secondary school level of education, yet students are still performing poorly in Physics (Shamin, Rashid & Rashid, 2013).

Physics educators and scholars are not satisfied with students' academic performance in Physics. To support this, Josiah (2012) lamented that results of Physics in most public examinations as the West African Examination Council (WAEC) have been worrisome. The situation is more disturbing to both teachers and parents according to Dupe (2013) that students' poor performance in Physics in the public examination are worrisome. Achievement of Physics students has been aching to the generality of the people most especially Physics educators (Folashade & Akinbobola, 2009). The students' Physics academic performance at the end of secondary school is discouraging (Musasia, Abacha & Biyoyo, 2012). According to Bello (2011), data from the WAEC for a state in Nigeria shows that 31.60% passed Physics in 2005, while only 28.10% passed in 2007. Thomas and Israel (2012), there is a decline in the students' Physics academic performance in post-primary schools in the past decades. It is pertinent to add that the situation with the students' academic performance in Physics is becoming worse in Nigerian schools every year in Nigeria. The table below shows the students' academic performance of a college of education in the country over ten consecutive years.

Table 2.2

Academic Performance in Physics

Year	Distinction.	Credit	Merit	Pass	Low Pass
2005	3	2	7	1	-
2006	2	5	1	4	-
2007	-	3	1	-	-
2008	-	5	5	2	1
2009	-	9	19	14	2
2010	1	14	23	32	-
2011	-	6	12	21	-
2012	1	2	11	18	-
2013	4	17	12	16	-
2014	-	12	15	16	1

Victoria (2011) said Physics had been stigmatized as a subject that causes underachievement. Many students believed that if you want a good grade in your studies, you should not enrol in Physics. Academic achievement in Physics has been penniless and not encouraging in Nigeria schools; this is applicable in other countries as viewed by Meltzer (2002); Grande, Tevar, Miranda & Reyes (2008). Wanbugu, Changeiywo, and Ndiritu (2013) confirmed that students performed poorly in Physics in Kenya schools. Many scholars have shown concerns over students' poor academic achievement in Physics (Akanbi, 2003; Oladejo, Olosunde, Ojebisi & Isola, 2011). Physics is a subject that students performed poorly in at all levels of education (Bello, 2011; Aina & Akintunde 2013; Omotade & Adeniyi, 2013; Eraikhuemen & Ogumogu, 2014).

Physics is an essential science subject that is crucial to the understanding of the world around us (Agommuoh & Ifeanacho, 2013). Physics is crucial for understanding the complexities of modern technology and vital for the technological advancement of a country (Erinosho, 2013). All engineering courses require a sound understanding of Physics and many of the medical sciences. Physics in physical science is a fundamental course (Shamim, Rashid & Rashid 2014), and that is why its teaching and learning must be taken seriously. Physics has been perceived to be a complicated subject, and that is why some schools do not register for it (Wanbugu & Changeiywo, 2008). Physics is one of the challenging courses in the Nigerian school curriculum (Oladejo, Olosunde, Ojebisi, and Isola, 2011). Physics is thought to be the most fundamental science subject whose concepts and techniques support the progress of all other branches of science (Sheriff, Maina& Umar, 2011). Given the preceding, no student is allowed to enrol in any engineering courses and medical sciences in the Nigerian Universities and Polytechnics without a credit pass in physics. Thus, the choice of this topic is essential.

Gender has a significant effect on students' achievement in Physics (Kelly, 2016). Many authors who had researched the gender effect on the students' academic performance in Physics had come up with different conclusions. However, many empirical results show that male students are better than female. Stephen (2010) indicates that male students are proved through research to have a higher manipulative ability than their female counterparts. Osborne, Simon, and Collins (2003) the boys' attitude towards Physics are better than that of the girls in schools. Wanbugu, Changeiywo, and Ndiritu (2013) viewed that there are low enrollment and performance of female students in Physics in Kenya schools. Musasia, Abacha and Biyoyo (2012) confirmed girls' low enrollment and poor performance in Physics in Kenya secondary schools. The low female enrolment in Physics might be due to the fear of low achievement; this is mere conjecture. Alao and Abubakar (2010) noticed gender gaps in Physics students' academic performance in colleges of education. Stephen (2010) and Victoria (2011) observed that boys performed better in Physics than girls in post-primary schools. Adeyemo (2012) noticed the underrepresentation of female in Physics. Greenberg (2006) submitted that generally in the world men study Physics more than female. Aina and Akintunde (2013) concurred that boys performed better than girls in Physics. Crouch and Mazur (2001) viewed that no gender gap exists in the conceptual understanding of introductory Physics among students taught with interactive pedagogy in the university. According to Gok (2013), boys performed better than girls in Physics in the area of problem-solving skill. As much as empirical evidence on academic performance in Physics based on gender may be accepted, it thus requires recent evident

There is no significant difference between the academic achievements of Physics students taught with a problem-based learning technique (Folashade & Akinbobola, (2009). No significant mean difference in the Physics achievement scores between the male and female students who were taught Physics using CAI (Josiah, 2012). There seems to be no gender gap in the Physics classroom as far as the level of higher-order thinking skills of students is concerned (Ramos, Dolipas & Villamos, 2013). By the above submissions, it is, therefore, germane to consider the conceptual understanding and problem-solving skills in

Physics because some authors believe that boys achieve better results than girls in problem-solving skills (Gok, 2013; Stephen, 2010). Therefore, this study examines students' performance based on gender in conceptual and problem-solving Physics questions before and after the PI intervention.

2.4 Authentic Learning (AL)

Authentic learning is learning by doing. It is active learning, where students learn by active participation. This is learning by inquiry strategy. It is a process where meaningful questions are asked seeking for information, concluding, and reflecting on solutions that possible (Milson, 2002).

It has been observed that students' learning is made practical before such learning could be useful in a real-life situation. For the training to be concrete, it needs to be student-oriented, which implies that students control the entire learning for themselves. The role of the teacher in such learning is to guide and not to control the learning. This is where authentic learning comes to fore. There are nine components of authentic learning were identified by Herrington (2000): some of these elements are believed to be relevant to this study. Therefore, the argument is made that through the PI and DAIM as instructional pedagogical tools, an authentic learning experience could be achieved.

The teacher gives a well-prepared outline of what the students are to learn, such as concepts, principles, laws, and theories. The teachers are guided by the curriculum designed by the experts and textbooks before given these tasks to the students. This study is significant because the learning tasks in the PI are ill-defined. The tasks have real-world relevance and also require the production of knowledge instead of reproduction of knowledge (Herrington, Reeve & Oliver, 2010). This is an essential element of authentic learning called authentic activities. Learning of this kind helps students to use classroom learning to solve the real-world problem outside the class.

The focus of authentic learning is on real-life, complicated challenges and their solutions, making use of role-playing exercises, and activities that are problem-based activities, including specific studies, and involvement in imitated societies of practice (Lombardi, 2007). Students are taking part in discourse, seeking for information, and enjoying the whole process of learning (Mims, 2003). Authentic learning tasks are specially constructed to give the students experiences in a real-world situation. Scholars in education have noted that learners participating in authentic learning are spurred to persevere despite initial difficulties and challenges, (Lombardi, 2007)

Herrington and Kelvin (2007) argued that because of ignoring the interdependence of situation and cognition much of the knowledge acquired in schools is abstract and cannot be retrieved in real-life. The author highlighted nine elements critical to authentic learning if the knowledge will be retrievable in real-life. The elements are authentic contexts, authentic activities, expert performances, multiple roles and perspectives, collaborative construction of knowledge, reflection, articulation, coaching and scaffolding, and authentic assessment. Each of these elements shall be reviewed thoroughly.

2.4.1 Authentic Contexts. This is a situation that shows the way the knowledge will utilise in real-life. It is an authentic learning context. An authentic learning environment gives an individual control on what the student learns and how it is learned (Watters & Ginns, 2000). Herrington and Kelvin (2007) stressed that authentic contexts in the classroom are not ordinary examples taken from real-life practice illustrating a concept to be taught. The authors agreed that authentic contexts must be all-encompassing, providing the purpose, motivation for learning and complicated learning situation that can be entirely explored. A learning environment resembles some real-life application: city management, house building, flying an aeroplane, setting a budget, solving a crime (Lombardi, 2007). The authentic learning environment must be a physical environment that mirrors the way the knowledge be used in real-world (Brown, Collins & Duguid, 1989). Learning within a real classroom environment gives a useful real-life situation for the learners, and in comparison to another teaching method, they often encounter at university (Herrington & Oliver, 2000). Herrington (1997) recommended that an authentic situation should be an essential number of resources for sustaining examination from some various perspectives.

2.4.2 Authentic Activities. Authentic activities or tasks show the kind of tasks that people do in real life, which can be finished over a sustained time, instead of a series of short disconnected examples (Herrington & Kelvin, 2007). According to Herrington (1997), the characteristics of authentic learning are ill-defined; promote exploration to enable students to find as well as solve the problems; provide the opportunity to identify relevant and irrelevant materials; and allow sustained thinking by exploring topics broadly. Authentic tasks match the real-life activities of professionals in practice as nearly as possible (Lombardi, 2007). The authentic task is made of complicated activities the students must examine for an extended period (Herrington, Oliver, and Reeves, 2003). Rule (2006) posits authentic activity as one component of authentic learning that is targeted towards a real problem, and that is having a possible impact outside the classroom.

2.4.3 Expert Performances. Expert performances and the modelling of processes, allow students to observe a task before it is attempted (Herrington, 1997, p. 48). Through the experts, students have the opportunity of comparing their performance, skills and understanding with the expert in the field (Collins, Deck, & McCrickard, 1991). Authentic learning environments provide students with the opportunity to have the thinking and performances of the expert and give the students opportunity observing the task before attempting it (Herrington & Kelvin, 2007). The expert's idea may be a video of movies of experts in their fields of the profession; the opportunity to share stories and narratives (Brown et al., 1989). This idea is from the apprenticeship system, also called work-integrated learning (WIL), where a student works with someone more experienced (Herrington, 1997).

2.4.4 Multiple Roles and Perspectives. The study situation that gives the students the chance to investigate many ideas, roles, and perspectives rather than learning through interaction with a single proponent such as a teacher (Herrington & Kelvin, 2007). Honebein et al. (1993) defined multiple perspectives as a significant cognitive activity that should be promoted in the design of authentic learning environments. It permits different perspectives from various points of view; not necessarily a single perspective- such as a textbook (Herrington, Reeves & Oliver, 2010). Multiple roles and perspectives permit different people, media, and resources to be applied as needed to give a rich array of views and points of opinion (Herrington & Kelvin, 2007). Herrington (1997) recommended that it is imperative to permit to crisscross the learning content by presenting more than one investigation within a resource-rich enough to sustain repeated examination.

Multiple perspectives is an authentic learning element very relevant to this study. Multiple perspectives allow different perspectives to be considered by learners from many different points of view. Traditional lecture method encourages Physics learning through the teacher only, which is against multiple perspectives. The study encourages students to consider their learning through different perspectives such as peer, textbook, digital libraries, and Google search. This makes the study significant because Electromagnetism I learning could be a vibrant and robust affair.

2.4.5 Collaboration. Collaboration as a component of authentic learning is unique to the PI. Students collaborating in PI to solve the problem are very significant to this study. It is crucial because the current learning of Physics in Nigerian school is mostly by lecture method where individualize learning is the focus.

The formation of groups during the PI for collaboration allows the students to defend their opinions about learning through argument. After that reaching a consensus and verbal presentation of the conclusion to the entire class is an essential element of authentic learning called articulation. This could be an innovation in Physics learning in Nigerian schools.

In other to ensure students learn in a way that will reflect the real-life situation, there is a need for collaborative learning. Collaboration and to construct knowledge collaboratively is a relevant component of authentic learning (Herrington, 1997). Collaboration is beyond the grouping of students during learning. Collaboration is solving a problem together, not only working together in a group. Herrington, Reeves, and Oliver (2010) argued that the features of a kind collaboration are: team or pairs, not individuals; task-focused groups not an individual with encouragement using technology.

Katz and Lesgold (1993) diligently insisted that collaboration is far beyond cooperation because collaboration is synchronous, whereas cooperation can be synchronous or asynchronous. Collaboration allows students to synthesize their ideas on problems, and to fully articulate their progress as they go about the activity (Herrington & Kelvin, 2007). According to Herrington, Reeves and Oliver (2010), collaboration provides joint problem solving and social support.

2.4.6 Reflection. Reflections are the cognitive and affective tasks in which people engage to examine their experiences leading to new knowledge and appreciations (Boud, Keogh & Walker, 1985). According to these authors, reflection has three characteristics which are, getting back to the experience, attending to feelings and re-assessed the experience. The need for reflection cannot be underrated in this study if a research question on the authentic learning in Electromagnetism I will be answered correctly. In support of this, Herrington and Kelvin (2007) were of the view that opportunities for learning are wasted in school when students have no chance to reflect upon and consolidate what was learned. For students to think about their learning, they should often return to what has been done, recollecting the critical considerations and relating them to their peers (Herrington & Oliver, 2000). Reflection enables students to think about, reflect and discuss choices. We have reflections *in* and *on* learning. Reflection *in* learning is making choices during the learning, while reflection *on* learning is choices made after the learning (Herrington, Reeves & Oliver, 2010).

2.4.7 Articulation. The articulating permits formation, awareness, development, and refinement of ideas during learning (Herrington, 1997). The students being allowed to verbalize their ideas in pairs permitted them to be aware of their learning and to make adequate connections to incorporate it into their cognitive frameworks (Herrington & Oliver, 2000). Articulation offers students an opportunity to speak and write about their understanding as it grows (Herrington, Reeves & Oliver, 2010).

Research studies show that student been able to defend his or her view in science through a logical argument is part of learning. Kuhn (2009) argued that the skills of the argument are necessary intellectual abilities, which require attention in science education. As a critical component of scientific inquiry, argumentation has functions in the generation and justification of knowledge claims (Erduran, Ardac &Yakmaci-Guzel, 2006). According to Kuhn and Reiser (2005), argumentation has been regarded to enhance student engagement with the process of learning and therefore, interaction with the content under study. Articulation gives the student the chance to make a public presentation to defend a proposition (Herrington, Reeves & Oliver, 2010).

2.4.8 Coaching and scaffolding. According to Rosenshine and Meister (1992), Scaffolding is a process where students are receiving support to enable them to apply new strategies and skills without assistance. Authentic learning context enables coaching at difficult period, the scaffolding of support, where the instructor offers the repertoire, technique, and connections the students cannot get to complete the activity (Herrington, 1997). The students derive some advantages from Scaffolding during learning: one of these advantages is that it provides a supportive learning context (Johnston & Cooper, 1997). These authors averred further that scaffolding learning context allows students to ask questions, provide feedback and support their partners to learn new things. Scaffolding is a useful instructional strategy gives the teacher the chance to accommodate the needs of every individual student (Kame'enui, Carnine, Simmons & Coyne, 2002). Choi and Hannafin (1995), succinctly argued that coaching in an authentic learning context calls for a strong, but various functions for the instructors.

2.4.9 Authentic assessment. Authentic assessment is the integration of the assessment with the activity rather than separate testing (Herrington, Reeves & Oliver, 2010). By these authors, it means coherent integration of assessment and activity. Young (1993) contended that assessment should form an integrated, ongoing, and coherent part of the learning context. Gardner (1992) viewed that regular tests and materials for assessment are not sensitive enough to take care of cultural differences, and they are seldom used in determining students' level of competence.

Lajoie (1991) reasoned that more authentic assessment is needed for assessing the learning which students would make use of in real life, as against the type of activities conventionally learned in a classroom. According to Herrington and Kelvin (2007), in an authentic learning context, the assessment must be coherently integrated with the task, that is, the assessment of students is on the activity they perform instead of a separate test.

Not mind the subject matter, when the students are involved actively in learning, it is possible to learn more and have longer retention than when knowledge is passively absorbed (Green, 2003). Students' interest and achievement lie within the teacher and students' interaction/relationship in a given subject (Onah & Ugwu, 2010). Creating classroom contexts that promote positive cultures with strong interactions can goad students to channel their efforts and aspirations to achieve their goals (Nugent, 2009).

Table 2.3

The Authentic Elements

s/n	Authentic learning elements	The manifestation of the learning environment
1	Provide authentic the context that reflects the way the knowledge will be used in real-life	• the classroom interface and programmme organization around the central context of Electromagnetism I classrooms • no simplification of real-life resources
2	Provide authentic Activities	• investigations in Electromagnetism I mirror the kind of tasks teachers face in real life • each investigation presents a complex task with a single sustained context • including the presentations to the class, students work on the Electromagnetism I materials for weeks rather than days • no attempt made to edit out irrelevant material • each investigation is addressed to a group, and students were advised to work in

		collaborative groups • assessment strategies presented are relevant to other disciplines
3	Support collaborative construction of knowledge	• each investigation was addressed to a group, e.g., the Electromagnetism sub-group • lecturers divided students into small collaborative groups • grades for class presentations are given for a group effort, not individually
4	Promote Articulation	• the complexity of the investigation affords a necessity to articulate to complete the task, rather than in response to cues built into the programme • collaborative groups recommended articulation and defense of findings in oral presentation to the class
	Provide coaching and scaffolding	• classroom context and open-ended, complex task with no simplification of procedures • non-linear design with no program feedback • suggestions on ways to implement the program in the classroom were provided • collaborative groups recommended, where more able partners can assist with scaffolding and coaching • suggestions were provided on the scaffolding and coaching role
6	Promote Reflection	• real classroom context and task • non-linear navigation enabling ready access to any media element in a non-sequential order

- students can compare their thoughts to an experienced classroom teacher and Physics education experts
- students can compare their thoughts to a pre-service teacher in NCE 3 of their teacher training course
- collaborative groups recommended enabling reflection with aware attention

Adapted from Herrington and Oliver (2000)

2.5 Pedagogies for Science Teaching

According to Anderson and Mina, (2003), electromagnetism as a unified field of Physics was provided by James Clerk Maxwell in 1873. Research indicates that students have challenges in learning and understanding of electromagnetism in schools (Constantinou, Papaevripidou & Hadjilouca, 2010). These challenges are due to some reasons which may be abstractness of concepts (Bertrand, 2007), misconceptions by students and teachers (Akanbi, Omosewo, Abdulraheem, & Ojediran, 2017; Eraikhuemen & Ogumogu, 2014); and teacher's teaching strategies (Wanbugu, Changeiywo & Ndiritu, 2013). Electromagnetism is challenging to learn by students because it does not use one of any human five senses (Dori & Belcher, 2004). The authors contended that visual imagery that can help makes the abstract concepts encountered in electromagnetism more concrete is often not possible. Many students showed misunderstandings and inconsistencies in electromagnetism that suggested they did not have a coherent framework of ideas about the course (Sağlam & Millar, 2006). Akanbi, Omosewo, Abdulraheem, and Ojediran (2017) study suggested that due to misconception, pre-service teachers in Nigerian colleges of education have difficulty in correctly explaining some concepts used in electromagnetism (Akanbi, Omosewo, Abdulraheem, & Ojediran, 2017).

Problem-based learning has been described as one of the successful methods of teaching electromagnetism in Asia (Cheng, Xue, Kwok & Cheung, 2003). Rodrigo, Demetrio, Luiz and Francisco (n.d), found an active-learning strategy to be effective in electromagnetic due to students' difficulties in assimilating electromagnetism. Constantinos et al. (2010), advocated for the inquiry-oriented teaching to overcome the problem of conceptual understanding of electromagnetism. Teaching electromagnetic has been difficult in France because of some reasons for which students' perception of the electromagnetism (Roussel & Helier, 2012).

There exist several strategies employed to teach science and the teachers' ability determines the effectiveness of these teaching methods. The students sometimes believed that science is challenging to learn (Aina, 2013a) because of its abstractness (Adeyemo, 2010). The reason for this erroneous belief is because of inadequate teaching methods. Most of these teaching paradigms are as old as science itself and must, therefore, be changed or modified.

The needs to use modern Physics techniques were underscored by the NCCE (NCCE, 2008). As mentioned, the NCCE recommends the following teaching methods: lecture-based instruction, inquiry method, demonstration, laboratory method, problem-solving, projects, Computer-Assisted Learning, team teaching and field trips (NCCE, 2008). Each of these methods will be reviewed.

2.5.1 Lecture-based Instruction. The method is based on the introduction of new information to students in a way that is familiar to them. According to Gehlen-Baum, Weinberger (2014), the lecture paradigm is a method that delivers new information to a sizeable cohort of students. The teacher is expected to prepare wide to be sure the students gain maximally by the interventions of various skills along with the information. The teacher needs right lesson notes, a room comfortable for learning and others as a preparation for the lecture method. Also, it is required that the teachers have good language skill and good motivational ability. Otherwise, the class is annoying since the teacher alone does the talking in the lecture method. Students only sometimes ask a question(s). Lecturing is a teacher-centred paradigm. There are criticisms that the method is a one-directional strategy of instruction rendering inactive in the class (Gehlen-Baum & Weinberger, 2014). In the same vein, Afolabi, Izuagba, Obiefuna, and Ifegbo (2014) said the lecture strategy is teachers' centred approach which makes student passive and learning superficially. According to Berry (2008), a lecture-based method is good at delivering information for a short period but not an active learning interactive engagement. The lecture-based strategy is often a unidirectional process that is not accompanied by the question, a discussion which makes it not a suitable method (Hatim, 2001). Lecture paradigm focuses on information instead of the students' learning (Al-Rawi, 2013). The lecture method supports teacher telling the students what they are to do rather than activating them to discover for themselves what to do (Miles, 2015). Franklin, Sayre, and Clark (2014) observed that students in a lecture-based class are likely to learn much to succeed in exams but may not in the subsequence course remember the topic.

Lectures may be used to organise information and also create interest in a course but insufficient to demonstrate practical skills. An excellent lecture may inspire and motivate students to learn, but it creates boredom, confusion, anxiety, and frustration in students (Wood, Joyce, Petocz & Rodd, 2007).

2.5.2 Inquiry method. This refers to an active learning process through problem-solving and dialogue, as well as generating and answering higher-order questions (Walker, Shore & French, 2011). The inquiry is a paradigm that gives student tasks to do, develop their knowledge and understand scientific ideas through open-ended, student-oriented, hands-on tasks where the teacher is a facilitator (Irinoye, Bamidele, Adetunji & Awodele, 2015). Inquiry-based teaching strategies promote the learning of scientific concepts and processes and also how scientists conduct their research in the natural world (Tatar).

Inquiry learning is described as permitting the development of students' and skill in a successful learning experience (Barron & Darling-Hammond, 2008). Observations show that to develop critical thinking skills and develop science contents require inquiry-based learning (Apedoe, Walker & Reeves, 2006). Peffer, Beckler, Schunn, and Renken (2014) similarly argued that the development of scientific reasoning skills needs an inquiry. Inquiry method is a student-centred instruction. Science inquiry involves asking the question, developing data explanation, a collection of evidence from different sources, communication of the findings, and to defend the conclusions (Hunter 2014).

The inquiry involves asking logical questions, seeking information, drawing conclusions, reflecting on what could be the solutions (Milson, 2002). Inquiry learning permits the student to focus their skills of investigation to the completion of scientific processes like observation and experimenting, data gathering, hypothesizing, and analysis (Keselman, 2003). According to Looi, Zhang, Chen, Seow, Chia, Norris, and Soloway (2011) giving out questions, obtaining and evaluating evidence, experimenting, and participating in the debate are the cynosure for the learner in an inquiry learning. This type of learning gives an opportunity for students to learn for themselves in a controlled environment and the teacher help and guides (Schoffstall & Gaddis, 2007). Inquiry learning encourages students learning. According to Löfgren, Schoultz, Hultman, and Björklund (2013), students are encouraged to study and evolve the right attitudes for learning science when taken part in inquiry tasks. Inquiry method demands that the students have the required repertoires before going for the on inquiry training. If students do not have the needed repertoires, inquiry learning may fail, and students might be frustrated (Kuhn, Black, Keselman & Kaplan, 2000)

2.5.3 The demonstration. It is a beautiful teaching strategy that improves the understanding of students and retention (McKee, Williamson & Ruebush, 2007). The demonstration allows the teacher to show the pattern of what she/he expects the students to investigate when the lesson ended (Daluba, 2013). The teacher shows the students the way of doing it and explains the process step-by-step (Chikuni, 2003; Ameh, Daniel & Akus, 2007). Mundi (2006) explained it as an exhibition that the teacher usually does as students watch with the utmost attention. The technique is useful in teaching any skill through observation (Sola & Ojo, 2007). However, available time to carry out these demonstrations is not enough to continue for the instructional time. Thus, the demonstration is frequently designed to allow students to observe instead of taken part in hands-on laboratory activity (McKee, Williamson, & Ruebush, 2007).

Iline (2013) viewed the demonstration as a direct means of explaining things to the learners. Nevertheless, the author issued a warning that it must be done for students correctly to follow the right methods of doing things. This is essential because the method is based on the axiom: we learn by "doing" (Sola & Ojo, 2007). It implies that when a teacher is not sure or has the expertise of the concept to be demonstrated, he or she should not demonstrate it. The demonstration method emphasizes telling, explaining, and showing with the primary aim of preparing the learner for problem-solving as a skill (Part, 2006).

The demonstration is a strategy of teaching which synthesis convectional lecture period and personal instructional systems (Maun & Winnitoy, 1980). A demonstration paradigm is a technique of teaching that joins verbal explanation with doing to communicate processes, concepts, and facts (Sola & Ojo, 2007). We use the demonstration to introduce a new skill to a whole group naturally, but it may be applied to individuals or a small group whenever more support is required for their learning (Owen, 2006).

The students actively participating in the learning process makes the strategy practical (Maun & Winnitoy, 1980). The technique uses illustrations, questioning opportunity, visual aids, and demonstrations. The demonstration allows the teacher to use activities that could be inimical to students within the typical classroom (Part, 2006). This method of teaching has some benefits both to the teacher and the learners. According to Ameh, Daniel, and Akus (2007), the following are some of the advantages of the demonstration method:

- It is an attention inducer and a powerful motivator in lesson delivery;
- Students receive instant feedback through their products;
- It gives a real-life situation of course of study as students acquire skills in real-life situations using tools and materials;
- It helps to motivate students when carried out by skilled teachers, and it is right in showing the appropriate way of doing things (Daluba, 2013, p.2).

This technique allows the student to come in direct contact with a teacher to explain the points missed during lectures (Maun & Winnitoy, 1980). Students learned physical or mental skills when they are supervised as they perform those skills (Sola & Ojo, 2007).

Iline (2013) stressed that the demonstration strategy allowed the students to see and hear the details of what is being taught and become proficient. Thus, the author recommends the method because it leaves nothing to chance. The demonstration as a teaching method with its benefits has some demerits requires consideration. These are few of the demerits:

- Teachers may overuse the method;
- The teacher determines what they want to "tell" the students rather than what students need to know;
- It is easier to prepare the daily lecture than it is to plan with the students and identify the kinds of learning experiences that will bring about the desired changes in insights and understanding (Part, 2006, p.4).

2.5.4 The laboratory method. This is similar to the demonstration, but the two are not the same. The students experiment individually or in groups (Knox, 1927). The students obtain data through this experiment and analyze the data, interpreted the result and write a conclusion on their own. This type of method has been given a central position in science education. According to Hofstein and Lunetta (1982), there are many benefits derived by science educators when using a laboratory method of teaching. The laboratory method helped the science educator to develop the power of observation in the students (Isozaki, 2017). Additionally, it equips the learner with the ability to perform a simple experiment and draw inferences from results (Hamidu, Ibrahim & Mohammed, 2014).

2.5.5 The project method. It is a broad investigation of a real-life topic worthy of a student's attention and effort (Chard, 2011). Project-based learning (PBL) is an instructional strategy where students by doing real projects, learn valuable skills (Holubova, 2008). The project learning paradigm is a teaching strategy that allows teachers to tutor learners through broad studies of real-life topics (Chard, 2011). In project learning, students learn to take responsibility for their learning; this instruction helps the students to form a stable base through which they could work with others throughout their lifetime. This method emphasizes building a whole unit around an activity which may be carried out in or out of school (Pattnaik, Chakradeo & Banerjee, 2014).

According to Knoll (1997), project learning is considered as a means by which students (a) develop independence and responsibility, and (b) practice social and democratic modes of behaviour. This author said project learning was introduced in the curriculum to help students study to work independently at school and be able to join theory and practice. The project method is a target-driven activity based on the challenge, fostering success and efficient cooperation, during which the students' activity gains more weight than the communication of knowledge by the teacher (Szállassy, 2008, p.49).

The project strategy is discussed under different headings such as project work, project approach, and project-based learning; it is one of the standard teaching methods. Project learning is action-centred, student-directed learning strategy and endeavour in which students take part in practical problem solving for a specified period (Artemieva, 2016). Projects, for example in Physics, may consist of the construction of a meter bridge, a ripple tank, designing a DC motor, or producing a video film of charges in motion. Many a time, a project is the teacher's initiative, the students could individually or in a group plan and execute the project themselves (Knoll, 2014). Not like the conventional strategy, projects centres on applying, not imparting, particular knowledge or repertoire, and are more tedious than lecture, demonstration, basically to enhance the intrinsic motivation, independent thinking, self-esteem, and social responsibility (Knoll, 2014).

Students are highly motivated, actively involved and produce quality work leading to growth individually or collaboratively if the project strategy is successfully implemented by the teacher (Chard, 2011). Knowledge in project learning is not acquired in sequential order; it must be well planned and executed correctly for the timely completion. These are some of the drawbacks of the project method of learning, as asserted by Pattnaik, Chakradeo, and Banerjee (2014).

Projects are utilised to a tool for teaching to achieve results and also for acquiring various skills (Holzbaur, 2010). This author further argues that projects are a robust method for teaching, training, and research in education.

The author, however, said there is also much effort accompanied by academic and pedagogical challenges, which calls for a systematic approach to the planning and conducting of projects. The role of the teacher in project learning should be as a friend, guide, and working partner. The teacher should learn with students and should not claim to know everything (Pattnaik, Chakradeo & Banerjee, 2014). If project learning is well planned and executed successfully, it has many benefits. Some of these benefits are, promoting co-operative activity; arousing and maintaining the interest of students; and developing scientific attitudes.

2.5.6 Computer Assisted Instruction (CAI). CAI comprises a wide range of computer technologies added to the classroom learning context and can dramatically increase a student's access to information (Collins, Deck & McCrickard, 2008). Technology has the use of computers for teaching and learning possible in schools today. This is the reason many schools make knowledge of Integrated Communication and Technology (ICT) compulsory for student's admission. According to Lansford (1999), CAI affords students lots of learning opportunities: students can work at their pace and spend time on skills they need to learn. For Aotani (1998), there is a low level of student-to-student interaction in CAI as students proceed at their pace. CAI is perfect for Physics students to the teaching of some difficult concepts that are dangerous to teach in the ordinary classroom. This is done through computer simulation. The use of computer simulations has the potential for enormous benefits to student understanding of Physics concepts (Bryan, 2006, p.239).

2.5.7 Team teaching. Traditionally it is a pedagogic approach or process in which more than one teacher would be involved in teaching and learning instruction in a classroom (Akpan, Usoro, Akpan & Ekpo, 2010). Team teaching is where all members of a team are involved in sharing responsibility for the instructions o.f students, assessed them, set and meet the learning objectives. Team teaching is not a single teacher teaching because it involves two or more teachers each with unique roles, sharing responsibilities for planning, presentation and evaluation of lessons for the same group of students (Esomonu, Akudolu & Ezenwosu, 2015). Hughes and Murwaski (2001) remarked that what distinguishes team teaching from a single teacher's teaching is a collaboration, cooperation, and interaction.

Team teaching is an effective way of constructing in-depth learning of concepts as learning alternative ways to teach the same subject-matter (Jang, 2006). Team teaching involves two or more teachers that work together with the same group of learners. Team teaching allows more than one teacher to combine their expertise, resources, talents, and interests to take a combined responsibility for teaching the same cohort of students (Main & Brye, 2006). Team teaching involves harnessing of the benefits of cooperative efforts among teachers: team teaching is valid and has a positive impact on students' academic achievement (Uwameiye & Ojikutu, 2008).

According to (Leavitt, 2006), team teaching assists in creating a dynamic and interactive learning context, providing teachers with a useful way of modelling, thinking within or across disciplines Team teaching is when a cohort of teachers are working together, planning, conducting and evaluating activities of learning for a group of learners that are the same (Robinson and Schaible, 1995). Team teaching leads to better student performance regarding greater independence and assuming responsibility for learning (Akpan, Usoro, Akpan & Ekpo, 2010). Team teaching enables students to witness how a collaborative team works (Yanamandram & Noble, 2005). Brandenbury (1997) team teaching exposes students to different types of teaching styles and strategies, which increases the potential for the team to meet the various learning styles of students.

Team teaching is not a perfect teaching method and has associated problems. When students are exposed to a variety of different teaching styles and viewpoints within the one subject, they may have the experience of frustration and confusion (Goetz, 2000). Besides, the author stressed that a smart student might attempt to play one teacher against the other to improve his/her grades. The role of teachers in team teaching should be made explicit to achieve success in the transmission and construction of knowledge.

2.5.8 The field trip. This is an essential component of science teaching. It is an excursion taken outside the classroom to make a relevant observation and also for obtaining specific information (Abdullahi, 1982, p.85). Profitable field trips enhance the development of students into young men and women who had more knowledge and more persuasive critical thinking skills and show increased historical empathy (Greene, Kisida & Bowen, 2014).

Research suggests that students retain a great deal of factual information from their tours. Beyond recalling the details of their trips, students who participated in a field trip had a stronger ability to think critically than those who do not (Greene, 2014). According to Legutko (2005), one apparent positive effect of field trips is that students enjoy getting out of the classroom and having real-world and first-hand experiences. Aina and Joseph (2013) observed that taking students out of class on field trips is vital because it makes teaching and learning of science practical.

Myers and Jones (2003) showed that teachers need to be actively involved in teaching activities during the entire field trip and use various teaching strategies than in traditional classrooms. For instance, interacting with students to assist answer questions, initiating a discussion with small groups of students through questioning, and playing more the role of facilitators or guides.

Field trips as a method of instruction have disadvantages like all other teaching methods. According to Abdullahi (1982), there are instructional problems of field trips: it takes more time than a class period; extra financial burden and the risk of accidents.

Pedagogy of teaching in most classes today is centred on theory rather than practice. That is why Herrington (2006) declared it is clear that the transfer of theory to practice in teacher education courses is not active. It implies the ability for students to practice what was learned is not active. The students have the theory but cannot transfer it to practice. This transfer is essential for students to apply the acquired knowledge in electromagnetism outside the classroom. In other word, students of electromagnetism must be reflective practitioners and life-long learners. Thus, the idea of authentic learning becomes critical

2.6 Objectives and Contents of NCE Physics Curriculum

Students enrolled for Physics in Nigerian Colleges of Education have a weak or little understanding of Physics concepts (Alao & Abubakar, 2010). These students were obliged to enrol for Physics as NCE curriculum required students to combine two teaching subjects with the principle and method of education. The result is that the Physics class comprised a mix of those students with a little school Physics background and those students with adequate school Physics knowledge.

The National Commission for Colleges of Education (NCCE) has a clear objective of promoting Physics education in Nigeria. This objective for the content and curriculum of Physics education is presented below. Physics is regarded as paramount for the technological development of any country. Physics is a core science subject crucial to understanding the world around us (Agommuoh & Ifeanacho, 2013). Physics is thought to be the most fundamental science subject whose concepts and techniques are required to support the progress of all other branches of science (Sheriff, Maina & Umar, 2011).

According to the National Commission for Colleges of Education (NCCE) minimum standard (NCCE, 2008), students should be able to:

1. Have a basic knowledge of the organizational concepts and techniques in practical Physics and laboratory management;
2. Be aware of the fact that the fundamental ideas of Physics evolved from a process of inquiry, which will enable them to develop scientific attitudes, which are transferable to

other situations;

3. Plan and effectively execute Physics-based lessons in secondary schools;
4. Have sound basic knowledge of Physics concepts and principles to equip them for further studies in Physics-related courses;
5. Explain the nature of science;
6. Use science resources effectively;
7. Use Information Technology (IT) effectively to support pupils/students learning Physics;
8. Demonstrate the understanding of the concepts of Physics, reflect upon them and revise them when necessary;
9. Organize Physics lessons for the whole class, groups, and individuals effectively;
10. Recognize the difficulties students face when learning Physics;
11. Remedy students' misconception in Physics;
12. Develop pupils' use of Physics language and
13. Carry out a formative, diagnostic and summative assessment of students' work (theory and practice) in Physics successfully (p.103).

NCCE (2008) knew the importance of sound pedagogy of teaching Physics and therefore prescribed different types of methods for the teaching of Physics. Some of these methods, such as demonstrations, laboratory inquiry, and lecturing amongst others, are discussed below.

This study has no preference for any of these methods because of the weaknesses associated with them, as highlighted in the literature. The focus of this study is to find out the veracity of a research-based pedagogy namely peer instruction (PI), especially when the goal of achieving the objectives of NCCE envisaged for Physics education remains elusive.

2.7 Challenges of Physics Education in Nigeria

Physics education is crucial to the development of any nation. Nigeria, as a country, has not developed in technology as expected for the aspiration of the citizenry due to challenges confronting its educational system.

Problems in Physics education delivery and understanding has been observed and commented upon by numerous scholars (Musasia, Abacha & Biyoyo, 2012; Thomas & Israel, 2013). The paucity of qualified Physics teachers has been an essential problem in Nigerian Physics education since independence. The teacher remains a critical educational resource in schools. (Boyd, Lankford, Loeb, Rockoff & Wyckoff, 2008). Sander and Rivers (1996); Aaronson, Barrow, and Sander (2007); Rockoff (2004) were of the firm opinion that a teacher could significantly influence students' achievement. Teachers have an essential role to play in preparing students adequately to play their role in teaching and learning in the society to achieve the objectives set for the nation (Okemakinde, Adewuyi & Alabi, 2014). The quality of any educational system is mostly based on the quality of teachers regarding academic and professional qualifications, experience, competence and the level of dedication to their primary functions (Oluremi, 2013, p.423). Teachers are the facilitators who emphasize the learning of science concepts (Owolabi, 2012). Teachers amongst others are regarded as one of the most critical factors in driving the effectiveness of schools and the quality of a child's education (Akinsolu, 2010). The study of Physics depends on the teachers' teaching quality (Apata, 2013). Without a well-trained, genuinely inspired, and teacher who is a well-supported, the attainment of excellence in Physics at the high school will not be possible (The American Association of Physics Teachers, 2009).

Qualified teachers are crucial, but they are mostly incapable of teaching Physics in most schools (Aiyelabegan, 2003; Akanbi, 2003; Adeyemo, 2010). Part of the problem lies in the recruitment of graduates from different discipline fields for teaching Physics in schools. Most of these graduates are not professional and did not specialize in Physics education, resulting in what is known as out-of-field teaching.

The problem of out-of-field teaching is uncommon in many Physics teaching literature in Nigeria. Many teachers who are teaching Physics in most of the Nigerian secondary schools are not specialized in Physics Education (Omosewo, 2009). In another situation, it is possible to find a teacher who specialized in Physics but then required to teach at a level for which he or she was not adequately trained. For instance, in Nigeria, the Nigerian Certificate in Education (NCE) graduates are trained for primary school and upper junior secondary class. However, current practice requires these graduates to teach Physics at the senior secondary school level because of a shortage of Physics teachers. These teachers have insufficient Physics knowledge.

Out-of-field is defined as teachers who teach out of their field of qualification; this area might be in a specific subject or year level. Teaching out-of-field occurs when a teacher teaches a subject he or she does not qualify in. Research data show that out-of-field teaching typically requires qualified individuals to teach subjects that do not match their qualifications (Ingersoll, 2002a, p.2; Du Plessis, Gillies & Carroll, 2013).

Out-of-field teaching is a problem of poorly prepared teachers (Ingersoll, 2002b). Interestingly, out-of-field teaching is a global issue not peculiar to Nigeria alone; it happens even in developed countries like the U.S, Australia and even in South Africa. Du Plessis, Carroll and Gillies (2014) cited that 16% and 30% of science teachers in Australia and South Africa respectively were unqualified while 31.4% of Physics teachers were unqualified in the United Kingdom.

In Nigeria, it is a common practice to see a qualified teacher teaching a subject he/she had no training for, at that point, such a teacher is regarded as unqualified. Du Plessis also said out-of-field teaching is when a qualified teacher became unqualified as a result of assigning him/her to teach a subject or levels lacked the required qualifications. Du Plessis et al., opinion was that out-of-field teacher is in the developing process, and not suitable to teach a subject he/she not qualified. Out-of-field teaching is an indication that the teacher is not adequate in subject-matter knowledge: inadequate subject-matter knowledge is found by scholars to be a severe factor lowering the standard of quality teaching (Darling-Hammond & Ball 1997). Out-of-field teaching is a problem for our educational system, and most of the problems caused by this phenomenon are so high that it may not be quantifiable. (Ingersoll, 1999, p. 29). Ingersoll (1999) highlighted a few consequences of out-of-field teaching as:

- Diminishing the time utilised for teaching preparation;
- Reducing the time for teaching and
- Decreasing in the morale and commitment of the teacher

The assignment of teachers to teach fields in which they have no training could change the allocation of their preparation time across all of their courses. They may decrease the time supposed to use for other courses in a way to prepare for the one(s) for which they have no background. An out-of-field teacher whose attention is on subject content new to him has limited time to focus on understanding students' needs and interests (Salleh & Darmawan, 2013). The self-esteem of out-of-field Physics teacher is low; there is the feeling they do not have the requirements (Du Plessis, Gillies & Carroll, 2013). Hobbs (2013) posited that out-of-field teaching could compromise 'teaching competence' and can disrupt a teacher's identity, self-efficacy, and well-being (p.274).

Darling-Hammond in McConney and Price (2009) said the employing under-qualified teacher is one of the principal factors causing students' underachievement. McConney et al., (2009) succinctly argued the stress in teachers is caused by the out-of-field teaching. Anecdotal evidence reveals that many so-called Physics teachers in Nigerian schools teach out of their field of specialization. He further pointed out that the problem of out-of-field teaching will not allow us to address a shortage of teachers adequately enough.

The adverse effect of out-of-field teaching is on the teacher. He examined how out-of-field teaching influences teachers' development opportunities. These authors further stressed that anything that inhibits the professional development of a teacher is also restricting his or her educational development. Out-of-field Physics teachers lacked adequate knowledge to approach their teaching duties (Du Plessis et al., 2013).

The success of any teaching and learning process, which influences students' academic performance depends on the teachers' effectiveness and efficiency (Sabitu & Nuradeen, 2010). According to the American Association of Physics Teachers (2009), the primary role of a teacher is to establish a learning environment where all students are motivated and able to learn. The quality of any educational system depends in no small extent on the quality of teachers both academically and professionally (Oluremi, 2013). Teachers are an essential element in schooling because they have the ultimate responsibility to navigate the curriculum and instruct their students in the classroom (Caballero, 2010). Clotfelter, Ladd, and Vigor (2006) viewed the quality teacher as one of the most significant institutional determinants of academic success. Quality education requires an adequate supply of qualified teachers (Hobbs, 2012). The teachers determine the quality of education in the classroom (Du Plessis et al., 2013).

According to Adeoti (2012), in the year 2011, more than 1,300,000 candidates are seeking for admission in the university in Nigeria, not up to 5% of these applicants made education as a choice. It indicates they do not have an interest in the teaching profession (Ibukun, 2004; Durosaro, 2006 & Adeoti, 2012).

There is a lack of recognition, motivation in term of salary and other incentive and nobody want to be a teacher; no new qualified teacher want to teach again, the old ones are leaving or retiring (Ibidapo-Obe,2007; Akindutire & Ekundayo, 2012). The qualifications for entry into the teaching profession by the pre-service teacher in Nigeria are low when compared with the standard obtained in developed countries such as Finland. Adeoti cited a university don as saying that many universities and colleges of education were using the old curriculum; many teachers are still teaching with the teaching method they learned many years ago.

Scholars have asserted that one of the problems in Physics education is students' poor academic performance due to the pedagogy of teaching (Harrison, 2010; Muriithi, Odundo, Origa & Gatumu, 2013; Erinosho, 2013). The problem of the pedagogy of teaching is not new. It existed in Physics education many decades ago (Adeyegbe, 1993; Griffin, 1994;

Rennie & McClafferty, 1995). Teachers' pedagogy is an essential factor motivating students' choice and learning of Physics. One of the major problems of the system of education in Nigeria in the present age is the issue of having sufficient qualified personnel to teach in schools at different levels (Ibidapo-Obe, 2007). Many Physics teachers lacked teaching experience, teach Physics in abstraction, lacked adequate knowledge of subject matter and also the competence to deliver. Poor quality of science teachers regarding adequate knowledge base and pedagogical skills is a problem of Nigeria science teachers (Omorogbe & Ewansiha, 2013). Similar to this is the submission of Odia and Omonfonmwan (2007) that teacher training institutions in Nigeria are producing teachers who are not trained well regarding knowledge of subject matter and pedagogical skills.

Physics education in Nigeria has a problem of producing teachers with inadequate pedagogical content knowledge to teach Physics. Lacuna exists in the training of Physics teachers between subject-matter content and the pedagogy. The pre-service Physics teachers in Nigeria are always sent to the faculty of science in the university to learn Physics while they remain students of education faculty. Experiences and observation show that these students who are oscillating between two faculties have not been able to learn very well. Therefore, these students are not well developed in the subject-matter content nor the pedagogy of Physics.

Another problem is teaching practice exercise. This exercise should develop the students' pedagogical knowledge, but because of poor policy, it has not. For instance, the Finnish pre-service teachers have practicing schools within the universities for proper assessment (Aina & Ogundele, 2015). In Nigeria, pre-service Physics teachers are sent out to many schools far away from the universities for weeks of teaching practice. This arrangement has failed to yield the right result because of poor teacher evaluation and follow-up counselling. The result is that students graduate with partial subject content as well as pedagogical knowledge.

Pedagogical content knowledge (PCK) is considered to be the characteristic of the knowledge a teacher has of how to teach the subject matter. PCK represents a unique form of teacher professional knowledge (Koh, Chai & Tsait, 2010). PCK is for professional teachers because it directs the teachers' actions when handling the subject matter in the classroom (Van Driel, De Jong &Verloop, 2000). It is a unique body of knowledge for the science of teaching that the teacher acquires to successfully implement teaching within complex and varied contexts (Park & Oliver, 2007).

Most Nigerian Physics teachers have a poor PCK due in part to inadequate teacher training exposure. PCK is the knowledge that teachers evolve, and through experience, on how to teach specific content in particular ways to enhanced student understanding (Koehler, 2011). PCK is different for teachers of any given course; it is unique expertise with individual characteristics and critical differences that are influenced by the teaching context, content, and experience. The combining of specific knowledge in a discipline with that of the teaching is a skill regarded as PCK (Nuangchalern, 2012). The author buttressed further that it is required by the teacher to combine content knowledge with the teaching strategies. The crucial position of PCK was underscored by Schneider and Plasman (2011) that it helps us to think about what the teacher should learn continuously in their teaching practice. A significant percentage of Nigerian Physics teachers are, for example, engineers who became teachers because they could not secure an engineering job. Thus, many of them lacked adequate PCK to teach Physics effectively in their schools.

According to Van Driel, Verloop and de Vos (1997), PCK is a construct that is surrounded by knowledge of the subject matter, general pedagogy knowledge, and contextual knowledge. PCK by Carter (1990) is the knowledge of teaching that is considered to be domain-specific. The author further stressed that PCK makes what a teacher know about the content of the subject understandable to students. The engineer who became a teacher may have the content knowledge but not necessarily know how to teach Physics students, which requires sound pedagogical knowledge.

Bozkurt and Kaya (2008) viewed PCK as the knowledge base needed for teaching that is subject matter knowledge and pedagogical knowledge consisting awareness of the curriculum, the knowledge of learning difficulties of students and the knowledge of instructional strategies and activities.

The importance of PCK in teacher education cannot be overemphasised as Van Driel, Verloop and de Vos said PCK is a knowledge base for teaching. The author further said PCK is not just the knowledge of the subject matter, but the understanding of learning difficulties and student conceptions. A physics teacher may be brilliant but, if he or she cannot interpret the subject content to help the students learn, he or she has failed. Therefore, PCK is a teacher's explanations of knowledge of subject content to enhance the learning of students (Van Driel, Verloop & de Vos, 1997).

PCK is worthwhile outside the classroom because teachers perform their best professionally through it. The knowledge of the subject content or that of the teaching strategy does not only make the professional development of a teacher but the combination of both (Nuangchalern, 2012). The case of many out-of-field Physics teachers we have in Nigeria is that they are sometimes exquisite in content knowledge but cannot deliver in the classroom.

Teacher self-efficacy is the beliefs a teacher has about his perceived capability in undertaking specific teaching tasks. It is the trust a teacher has that he or she can do a specific teaching task (Lunenburg, 2011). Many of the teachers we have in Physics class today are such with low self-efficacy, and that is why many topics of Physics were never taught until the students are about to write their final examination (Aina, 2013).

Pendergast, Garvis, and Keogh (2011) said teachers with a high level of teacher self-efficacy were more flexible in teaching and may likely endure at a trying time to students attain their potential academically. A teacher who has a firm trust in his or her efficacy would stay on to resolve challenges and, most fundamentally, learn from past activities (Frost & Bang, 2012). Many Nigeria Physics teachers are not resilient in solving Physics problem perceived challenging to students.

Lunenburg (2011) believed that self –efficacy affects teachers' level of efforts and persistence when learning difficult tasks. The lack of self-efficacy makes some Physics teachers believe that some topic like Gauss law, flux density, and electric potentials are difficult to teach (Aina, 2013). Teachers who have no trust in their efficacy may be avoiding dealing with challenges in academic but rather yield their effort toward relieving their emotional distress (Bandura, 1993). Teachers with high efficacy perceptions persisted with low-achieving students and used better teaching strategies that allowed such students to learn more efficiently. Conversely, teachers with low self-efficacy spent more time on non-academic tasks and used less efficient teaching strategies that hindered student learning (Sharma, Loreman & Forlin, 2011, p. 13). This submission has been the principal reason many girls are not offering Physics in Nigerian schools.

The low level of achievement often recorded in Physics in Nigeria today could be traced to low teachers' self-efficacy as opined by Tschannen-Moran and Woolfolk (2001) that teachers' self- efficacy has proved to be powerfully related to meaningful educational outcomes such as students' achievement. Capara, Barbaranelli, Steca, and Malone (2006) asserted that teachers' self –efficacy beliefs are a determinant of job satisfaction and students' academic achievement. Many Nigeria Physics teachers are not satisfied with the teaching job because of poor remuneration and this affect student's academic achievement. Low teachers' self-efficacy causes a low student's academic achievement in any subject (Dimopoulou, 2012).

Teachers teaching Physics should have that trust in himself that he can teach the subject. Otherwise, he should not teach the course. According to Ghanizadeh and Moafian (2011), the trust a teacher has about his/herself, and the capabilities may influence the quality of the teacher 's performance. It is not an overstatement to say that poor academic performance often recorded among Physics students in Nigeria secondary schools may not be separated from teachers' low self-efficacy. Teachers' self-efficacy is consistently associated with students' academic achievement (Holden, Groulx, Bloom & Weinburgh, 2011). Bandura (1993, p. 134) put it that, when an employee (teacher) has high self-efficacy they are more likely to work harder to learn a new task as they will be more confident in their abilities than an employee (teacher) with low self-efficacy.

Lack of motivation is a severe challenge to Physics Education in Nigeria. In Nigeria, citizens are not encouraged to choose Physics education as a field of study. Those who defied all odds to study Physics Education are not motivated by providing them jobs. Based on the anecdote, those who study Physics Education are fewer in Nigeria workforce than any other fields. The situation is worst, seeing many graduates in Physics Education roaming the street jobless while engineers are teaching Physics in schools. It makes it tough for many Nigerian students to choose Physics Education as a field of study. Motivation can act as a catalyst for many Physics students who have lost interest in the course, maybe because of the abstract nature of the subject (Adeyemo, 2010; Aina, 2013) or because of teachers teaching strategies (Wanbugu et al., 2013). According to Christiana (2009), motivation is vital to students' learning. Where this motivation is lacking either from the government or the teachers, the result is always not good. Adeyinka, Asabi, and Adedotun (2013) are concern about the negative response of students toward the aims and objectives of education which could be attributed to the teacher's low motivation.

Lecturers and professors in the universities killed students' interest in Physics Education. Most of these scholars do not teach but read formulae and equations to students. They looked at Physics Education students as strangers in the Physics class who cannot cope with memorization of factual knowledge. As a result of this, the attrition rate in Physics education is higher than any other courses. Motivation is crucial to learning.

The inadequate educational resource is a problem of Nigerian Physics education. The Nigerian government has no right vision for Physics Education. According to Ajileye (2006), poor science teaching and learning resources are primarily the problem of Physics education in Nigeria. Some of the resources that are not adequate are science equipment, laboratories, specimens to be used as teaching aids and many more.

Many students learned Physics in Nigeria schools without adequate laboratory knowledge because the government failed to provide the required Physics laboratory equipment. Aina (2012) once observed that schools in Nigeria lacked good laboratory for teaching and learning of science. Where they managed to convert a classroom to a laboratory, the Physics apparatus in such laboratory are those probably purchased since Nigerian independence in 1960. Worse still, where there are few modern types of equipment, the teacher is not able to handle such equipment due to insufficient knowledge.

Most colleges of education running Physics education in Nigeria lacked simple Physics equipment for learning. These colleges award certificate to students to go and teach Physics in schools. There are good numbers of simple Physics apparatus I have never seen as a Physics teacher in my life. I learned this equipment as a student and now as a teacher never seen it yet teaching it in abstraction.

The government shows a lackadaisical attitude to the provision of learning resources for Physics education at all levels. The types of teachers recruited are those who had not secured a job in their field of studies and used Physics teaching as an alternative. These teachers lacked the right fundamental qualities of Physics teachers. Many do not have professional development for an extended period while teaching. According to Oluremi (2013), professional development is systematic steps of ensuring teachers upgrading and regular self-development. Professional development is critical to the retention and improvement of any Physics teacher in the classroom (American Association of Physics Teachers, 2009). Professional development helps practicing Physics teachers to update their teaching skills, content knowledge and adjusting to the emergence of new curricula and research findings on teaching and learning (Agharuwhe, 2013).

Most students entered into Physics education with great interest, but the majority of these students dropped out before graduation. Besides, some dropped Physics education for another course in mathematics education. However, this is not a problem that is peculiar to Nigeria alone; it happens in another developed world as the United States of American.

Research indicates that most of these students dropped Physics education for other courses as a result of poor teaching pedagogy (Watkins and Mazur, 2013).

The worst of all the problems of Physics education in Nigeria is corruption. Corruption pervaded all sectors of the Nigerian educational system, especially Physics education because it is not a popular discipline among Nigerian students. Corruption is the abuse of public office for private gain, and it is an aspect of lousy governance (Ogundiya, 2014). Funds allocated for buying equipment for Physics education are often misappropriated and used for none educational purposes. Where laboratory apparatus is purchased for Physics: shallow qualities ones are bought. Because of corruption resources from the country treasury supposed to be used for research are being controlled by a few politically powerful individuals (Otoghile, Igbafe, & Aghontaen, 2014). Modern and relevant Physics books are very scarce in the school library, yet funds are budgeted for good books. Lecturers and teachers are not left out in the Nigeria corruption saga.

Many of the lecturers have lost the value of academic excellence because of the pecuniary advantages. They make learning difficult for the few students in Physics education by selling handout to them at a very high price. Most of the handouts are written obsoletely and compiled many years back with no effort to update them. Some lecturer tampered with students' scores with impunity—all these discouraged students from learning.

The nature of Physics and the school background is another problem. Many believed that Physics is abstract and challenging to learn (Adeyemo, 2010). Examples abound where parents and friends dissuade wards and friends from enrolling for Physics education because they believed it is hard to pass with a good grade. Many of the public universities and colleges of education are so terrible that it makes meaningful learning tough. Mekonnen (2014) asserted that the environment and the school students attended play significant roles in students' learning. Many lecture rooms are without the right furniture, no internet facilities, no adequate lighting system and much more. All these impede teaching and learning of Physics education. The problem may seem general to education, but the impact is more on Physics Education because of its nature. Physics is a science of measurement (Omosewo, 2009) and involved calculations of higher thinking order (Ramos Dolipas & Villamor, 2013), thus need more concentration.

Poverty is another problem confronting Physics education in Nigeria. According to Otoghile, Igbafe, and Aghontaen (2014), corruption breeds poverty, and it affects disproportionately those in the low-income status because resources are pulled from the country treasury into the hands of politically powerful few individuals. The Nigeria economy has been in a sorry state for more than two decades due to corruption. The state of the economy affects both the teacher and the students. The few lecturers and educators in Physics education combine more jobs with their first working of teaching. The commitment of these teachers to effective teaching will be low, thus impact students' achievement negatively. There was a case of a lecturer in a public college of education which will not enter the classroom to teach until a few weeks to the semester exam. There are many of this type of lecturer in the universities and colleges of educations. These lecturers always go around looking for jobs in the private organization for more money to meet the needs of their families. Some deliberately refused to teach because they felt their pay does not commensurate with their teaching and lecturing job. The question is: what is the impact of these challenges on Physics learning? This question leads us to Physics students' academic performance.

2.8 Misconceptions in Science

The misconception is another challenge of learning Physics in Nigerian schools. According to Stein, Larrabee, and Barman (2008), science education teachers are expected to have knowledge that will specifically challenge students' common misconceptions. This submission is germane if the teacher will positively impact the scientific understanding of the students. According to Gooding and Metz (2011), if misconception remains unchallenged for an extended period, the tendency is to remain permanent. To solve the problem of students' misconceptions, teachers must first identify those misconceptions (Gooding & Metz, 2011).

One of the purposes of the PI and also its importance is that it helps the teacher to identify students' misconceptions in science quickly. The success of PI depends on the use of conceptual questions that will target the common misconceptions and basic subject concepts (Porter et al., 2011). Crouch et al., (2007), contended that the incorrect answer choices in PI class reflect students' most common misconceptions. Personal observation during the group discussion revealed that the answer a student gave to a ConcepTest directly tells his or her conception. Thus, PI, unlike some other science pedagogies, has the potential to detect students' misconception. There were instances when students misconceived the concept of the resistor as being the resistance. Similarly, the idea of capacitor and capacitance is another area of misconception**.**

At this juncture, it is vital to discuss the Peer Instruction in details. PI has been used in many schools by many teachers, which makes reviewing its processes and results, worthwhile. For instance, Al-Hebaishi (2017) used PI in Taiba University, Saudi Arabia, among the pre-service teachers. Similarly, Nielsen, Hansen-Nyg°ard and Stav (2012) conducted a PI at Sør-Trøndelag University College, Norway. The work of Nitta (2010) in Tokyo Gakugei University on PI is one of many examples that also need to be mentioned.

2.9 Peer Instruction (PI)

PI is a cooperative paradigm to engage students in classroom discussion through the questioning process in an interactive manner to promote critical thinking, problem-solving, and decision-making skills (Rao & DiCarlo, 2000). It is a method created to help make lessons more interactive and to get students intellectually engaged with what is going on in the class. It has been tested in many classes and found to be useful for improving students' performance and also used to identify students' difficulty areas in many developed countries of the world.

A survey carried out by the PI users at Harvard University some years back indicates no African countries use PI as a pedagogy of instruction in schools. Table 2.2 below shows the demographic breakdown of survey respondents using PI according to the country of the instructor.

Table 2.3

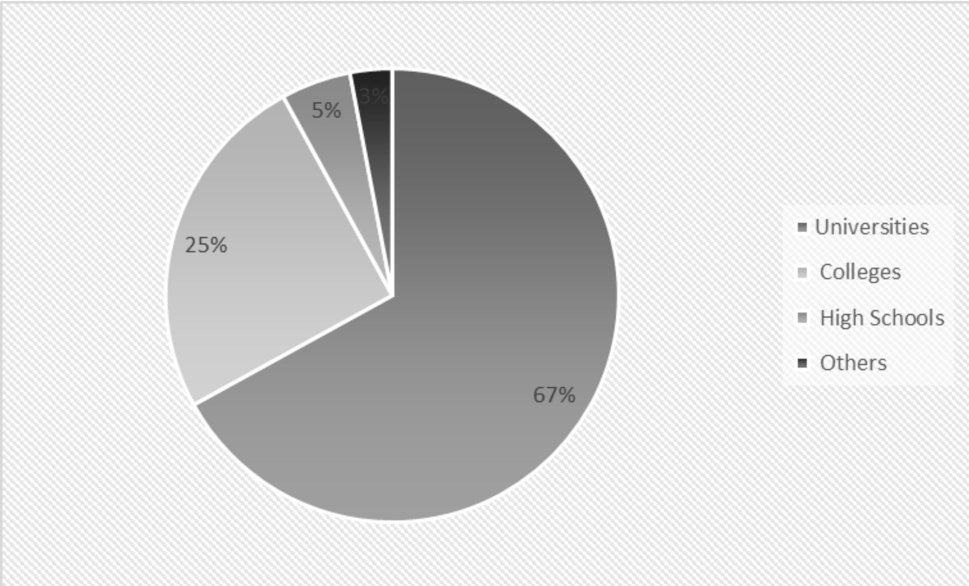
Peer Instruction Implementation Based on Country

s/n	Country of instructor	Count
1	United States	320
2	Canada	20
3	Australia	11
4	Belgium	3
5	The Netherlands	3
6	Spain	3
7	Sweden	3
8	Colombia	2
9	Hong Kong	2
10	Scotland	2
11	Others (1 each)	12

Source: Fagen (2003)

Countries with one survey respondent each are Argentina, Chile, Cyprus, Israel, New Zealand, Peru, Philippines, Portugal, Slovenia, Taiwan, Thailand, and Venezuela. The above table did not show any Africa country using PI in schools which implies the instruction was not well recognized in the continent before 2003. Nonetheless, only a few science educators had implemented the PI in Kenya in recent time (Ouko, Aurah & Amadalo, 2015). Moreover, there are instructional methods similar to the PI, such as cooperative learning and peer teaching in many African schools. However, these are different from the PI, where the ConcepTest is being employed.

The figure below indicates how institutions use PI in the countries represented in the table above.



Source: Fagen (2003)

Figure 2.1 Peer instruction

Figure 2.1 shows how institutions employed the PI in countries of the world after it was first introduced at Harvard University in 1997. It shows that Universities had the most significant percentage of usage.

Peer Instruction is a paradigm of instruction used to engage students in a classroom teaching utilising a structured questioning process involving every student (Crouch, Watkins, Fagen & Mazur, 2007). PI provides a structured environment for students to voice their ideas and resolve misunderstandings by talking with their peers (Gok, 2012). Peer instruction is a cooperative learning strategy that enhances critical thinking, problem-solving, and skills for decision-making (Rao & DiCarlo, 2000). PI evolved to improve the learning process in the science classroom (Rosenberg, Lorenzo & Mazur, 2006).

PI is more effective at developing the conceptual understanding of students' than conventional lecture-based instruction (Lasry, Mazur & Watkins, 2008). PI helped to improve student mastery of both conceptual understanding and quantitative problem solving (Lasry et al., 2008). According to Gok (2012), PI encourages students to be responsible for their study and emphasizes understanding. PI does not reject the lecture strategy, but it is a supplement that helps to engage students who have various learning styles (Rosenberg et al., 2006).

Peer Instruction engages students in the classroom using activities that require every student to apply the basic concepts that are presented and explain these concepts to their fellow students. Lessons in PI made use of the short presentations on the main points, each followed by a ***ConcepTest***– short conceptual question, commonly posed in a pattern of multiple-choice, on the subject under discussion.

Discussion sections and homework are used to address the quantitative learning ability of students. The teacher will demonstrate to the students by solving a problem, and then students go into a group discussion. The teacher moves around to assist students that may encounter any problems. Students are required to submit their written solutions to the problems at the end of the week (Crouch, Watkins, Fagen & Mazur, 2007).

All the aspect of the PI is essential; however, as indicated in the developed model in Chapter One of this study, the critical thinking period is crucial. After the ConcepTest is posted the next period is to allow the student to think critically before the choice of the correct answer (Crouch, Watkins, Fagen & Mazur, 2007)

The PI has been criticised that it does not promote learning, but students copied the right answer to the ConcepTest from the brilliant ones. Given this, there is the need to ensure both the bright and the poor students actively participate through dialogical argumentation to interrogate concepts to reach consensus on the correct answer to a statement, problem or related issue. For this discursive strategy, the incorporation of the Dialogical Argumentation Instructional Model assisted with the strategy of cognitive engagement through a process of cognitive argumentative steps, namely individual (intra-argumentation); small group discourse (inter-argumentation); small-group presentation (trans-argumentation); whole-class discussion (meta-argumentation); reflection focus group interviews (relational argumentation) in order to reach cognitive harmonisation as an outcome (Langenhoven, 2014).

2.10 Critical Thinking

Critical thinking is the application of knowledge in more complex ways. It is the utilization of knowledge after careful and measured examination of every information and viewpoints, to make decisions which are not centred on self (Flores, Matkin, Burbach, Quinn & Harding, 2012). Mazer, Hunt & Kuznekoff (2007) said critical thinking is the ability to construct meaning and articulate and evaluate arguments, as well as evaluate sources and support. Critical thinking is a purposive, and thoughtful way of solving problems and for which an incontrovertible solution is not likely (Rudd, Baker & Hoover, 2000). Critical thinking is also understood as argument analysis and as such requires an understanding of informal logic, definitions, evidence, assumptions, conclusions, and implications as well as the knowledge and theoretical basis of the discipline in question (Jones, 2007, p.211). The role of critical thinking has been dated back to the time of Socrates; this is not a new construct in education (Visser, Visser & Schlosser, 2003).

PI involves a student's cognitive ability. Thus Jones (2007) affirmed that critical thinking is a set of cognitive skills usually involving problem-solving. The success of PI is centered on the students being able to convince his or her peer through a logical argument after a few minutes of critical thinking. Thus, Jones (2007) viewed critical thinking as an ability to examine the logic of an argument. For a student to be able to convince his or her peer, there is the need for a proper understanding of the concept under discussion. Therefore, Visser, Visser, and Schlosser (2003) concurred that critical thinking demands an adequate understanding of the issue of the investigation. According to these authors, critical thinking requires the willingness to change one's view as a result of examining ideas and facts that may seem obvious.

Critical thinking is crucial in students learning as underscored in the process of PI. According to Jones, Merritt, and Palmer (1999), students should be able to think critically both within across the various disciplines that make up their study programme. In any discipline, the role of critical thinking should not be watered-down. It is more than a decade ago when Pithers and Soden (2000) argued that in the educational system, it is not only the contents information that is important but also developing skills for thinking critically. Similarly, Flores et al., (2012) advocated for the shifting of education from content to teaching students how to become critical thinkers. Today, developing the critical thinking skill of every student should be the concern of every teacher. One key objective of PI is to enhance learning that students can always apply outside the classroom: in other words, life experience learning. Therefore, it is correct, the observation of Al-Fadhliand Khalfan (2009) that educators are always emphasizing the importance of developing thinking skills that can be practiced in life experiences. Grafstein (2007) said it is imperative always to encourage students in higher education to develop critical thinking skills.

According to Halx and Reybold (2005), critical thinking calls for students reflection; setting aside the assumptions they established, and consider other. Therefore, critical thinking needs the presence of mind to evaluate and examine knowledge before its acceptance (Tsui, 2003).

After critical thinking, the students make choices of the answer, which if only a few got it correct, they need to go into a group discussion. Research studies indicate that there is always an increase in the percentage of correct answers (Crouch, Watkins, Fagen, & Mazur, 2007; Aina, 2017). Nevertheless, how the right answers increases is still a subject of debate. Therefore, to solve this problem, the scientific argumentation method is applied to group discussions.

Learning theories provide perceptions of what enhances learning effectiveness and the way students learn (Mugisha & Mugimu, 2015). According to Alzaghoul (2013), a learning theory helps to understand the primary complex learning process which describes how people and animals learn. The two theories, social constructivism and the constructive controversy reviewed below were adopted for the study.

Constructivism learning theory is the active construction of new knowledge which is based on the student's prior understanding (Alzaghoul, 2013). Constructivism describes the way that the students can make sense of the material and also how the elements can be taught effectively (Amineh & Asl, 2015). The Constructivism as a learning theory allows teachers to consider what students know and let them put their knowledge into practice (Amineh & Asl, 2015).

Social constructivism assumes that understanding, significance, and meaning are joint human beings development (Amineh & Asl, 2015). According to Cornu and Peters (2005), constructivism is the thought that students have active roles to play in constructing their meaning during learning. The constructivism holds the view that the role of teacher shifts from being a source of knowledge to a facilitator of learning (Ng'ambi & Johnston, 2006). Through interaction between the students and teacher ideas are constructed in social constructivism classroom. (Powell & Kalina, n.d). Social constructivist learning theory opined that students must actively participate in their learning (Harkness, 2009).

Social constructivist supports the idea that knowledge should not be the property of individuals, but, it occurs in a group setting, distributed and shared (Dori & Belcher, 2004). According to Dori and Belcher, the role of social interaction is crucial in science teaching and learning. Learning is a social and collaborative activity which allows students to construct meaning as they interact with one another (Schreiber & Valle, 2013).

Constructive controversy is a thoughtful discourse, a discussion of the merits and demerits of proposed actions, targeted at bringing together novel solutions (Tichy, Johnson, Johnson & Roseth, 2010). Constructive controversy is not individualistic learning but, a collaborative one in the group (Tichy, Johnson, Johnson & Roseth, 2010). Research indicates that constructive controversy produces higher-level reasoning as against individualistic learning (Tichy, Johnson, Johnson & Roseth, 2010). Constructive controversy is not agreement seeking, debate, and individualistic attempts to learning (Roseth, Saltarelli & Glass, 2011).

Constructive controversy promotes higher levels of moral character, moral reasoning and moral motivation than individualistic learning (Tichy, Johnson, Johnson & Roseth, 2010. The process of constructive controversy is organizing information and deriving conclusions in the classroom learning context (Johnson & Smith, 2012). It helps students to improve their skills to constructively and innovatively think and find solutions to complex learning problems (Daniels & Cajander, 2010).

The four cognitive processes of analysis, comparison, inference, and evaluation are collectively called critical thinking skills or higher-order thinking skills (Ramos, Dolipas & Villamor, 2013). For the students to be adequate in their knowledge of electromagnetism, the four cognitive processes are imperative.

Critical thinking is displayed by a person's capacity to identify issues, being able to infer, evaluate evidence, and generate conclusions (Bohlander, 2010). Critical thinkers conclude that after they have only defined their terms, distinguishing fact from opinion, asked relevant questions, made detailed observations, and uncovered assumptions (Herr, 2012). Students must be able to identify an issue, create a plan for action and reflect on their experiences both during the process and after (Zaff & Lerner, 2010). Sedlack, Dohney, Panthofer, and Anaya (2003) define critical thinking as a reasoning process reflecting on ideas, actions, and decisions. One of the most critical aspects of learning in high school is having the critical thinking abilities to make connections between subject areas (Milne, 2014). Halx and Reybold (2005), a student with high critical thinking ability level would reflect and set aside assumptions to consider others views. Ramos, Dolipas, and Villamor assert that for students to be able to confront the real-world, their type of thinking process must go beyond the mere learning of facts and content. Ramos et al. cited critical thinking as a means of thinking process that progresses upward in the given direction.

Deficient in critical thinking skills are manifested by the inability to integrate multiple perspectives with a multiplicity of facts and determine the best course of action (Flores, Matkin, Burbach, Quinn & Harding, 2010, p.214). The students are deficient in the analysis, according to Stiggins, Rubel, and Quellmalz (1988), cited in Ramos et al. (2013) analysis is more than rote repetition; instead, it involves reflectively structuring knowledge in new ways (p.50). Evaluation tasks require students to judge quality, credibility, worth or practicality using some established criteria and explain how the criteria are met or not met (Ramos et al., 2013). Saingan (2008) cited that inferential thinking is the ability of a student to form an idea, opinion or a conclusion after he/she has made a series of reasoning and speculating outcomes of a situation. The focus of education should be shifting from teaching content but to teaching students how to become critical thinkers. Critical thinking requires that a student has a thorough understanding of the topic under consideration (Visser, Visser & Schlosser, 2003). Thus, this study considers the Dialogical Argumentation Instructional Model (DAIM) in support of PI to investigate students' understanding of Electromagnetism I. by creating teaching and learning moments as spaces for argumentation.

2.11 Dialogical Argumentation

Scientific argumentation is an attempt to refute a claim by giving reasons in a way that shows the values of the scientific community (Norris, Philips& Osborne 2007). According to Bricker and Bell (2009), argumentation is a primary knowledge practice of science. Therefore, the goal of science education must not only be mastery and memorization of scientific concepts but also learning how to engage in scientific discourse. Science will not be different from any other subjects if it depends only on the mastery of concepts. Therefore, students must be able to engage in the scientific discourse

Abell, Anderson, and Chezem (2000) explain the relevance of scientific argumentation in science education because the objective of scientific inquiry is the generation and justification of epistemic claims, beliefs, and actions taken to understand nature. It is therefore crucial for the teachers to be well knowledgeable about scientific argumentation. Teachers need to give students more opportunities to craft scientific arguments and participate in discussions that demand the students to support and challenge claims based on evidence (Sampson, Enderle & Grooms, 2013). It implies that any teacher who cannot justify his or her scientific knowledge claims may not be able to guide the students in scientific inquiry.

It is essential to understand that scientific argumentation is entirely different from a typical argument between people. In scientific argumentation, however, explanations are generated, verified, communicated, debated, and modified. The idea behind participating in scientific argumentation should be to refine and build consensus for scientific ideas, based on evidence (The Science Teacher, 2013).

It has been widely endorsed that the science concept as an argument should be recognized and the view that involving in scientific argumentation should play a principal role in science education (Kuhn, 2009). It is essential to investigate the understanding of science teachers' argumentation during pre-service teacher education as it gives the opportunity to address any weakness in their understanding of the argumentative nature of science (Aydeniz & Ozdilek, 2015). Students taught with argumentation-based instruction developed their scientific reasoning better than students who received conventional instruction (Acar, 2015). It could be thought of as a constructivist teaching strategy because student discussion and reasoning are at the fundamental of this form of instruction.

Students required work in groups, listen to each other and articulate their ideas for argumentation to take place (Simon, Erduran & Osborne, 2006). Supporting the submissions of these authors, the underpinning theory for this study are Social Constructivism and the Constructive Controversy. The theories underscore the interactions, and constructive dialogue as the students work together in groups. For students to be proficient in science, there is a need for the teacher to engage students in scientific argumentation as a part of teaching and learning pedagogy (Sampson & Schleigh, 2013). Proficiency requires every student to be able to articulate his or her scientific knowledge anywhere and at any time. Many students claim scientific knowledge but to defend the knowledge claims is sometimes a problem.

The understanding that learning of science through argumentation helps the student to develop an enhanced understanding of the nature of science is one significant reason it received attention (Driver, Newton & Osborne, 2000). Exposure to dialogical argumentation can help learners to think critically and independently about essential issues and contested values (Siseho & Ogunniyi, 2012). The science teacher education community must take pre-service science teachers' understanding of scientific argumentation seriously (Aydeniz & Ozdilek, 2015). Personal observation show that human beings remember more easily any debate that he or she had participated in; it is essential to inculcate the attitude of scientific discussion in pre-service teachers.

The Dialogical Argumentation Instructional Model (DAIM) has been employed to teach science with incredible results. A dialogical argumentation-based classroom provides learners with the opportunity to express their views freely as well as clear their doubts relating to their scientific understanding. (Angaama, 2012; Loggenberg, 2012; Langenhoven & Stone, 2013; Langenhoven, 2014). The purpose of DAIM is to create a discursive classroom environment where teachers and students argue, discuss, dialogue and learn together (Hlazo, 2014). The participants in this discussion and argument have the ultimate objective of reaching consensus on various scientific issues.

DAIM allows students to experience science as an argumentation philosophy, to be challenged, to think, to engage in discursive activities, improve students' understanding of scientific topics in-depth and have confidence in communicating the scientific use of evidence and reason (Nuryandi & Rusdiana, 2015). Students enter into science classes with misconceptions or alternative conceptions due to exposure to various factors and experiences: identifying and correcting this is the responsibility of the teachers. Thus, confirming the claim by Goodman (2015) that the Dialogical Argumentation Instructional Model improved the learners' conceptions of the capacitor for instance when exposed to this pedagogical model.

2.12 The Underpinning Theory

Learning theories provide perceptions of what enhances learning effectiveness and the way students learn (Mugisha & Mugimu, 2015). According to Alzaghoul (2013), a learning theory helps to understand the primary complex learning process which describes how people and animals learn. The two theories, social constructivism and the constructive controversy reviewed below were adopted for the study.

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2.13 Chapter Summary

In this chapter, the context for the study was provided as well as a review of the literature and similar studies which considered PI as a teaching strategy for use in science classrooms. The chapter focused on the rationale for using PI for teaching Electromagnetism I in Nigeria as supported by the extant literature. The chapter reviewed the NCE curriculum and challenges confronting Physics education in Nigeria which probably contributed to the poor academic performance in Physics as reported. The focus of the chapter was on several other kinds of literature, as mentioned both in the theoretical and conceptual frameworks. These kinds of literature include conceptual understanding and problem-solving skill in Physics, the misconception in science, the pedagogy of teaching, authentic learning, critical thinking, and dialogical argumentation. A case was made to move beyond the traditional rote learning and memorization of teaching and learning approach to a more robust student-centred-argumentative discourse to deepen conceptual understanding. My interest in this study is to assess whether PI-DAIM as pedagogy is useful in teaching Electromagnetism I to first-year Physics pre-service teachers at a Nigerian College of Education. Thus, the research methodology which is the cynosure for the entire study, will now be discussed in Chapter Three.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter explains the procedures used to carry out the study on the Effectiveness of Peer Instruction (PI) in Enhancing pre-service teachers' understanding of electromagnetism in a College of Education. This chapter explicates two aspects, namely, research design which tells one what was done and research methodology, which shows one how it was done. The research design detailed the research paradigms, research approaches and also the research strategy. The research methodology includes aspects such as the sample, setting, data collection techniques, data analysis techniques and reliability and validity assessment of the instruments and trustworthiness of the data mainly in the qualitative findings of the research. Furthermore, professional ethics considerations are explicated to ensure that participants are comfortable with the purpose of this study. The various methods of data collection and analytical procedures are pertinent towards providing critical responses to the research questions, as stated in Chapter One.

3.2 Research Setting

The study was conducted in a College of Education in the Kwara North senatorial district. The state is divided into three senatorial regions, which are Kwara South, Kwara North and the Kwara central. The entire state is made of two dominant ethnic groups namely the Yoruba and Nupe. The location of this college falls in the Nupe ethnic group. The town where this school is located can be classified as a semi-urban town which is mainly occupied by both the Yoruba and the Nupe. However, we have other tribes in the city, but the Yoruba and the Nupe are the significant dwellers in the city. The dwellers of this town are majorly farmers, teachers, and traders.

The majority of the students' population in the college are the Nupes and the Yorubas while there are few other tribes but not significant. The languages that are prominent among the students are English, Nupe, and Yoruba. The English language is the official language of instruction in the college. Nonetheless, the Nupe language is more prominent among the students because it is the language spoken in the community.

3.3 The Experimental Group

This is an entire class of physics students of electromagnetism I. The total number that finally participated in the study due to attrition was fifty-two students of which twenty-six were randomly picked for the experimental group. The group was made up of 15 male students and 11 female students. The researcher had two hours lecture with this group using the PI every week of the intervention. The researcher was assisted by the three research assistants who had adequate knowledge of Physics. The lectures were guided by the instructional programme prepared before the research begins. The instructional programme was validated through the scrutiny by the lecturers and the doctoral students in the school of science and mathematics education of the UWC. See Appendix A for the full instructional programme used in the study.

3.4 The Control Group

This group comprises of twenty-six participants who were 15 male and 11 female students. The group always had a two hours lecture during the week of the intervention. The researchers taught this cohort of students using only the lecture method without the PI. This group was monitored to ensure that none of the students had access to the PI class.

3.5 Population and sample of the study

The population for the research was made of all the Physics students in the college. The sample is a random sampling of fifty-two pre-service teachers who enrolled as Physics students at a College of Education (Technical) in Nigeria. The purposive sample is homogeneous regarding some internal and external factors such as academic background (all have at least a West African Secondary School Certificate in Physics). All the students had credit pass in Physics, Mathematics, and English language. The credit pass implies the student scores between 50% and 100% in WASCE as shown in the table below

Table 3.1

WAEC Standard Grading System

Grades	Definition	Interpretation
A1	Excellent	75-100%
B2	Very Good	70-74%
B3	Good	65-69%
C4	Credit	60-64%
C5	Credit	55-59%
C6	Credit	50-54%
D7	Pass	45-49%
E8	Pass	40-44%
F9	Fail	0-39%

Source: The WAEC

The table shows the grading system used by the WAEC in Nigeria to rate secondary schools result.

All the students also combined Physics with any other science subject in addition to doing obligatory core Education modules such as Methodology, Sociology of education, Educational psychology and Research method in education.

There were twenty-six students placed randomly into each group. These were students who combined Physics with any one of the following subjects: biology, chemistry, computer science, integrated science, and mathematics. They come from different departments within the Nigerian college structure. One reason for this sample is the fact that all our Physics students who are compelled to combine Physics with one other science subject as stipulated by the NCCE. Note also that these students were at the introductory level study of Electromagnetism I.

3.6 The research instruments

Three different instruments were designed to generate data for this study. The instruments used in the study are the following: Instrument 1-Electromagnetism Physics Assessment (EPA); Instrument II - Peer Instruction Dialogical Argumentation Questionnaire (PIDAQ); Instrument III - Semi-structured interviews. The fourth instrument was the ConcepTests which were the PI instrument used to teach the experimental group during the intervention and not for data collection. Three instruments (EPA, PIDAQ, and interviews) were for data collection while the ConcepTests were for the classroom instruction. The EPA was made up of conceptual questions, a real-world problem, and problem-solving questions. The conceptual and real-world problem questions were ten in number, and only three questions were on problem-solving. The reason for this limited number of problem-solving is because there are more of conceptual Physics than problem-solving in the Electromagnetism I. The questionnaire was designed to investigate if the students can apply their knowledge of Electromagnetism I to solve problems in life experiences. PIDAQ was prepared to get the opinions and views of the students who responded to the ConcepTest in PI class and their engagement with each other to reach consensus on incorrect responses and also their experiences of using dialogical argumentation in peer instruction (PI). The semi-structured interviews involved a series of open-ended questions soliciting students' narratives about their experience in PI (Mathers, Fox & Hunn, 2002). The choice of this type of interview sought to cater for questions that may arise during the researcher-student dialogue (DiCicco-Bloom & Crabtree, 2006).

3.7 Research methods

The study employed both quantitative and qualitative research methods to generate data for the study. Data were derived from the students' performance in the achievement test using EPA, student responses to the questionnaire (PIADQ) and the semi-structured interview.

3.7.1 Quantitative data collection. Data are collected as numbers through instrument I (EPA). The achievement test scores formed the essential quantitative data for the study. The data collected were analyzed using SPSS statistical tools.

There were two groups, as already stated in this chapter, which are the experimental and the control groups. The experimental group was taught using the PI, and the control group was not exposed to the PI intervention. The EPA was administered to the two groups both before and after the intervention. The scores obtained were analyzed using the ANCOVA and the T-test statistical tools.

3.7.2 Qualitative data collection. This research approach is aimed at getting an in-depth understanding of an issue as against a surface description of an extensive sampling of a population. It requires no experimental treatment or variable manipulation. It is a research method that tries to explore the meaning of peoples, experiences, culture and particular issue. It is exploratory research that made use of research question with no hypothesis; it is not predictive. A researcher in the qualitative study gets meaning from the participants and can adjust to the setting of the study.

The data collected here were principally from the questionnaire (PIDAQ) and the semi-structured interviews. Both the questionnaire and the interviews were administered to the experimental group. The questionnaire focused on the students' experience during the PI intervention as the students' dialogue through argumentation to get correct answers to the ConcepTests. The interviews were conducted for the experimental group to gain an in-depth knowledge of all that happens during the PI intervention.

The data collected from the questionnaire were analyzed using the frequency count and the simple percentage. The discussion among the students during the PI intervention was also transcribed to form the argumentative data. The PI provides an opportunity for students to freely discuss and argue in each group to arrive at a correct answer for any ConcepTest posted. The triangulation of quantitative and qualitative data provide robust results for the study.

3.8 Research Design

The study is a true experimental pre-post-test control group design. It is a robust design that has control over all the threats to internal validity (Cohen, Manion & Morrison, 2007; Ross & Marrison, 2003). The design allows the researcher to assign participants to groups (Ross & Marrison, 2003; Salkind, 2011). The design increases both internal and external validity through randomization (Salkind, 2011). The symbol system of the design is given and defined below.

Experimental Group: R O_1 X O_2

Control Group: R O_3 O_4

In this design, R indicates participants are randomly assigned to groups, O_1 *and* O_3 *representing* pre-tests, X represents the treatment implemented, and O_2 *and* O_4 represent post-tests.

The experimental group was subjected to eight weeks of lecturing interspersing lecture method with peer instruction. Twenty adopted Electromagnetism I ConcepTests from Peer Instruction User's Manual by Mazur (1997) were utilized for the lectures. (See Appendix A for the instructional programme). The pre-service teachers in this group attended two hours of lecture every week. The teacher introduces ConcepTest using a projector and gives two minutes for the students to think about the concepts. After two minutes, students responded to the ConcepTest by flashcards. When the percentage of the correct answer was more than 70%, the teacher gave a summary of the ConcepTest and moved to another ConcepTest.

When the percentage of the correct answer was less than 70%, the students moved to different groups to discuss the answer with their peers. The students were given time to argue out and reach consensus on the correct answer in each group. The teacher moved around the class to observe and listen to the students as they discussed among themselves. The groups selected a leader among themselves to discuss their answer with the whole class while members of the class were free to object to the answer with the reason(s). The teacher concluded the argumentation session with an explanation on the ConcepTest as the case required. The time for this session was 30 minutes.

The control group also attended two hours of lectures every week in Electromagnetism I. The teacher only uses the traditional lecture method for this group. This group was not exposed to the use of ConcepTests. However, the same topics that were taught using ConcepTests in the experimental group were also taught but with only the lecture method. The researcher taught both the experimental and the control groups by himself throughout the intervention period.

The last week of classroom instruction was used to assess the students. The Research Instrument (EPA) as pre-test was already administered to both the control and the experimental groups at the start of the intervention. The same EPA was administered (post-test) to both groups after the intervention, while the Instrument, Peer Instruction Dialogical Argumentation Questionnaire (PIDAQ) and the interviews were applied only to the experimental group.

3.9 Data Analysis

The data collected was triangulated, accurately scored, and systematically organized to facilitate analysis. The SPSS statistics programme of version 23 was used to analyse the quantitative data. The SPSS statistics package provides the opportunity to check for the reliability of the data and also for specific assumptions before the use of the statistical tools. For the qualitative analysis, the interviews records and the argumentative discourse were transcribed in addition to the responses to the questionnaire items.

3.10 Pilot Study

The pilot study is the specific pre-testing of a particular research instrument (Van Teijlingen & Hundley, 2002). It is a study used for gathering preliminary support for the next research step (Moore, Carter, Nietert & Stewart, 2011, p.332). Turner (2010) posited that a pilot test should be conducted with participants that have similar interests as those that will participate in the intended study. A pilot study is critical to the design of a useful research study. However, Van Teijlingen and Hundley (2002) contended that conducting a pilot study does not guarantee success in the main study, but it does increase the likelihood of success (p.33). A pilot study is imperative because of its numerous benefits. Cone and Foster (2005) highlighted the following advantages of a pilot study:

- Enable the participants to respond according to instructions
- To identify and decide how to handle unforeseen problems
- To find out how long it takes the participants to finish their tasks, and
- To learn how to use and to check the adequacy of the instruments (p.228).

A pilot study was conducted among pre-service teachers in a college of education using the EPA that was already ranked by the experts. This college of education is different from the college of education sampled for the intervention. The instrument was administered to pre-service teachers in the Physics department. The pilot study was carried out before the real intervention took place. The results of the pilot study were collated, which indicated poor understanding by the students. The reliability of the instrument was calculated using SPSS software package. The outcome of the reliability test deleted some questions amongst those already ranked by the experts, bringing the EPA questions to only thirteen from twenty.

The outcome of this pilot study was presented at an academic conference and also published in reputable journals (Aina, 2016; Aina. 2017).

3.11 Reliability and Validity

The reliability of an empirically designed instrument is the degree to which the collected data can be interpreted consistently across different situations. It may be subjected to various methods such as test-retest and inter-scorer reliability. Before instruments were administered, the inter-scorer method was used whereby raters scored items on a scale of 1 to 5. This study used inter-scorers' reliability for measuring the degree of agreement between two or more scorers, judges or raters. Any item scoring an average of 3 or less was discarded. The reliability statistics of the instrument was calculated using SPSS software to get the Cronbach's alpha coefficient to be 0.876, according to Pallant (2011), Cronbach's alpha coefficient above 0.7 is reliable.

Secondly, validity refers to the degree to which a measuring instrument has measured what it is designed to measure (Ramaligela, 2013). According to Joppe (2000), validity is to find out if the research truly measures that which it was purposed to measure or how accurate the research results are. Golafshani (2003), validity is whether the means of measurement are correct and whether they measure what they are intended to measure (p.599).

In this study, questionnaires were used to get pre-service teachers views about peer instruction using dialogical argumentation in electromagnetism I class. In other to ensure the reliability and validity of the instruments, a pilot study was carried out using pre-service Physics teachers in another school different from the participating school. It was done before the commencement of the intervention to assess the validity and appropriate use of the instruments. For the reliability and validity, these questionnaires were submitted to a panel of science teachers and science education lecturers for rigorous testing in 2015. The panel interrogated and ranked the items on a scale of 1-5, (1 indicating a poor item and 5 showing an excellent item). This ranking results in the elimination of some questions in the EPA which was used for the pilot study. The EPA was also submitted to a Physics lecturer at a Nigerian University for a thorough scrutinizing before administering it to the students.

The mixed-method was adopted in this study because it provides a better understanding of research problems than either approach alone; provides more extensive evidence for studying a research problem than either quantitative or qualitative research alone. Besides, it offers strengths that offset the weaknesses of both quantitative and qualitative research. It also helps answer questions that cannot be answered by qualitative or quantitative approaches alone. The use of mixed- methods in research, such as recording, observation, and the interview could yield more valid and reliable results.

Table 3.2

R*eliability Statistics of EPA*

Cronbach's Alpha	N of Items
.876	13

The table shows the

3.12 Lectures

Eight weeks were spent for the PI intervention in a College of Education: during this period, lectures were held for the two research groups. The experimental group had their lecture with the PI while the control group was taught using a lecture method without the PI. The researcher and the three research assistants were always involved in the experimental group lecturing. The researcher introduces the ConcepTest and gives a few minutes for the students' responses through the flashcards. The research assistants did the counting and recording of the students' responses. The lectures in the control group did not involve the research assistants.

3.13 Electromagnetism Physics Assessment (EPA) (See Appendix B)

These questions were drafted to test the students' conceptual understanding and problem-solving skill on Electromagnetism I contents. The questions comprised ten conceptual questions and three problem-solving questions. The reason for this ratio was that Electromagnetism I course content for this level is more of a conceptual nature than a problem-solving. Few of the conceptual contents are the concept of charges, charge distribution and electric field while calculations involving current and electrical power are problem-solving

3.14 Interviews (See Appendix I)

The interview is vital for gathering data in qualitative research for a robust result. According to Gill, Stewart, Treasure, and Chadwick (2008), the purpose of the research interview are to explore the views, experiences, beliefs, and motivations of individuals on specific matters (p.292). Interviews enable participants to discuss their interpretations of the world in which they live and to express how they regard situations from their point of view (Cohen, Manion & Morrison, 2007, p.350). According to Cohen, Manion, and Morrison (2007), an interview is a flexible tool for data collection that enables the use of multi-sensory channels like verbal, non-verbal, spoken and heard. The interview was conducted to get students' opinions concerning the use of ConcepTest and also to record their arguments and experiences during peer discussion in the group. Two questions asked during the interview.

Two of the questions asked during the interviews are given below. The full questions are in the interview protocol presented as appendix I

(1) Tell me your own experience about the dialogical argument in your group discussion

(2) How did you personally get the correct answers to the ConcepTests in the PI classes?

3.15 Questionnaires

The questionnaire was administered to investigate the experience of the students on how they arrive at the correct answers during the PI intervention. The PI had been criticised that students did not learn but copied a few ones who got the correct answer to a ConcepTest. The items of the questionnaire were constructed to interrogate the personal experience of each student as they get involved in the group dialogue during the PI intervention. The questionnaire was administered to only the students in the experimental group. The questionnaire was tagged "**Peer Instruction Dialogical Argumentation Questionnaire."(See** Appendix D**).** This questionnaire was drafted to allow students to express their experiences in the space provided by the PIDA model for argumentation in the Electromagnetism I class. Three items among many that were in the questionnaire to seek for the participant's experiences during a dialogical argument are the following:

1. My experience in this peer instruction with the argument is interesting
2. I always get the correct answer in peer instruction before group argument
3. .List three concepts in electromagnetism, you understood more through the peer instruction argument?

The questions 1 and 2 required the students to Agree (A), Disagree (D) or Don't Know (DK)

3.16 ConcepTest (Appendix C)

These are short conceptual questions, typically posed in a multiple-choice format, on the subject being discussed. (Pilzer, 2007; Nicol & Boyle, 2003). ConcepTest serves two purposes simultaneously, which are, feedback and learning (Green, 2003). The instrument was adapted from the PI User's Manual by Mazur (1997) and subjected to a rigorous validation by the experts in the School of Science and Mathematics Education (SSME), University of the Western Cape (UWC) with students and in-service Science teachers. It was designed to reveal any common alternative conceptions or misconceptions that students may hold about Electromagnetism I (Fagen, Crouch & Mazur, 2002). The instrument was not used as a data-gathering tool but for teaching in the PI. The fundamental difference between the other interactive-engagement strategies such as cooperative learning, inquiry learning, and collaborative learning is the ConcepTest. Thus, the reason from the literature reviews in Chapter Two it has been described as the cornerstone of teaching with PI by Crouch et al., (2007).

3.17 Data Analysis

The statistical analyses found appropriate for this study are Analysis of Covariance (ANCOVA), t-test and descriptive statistical analysis. ANCOVA offers a way of statistically controlling the effect of variables one does not want to examine in a study. ANCOVA allows the removal of covariates from the list of possible explanations of the variance in the dependent variable. For example, the pre-test scores of the students in the experimental group may influence the outcome of the study as a result of the contamination effect if not statistically controlled. In typical pre-post-test setups, the related phenomenon of regression towards the mean can be handled by ANCOVA (Hennig, Mullensiefen & Bargmann, 2009, p.5).

ANCOVA can be used in a two-group pre-test/post-test design, such as comparing the impact of two different interventions (Pallant, 2011). An ANCOVA is used to determine if any statistically significant difference exists between the adjusted population means of three or more independent groups (Laerd statistics, 2013).

In this study pre-test on the experimental group is the covariate in other to reduce the error variance and eliminate systematic bias. With randomized designs, the primary purpose of ANCOVA is to reduce error variance, because of the random assignment of subjects to groups guards against systematic bias (Dimitrov & Rumrill, 2003, p.161).

It was argued that the ANCOVA be a better option over the others like the Analysis of Variance (ANOVA) because it generally will have more power and can readily be adapted to resolve problems such as heterogeneity of regression and nonlinearity of the relationship between pre-post-test (Wuensch, 2015).

The t-test is the most suitable method for comparing the values of some continuous variable for two groups or on two occasions (Pallant, 2011). For instance, independence t-test shall be used to compare the gender scores before and after the intervention.

Descriptive statistical analyses are used to organize and describe the characteristics of educational variables in short and meaningful measurable terms (Daramola, 2006). Such is exploring frequency count and percentages to determine students' understanding in the EPA.

3.17.1 Analysis of the electromagnetism physics assessment (EPA). The students' achievement scores were analyzed using the ANCOVA, the T-test and the descriptive statistical tools to answer research questions 1 and 2. The various assumptions that must be satisfied before employing the ANCOVA and the T-test statistical tools were presented in the results section in Chapter Four of this study.

3.17.2 Analysis of the audio records. The discussions of the participants in the various groups during the PI intervention was recorded and transcribed. The students in each group engaged in argumentative discourse before reaching a consensus on a correct answer to any ConcepTest. The transcription of this dialogical argumentation is presented in Chapter Four as part of the data to answer the research question 1.

3.17.3 Analysis of the questionnaire. The items of the questionnaire were made of two types of question: close-ended and open-ended. In the close-ended the respondents had the following options: Agree (A), Disagree (D), Don't Know (DK). The simple percentage was adopted to analyze the close-ended questions. The open-ended questions were analyzed by what each respondent wrote.

3.17.4 Analysis of the interviews. The interview tapes were also transcribed and analyzed to answer research question 3. As the interviews took place after the PI, it was used to determine the authentic learning experience of the students in addition to the achievement scores on the authentic learning questions.

3.18 Instruction Programme

The instructional programme is a full description of a course of programmed instruction, containing cogent statements regarding the size of lessons, the division of the learning materials into units. It is a replicable instructional activity designed and implemented to achieve an instructional goal, which may be, apparently defined change or changes in a selected group of learners.

An essential feature of the instructional programme has a curriculum component that defines the goal or goals we have for the learner and a set of teaching procedures planned to be used for achieving the curriculum goal. Crucial to an instructional programme is the change or changes intended to bring into the learner as already defined. Therefore, the need for a definite learning outcome is imperative.

This instructional programme will be in the following order:

- The teacher starts the lecture (videorecording)
- The teacher posting of ConcepTest (audio and video recording)
- Counting and recording of answers (videorecording)
- Division of students to groups (videorecording)
- Students group discussions (video and audio recording)
- Group leader explanation to the class (video and audio recording)
- The teacher's brief explanation of the final answer (audio and video recording)
- Selected students' interview (video and audio recording)

The programme was for eight weeks of learning activities involving Physics students in NCE 1 of the college. There were 2 hours of learning activities every week. The instructional programme was divided into two aspects that are training and classroom activities.

TRAINING

Staff

Four support staff participated in the research. Three as a research assistant and one to control the class control for adequate class management. Therefore, there was a week training for these participants on how and when to count and make a video and audio recording. Support staff was also trained on how to control the students during the class for effective classroom management. This is necessary because Peer Instruction is a new programme that has not been implemented in this school before.

Students

Students in the experimental group were trained on the various activities that took place in the classroom before the beginning of the intervention. It was crucial to train these students because the activities of the PI and the dialogical argumentation are different from that of traditional lecture activities. If these students were not adequately trained on the stages and processes that were involved the whole class may be noisy and the objective of the research not achieved.

CLASSROOM MANAGEMENT

One support staff and the teacher were always ensured all learning materials and the students were well positioned before the start of the lecture. A support staff assigned to the management of the class was always in the class with the teacher to guide the students. The same staff was also ensured that the classroom was adequately lighting and clean.

Classroom Activities

The lesson plan for each week guided the classroom activities. In this lesson plan, the ConcepTests that indicates the topic under discussion were highlighted. Other things included in the lesson plan were different activities of PI and dialogical argumentation in the class. The lesson plan was designed as shown below. The real lesson plan is presented in appendix A.

THE LESSON PLAN

Topic: ConcepTest number

Duration:

Material Resources*:* multimedia projector, laptop, flashcard, camera, video and audio recorder, whiteboard markers, chalk, Physics textbooks and Peer Instruction: A User's Manual.

Performance Objective:

Previous Knowledge:

Introduction:

Teacher's Activities:

Students' Activities:

Conclusion:

The above lesson plan format was used to plan the lesson for each week.

3.19 Ethical Considerations

The ethical standard guides all social science research because it deals with the human being. Therefore, before the start of this study, written permission was obtained from each of the participants. The participants took part in the research voluntarily. When the research began, the participants were made aware as to when, where and how the research will be conducted. The researcher ensured no harm or injury to any form comes to any of the participants as a result of the study.

The dignity and integrity of the participant are essential and was not violated. Anonymity and confidentiality were respected. For anonymity purpose, the real name of the sampled college was replaced by Aseyori College of Education (pseudonym) throughout the study. Anonymity also applied to the collation of data from the questionnaires, checklists, argumentation frames and the interviews. Interviews were conducted in private. The recorded information remains in the custody of the researcher for safekeeping until such time that it can be disposed of safely.

The researcher researched such a way that there were no favouritism and bias. The researcher granted any participant freedom to withdraw from the research at any stage if he or she feels the need to do so. The researcher ensured a comfortable and conducive atmosphere is maintained for the participants during the research. The research was conducted at a time convenient for all the participants.

In abiding by accepted professional ethics of research, the aims of the study, research design, and methodologies were communicated and discussed with all those involved in any data collection. There was full disclosure of the research topic and promise to convey the results of the study to all participants. Ethical clearance was sought from and approved by the relevant stakeholders in education.

3.20 Chapter Three Summary

This chapter provided an overview of the research design. The peer instruction paradigm was explained, and the data collection to be used by a mixed-methods approach. Both the quantitative and qualitative data were to provide different views of peer instruction among the pre-service teachers. Participants would be led into an interactive learning paradigm. The study sample was described along with the instrument for the data collection and the reliability and validity of the instruments. Ethical considerations were discussed regarding confidentiality and anonymity. The collation of data through the EPA, PIDAQ and the responses provided during semi-structured interviews was a rich bank of data for analysis and discussion in chapter 4.

CHAPTER FOUR: RESULTS AND FINDINGS

4.1 Introduction

This study investigated the effectiveness of peer instruction (PI) in enhancing pre-service teachers' understanding of Electromagnetism I in a Nigerian college of education as explicated in Chapter One. The focus was incorporating PI into the DIAM to have more robust results and strengthen the perceived weakness of the PI. It was to ensure that pre-service Physics teachers are entirely in compliance with the objectives of the National Commission for Colleges of Education (NCCE) and the Nigerian National Policy on Education (NPE). Both the NCCE and the NPE stipulates that students should have sound basic knowledge of the Physics concepts and be able to apply it in solving real-life problems (FRN, 2004; NCCE, 2008). To achieve this, the NCCE set specific objectives for colleges of education in Nigeria and developed a student grading system, as presented in Table 4.1 below. The NCCE objectives for Physics Education in Nigeria are reflected in Chapter Two of this study.

Table 4.1

NCCE Student Grading System

S/n	Grades	Interpretation (%)	Points
1	A	75-100	5
2	B	65-74	4
3	C	55-64	3
4	D	45-49	2
5	E	40-44	1
6	F	0-39	0

Source: NCCE (2008)

Table 4.1 is showing how the NCCE grades a student in the Nigerian colleges of the education system. As indicated by the table, the highest grade obtainable is a Distinction with 5 points, and the least is a Pass with a value of 1 point. Any student who scores between 0-39 has no point and is graded as a Fail and therefore cannot be certificated.

This chapter describes and analyses the data obtained from the administration of the various data collection instruments namely, the Electromagnetism Physics Assessment (EPA), the PIDAQ (Peer Instruction Dialogical Argumentation Questionnaire) and the interviews (semi-structured interviews). The semi-structured interview was used mainly to record the narratives behind the students' experiences with PI (Easwaramoorthy & Zarinpoush, 2006). A selection of results based on the research data collated is used to answer the following research questions:

4.1.1 (RQ 1) Research Question One

Does the incorporating DAIM into PI intervention have an impact on the pre-service physics teachers' understanding of electromagnetism I?

4.1.2 (RQ 2) Research Question Two

Is there any gender impact of incorporating PI into DAIM on the pre-service science teacher in the learning of electromagnetism I?

4.1.3 (RQ 3) Research Question Three

Is there a correlation between authentic learning classroom and the constructivism classroom based on the students' academic performance of electromagnetism I?

Since many authors are of the view that students' academic performance in Physics is poor in Nigeria (Ukoh, 2013; Mekonnen, 2014), the first part of the analysis looked at the impact of incorporating PI in DAIM has on the pre-service Physics teachers' achievement scores of Electromagnetism I. This provides an opportunity to determine if it has improved students' marks and to what extent scores can be correlated to inferring their understanding of Electromagnetism I concepts.

In other words, the first aspect of the analysis centered on the academic performance of the pre-service Physics teachers and the related achievements based on gender (male and female). The outcome for research question 1 was derived from the results and responses to the EPA, PIDAQ, the transcript of argumentative discourse and the semi-structured interviews. A methodological triangulation process was adopted to verify result validity and reliability (Golafshani, 2003).

The next dimension of the analysis focused on identifying any Authentic Learning (AL) acquisition which emerged from the pre-service Physics teacher's experiences. Besides, the correlation between the authentic classroom and the constructivist classroom based on the scores in EPA was also examined. The concept of authentic learning refers to the students' ability to apply what he or she learned in the Physics Electromagnetism I module to solve real-world problems. The main thrust of Authentic Learning (AL) is for retention and transfer of knowledge. Blooms' Taxonomy talked much about the process of learning, and according to Mayer (2002), the Revised Blooms Taxonomy elaborates on the ability of the participant in being able to use acquired knowledge as an application in a variety of real-life situations. For instance, students learn fuses and its application in electromagnetism I. The students should be able to solve the minor electrical problem at home, such as damaged home electrical appliances.

Retention debates, as is common in most learning today require the student to remember what was learned. In many subjects like Physics, retention is only through memorization, and that is why what was learned does not last long (Haskell, 2001). Bransford, Brown, and Cocking (1999) noted that retention requires remembering and being able to use what was learned. A perception exists that meaningful learning of Physics is defective because students do not retain the knowledge gleaned from learning materials for any length of time; besides, they find it difficult to transfer what was learned to solve problems in new situations.

According to Mayer and Wittrock (1996), the transfer is the ability of a student to be able to use what was learned to solve new problems, answer new questions and to facilitate the learning of the new subject matter. Hence the reason for focussing on authentic learning as an outcome when considering Physics teaching and learning as discussed (Aina, 2017a).

In this study, readers would have the privilege of assessing which of these fundamental elements of authentic learning are relevant to PI. Careful examination of the three research questions may reveal whether the use of PI when integrated to the DAIM as an instructional methodology could improve students' academic performance in Physics or not. The research questions may reveal whether PI could in any way lead to authentic learning of Electromagnetism I in Physics.

The following three statistical tools, namely, ANCOVA, T-test, ANOVA and Descriptive Statistics, as described below, is used to analyze the data in this study. These statistical tools are defined, and reasons are provided for choosing them.

4.2 Using the ANCOVA, ANOVA, **T-test and Descriptive Statistics as Analytical Tools**

Research questions one and two deals with parametric tests where specific characteristics of a population are addressed. Research question three is more qualitative, with themes and trends expressed regarding frequency tables.

Reason for using Analysis of Covariance (ANCOVA) is on the need to statistically control the effect of variables that are not necessary for the study. For example, in this study, the pre-test of the experimental group is a variable that was statistically controlled, which could also eliminate the effect of any contamination.

ANCOVA allows the removal of covariates from the list of possible explanations of the variance in the dependent variable. An ANCOVA is used to find any statistically significant difference between the adjusted population means of three or more independent groups (Laerd Statistics, 2013). The study made pre-test on PI to be covariates which must be statistically controlled so as not to influence the research outcome. The Analysis of Covariance has the potential to do this task. ANCOVA is the best option because of the random assignment of subjects to groups to guard against systematic bias (Dimitrov & Rumrill, 2003). To resolve problems such as heterogeneity of regression and non-linearity of the relationship between pre-test and post-test ANCOVA is required (Wuensch, 2015). ANOVA is used for detecting differences between the means of experimental groups (Sawyer, 2009).

The independent t-test has been adopted to compare the values of two different groups, and the same group on two separate occasions (Pallant, 2011). This test was applied to answer Research Question Two on gender.

Research Question Three was answered using the results of the PIDAQ (questionnaire), the semi-structured interviews and the EPA. A frequency table of percentages is constructed from the data collected, and descriptive statistics are used for the analysis. It is used for organizing and describing the characteristics of educational variables in short and measurable quantifiable terms (Daramola, 2006).

4.3. Results

The research questions were answered by drawing on the data collection, illustrative graphs, transcripts of interviews, support from literature and interpretations by the investigator. The legend provided an interpretive narrative of selected essential observations and findings.

4.3.1 (RQ 1): Does the incorporating DAIM into PI intervention have an impact on the pre-service physics teachers' understanding of electromagnetism I?

Consideration will first be given to the analysis of the pre-test in the control group and the experimental group of the Electromagnetism Physics Assessment (EPA) achievement score data. Table 4.2 is the t-test comparing pre-test in control and experimental groups of the students in the EPA.

Table 4.2

T-test comparing Pre-test in Control and Experimental Groups

		Levene's Test for Equality of Variances					t-test for Equality of Means			
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	95% confidence interval of the difference	
									Lower	Upper
Score	Equal variances assumed	.144	.705	1.09	50	.280	2.885	2.644	-2.425	8.194
	Equal variances not assumed			1.09	48.367	.281	2.885	2.644	-2.430	8.194

The t-test in Table 4.2 shows that there is no significant difference in the academic performance between the two groups before the intervention. This is evidenced by the observed 0.280 level of significance, which is higher than the probability value of 0.05. Thus, the students in the control and experimental group are assumed to be at the same academic level before the intervention.

In Table 4.9 transcripts of students discourses in dialogical argumentation support the result in the achievement test showing that students understand before the intervention in Electromagnetism I was weak and more specifically in the topics: electrical fuse, electrical connection, resistor, and resistance. Also, the narrative indicated that students had an indigent knowledge of electrical power, electrical charges, capacitor, and capacitance. Some questions in EPA confirmed that the students' knowledge is inadequate in these areas of Electromagnetism I. For instance, 42.3% of the students answered question 6 on charges correctly; 19.2% answered question 11 on electrical power correctly, and question 13 on capacitor had 30.8% correct answer. To extrapolate these assertions, I wish to use the following argument. Let us consider students understanding of selected Electromagnetism I concepts exposed in tables 4.10 and 4.11 then compare it with the EPA scores.

Student S1, S2, and S3 in Table 4.10 understanding of a transistor, electrolyte, and diode were seen as an Ohmic substance that perfectly obeyed Ohm's law.

The students' conversions in the table are shown below

S1: The transistor is one of the materials that obey Ohm's law

S2: Electrolyte also follows Ohm's law

S3: Both diode and transistor are Ohmic substances that obey Ohm's law perfectly

Student S13 in Table 4.10 said "the reason why power supply is transmitted with high voltage was to pass through a transformer. Student S16 believed it was to increase power while student S15 said it was to make power travel faster. By comparing the narrative with the achievement test scores show that the PI had little impact on the students' understanding of electrical power transmission. Thus, the submission, as expressed by the three students was a reflection of their scores in the EPA.

Table 4.10 shows that the students' understanding of a capacitor is not adequate as revealed by the discourse of student number 19, 20 and 21. The students' conversations are recorded thus:

S19: the two parallel plates of a capacitor carry charges on them which may not be equal.

S20: the charges depend on the types of plate.

S21: the separation between the plates is called an insulator.

The underlying principle for the students' discourse is the theory of constructivism. The theory has entrenched the understanding that a learner came into the learning situation with prior knowledge. This knowledge of students in Electromagnetism I identified from the dialogical argumentation transcript shows that the students' understandings before the intervention were inadequate. The conversation of all these students in Tables 4.10 and 4.11 revealed their inadequate knowledge of Electromagnetism I before the intervention. This further underscores the importance of constructivist learning in Physics as highlighted by a constructivist learning model (Aina, 2017b). The underlying themes in the constructivism model are the cognitive and social constructivism. These ideas are apparent in the transcript as indicated in table 4.10 and 4.11. For instance, in table 4.10 students S4, S5, and S6 submitted the following:

S4: ***The capacitor is the same as the capacitance.***

S5: ***Capacitance is the ratio of charge to the potential difference.***

S6: ***The capacitor is used in electricity***.

The students' statements here are based on individual perspectives which are in the realm of cognitive constructivism. The students interacted to argue on the different propositions and come to a consensus. The above statements concluded that "***the capacitor is an electrical***

device used to store charges." The conclusion is based on social constructivism because of social interaction during the argument.

A t-test was used to compare the scores in the two groups, as shown in Table 4.3 below to determine if there is a significant difference between the control and experimental scores. The t-test is used to compare the scores of continuous variables. We have one-sample t-test, paired-samples t-test, and independent-samples t-test. The latter is adopted for this analysis; it is used when comparing the mean score, on some continuous variable, for *two* different groups of participants.

Table 4.3

T-test Comparing Pretest-Posttest of the Experimental Group

		Levene's Test for Equality of Variances						t-test for Equality of Means		
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	95% confidence interval of the difference	
									Lower	Upper
Score	Equal variances assumed	.528	.471	3.25	50	0.02	10.04	3.086	16.24	3.839
	Equal variances not assumed			3.25	49.149	0.02	10.04	3.086	16.24	3.839

Table 4.3 shows the non-violation of the assumption of equal variance because the significant value of 0.705 is higher than the probability value of 0.05. The t-test for the equality of mean value has 0.02 (2-tailed) which is smaller than the probability value of 0.05; this implies that there is a significant difference between the groups. It could, therefore, be argued that incorporating PI into DAIM intervention has impacted students understanding of Electromagnetism I.

4.3.2 Results of EPA. This section provided results on the students' achievement scores based on the Electromagnetism Physics Assessment. The next section is crucial to this study to make the result interpretation understandable to the reader who may be a novice in

Physics. The brief explanations of concepts tested in each question will inform the reader some academic knowledge of aspects of the Electromagnetism I in the questions. Table 4.4 explains the performance in EPA before and after the intervention.

Table 4.4

Students Performance before and after Intervention

Question	Pre-intervention score (%)	Post-intervention score (%)
1	65	58
2	42	19
3	8	12
4	58	35
5	19	42
6	12	23
7	31	39
8	12	15
9	31	46
10	0	27
11	35	19
12	31	42
13	42	31

Statement 1: ***An electric charge could be transmitted through…***

This question tests the students' knowledge about the movement of charges through different materials. There are two types of substance that may either allow charges to flow through them or not. The substances are called conductor and insulator: conductor allows charge to flow through it while insulator does not. The critical difference between conductors and insulators is the mobility of the charges. In a conductor, the individual charges (i.e., the electrons) are highly mobile: in an insulator, each charge is substantially fixed in one location. The difference in the mobility of charges is a factor of 10^{20} between an insulator and a conductor. Because charges can move freely in a conductor, two critical things result:

a) The electric field is zero (**E**= 0) everywhere within a conductor. If not, charges would move along field lines, and thereby reduce the field, eventually to zero.

b) From the Gauss' Law, this implies that the charge density within a conductor is everywhere zero. The only place that there can be an excess of negative or positive charge is on the surface.

In insulators, charges are fixed, and it is secure. In contrast, a conductor will adapt to any externally applied charges, fields, or potentials and we must be able to calculate the response of the conductor (Lilly, 2010).

It is also paramount for the students to know that an electric charge is a form of energy. Given that, the conductor is a material that allows the passage of energy. Therefore, in this case, the conductor is a material that permits the electric energy to pass through it. The insulator is a poor conductor of electrical energy. In an insulator, energy does not quickly move from one particle to another.

Table 4.4 reveals that 65% of the students got the question correctly before the intervention. However, the percentage of the students who got the question correct dropped to 57% after the intervention. This outcome implies that the students had adequate knowledge of charge and the distribution of charge through various materials before and after the intervention. The situation here is strange. However, this may be as a result of lack of proper understanding which might result in guessing the answer by the students. This may not be entirely new, as Nielsen et al. (2012) had observed that students' picked the correct answers through the initial voting of other students.

The transcript of dialogical argumentation also revealed that the students' understanding of electrical charges improved after the PI intervention. The students in their conversation concluded as follows:

"Both the conductor and insulator carry charges."

"Charges move in a conductor makes it a conductor."

"The charges in insulator do not move and cannot conduct."

This is reflected by the conclusion that the students had an accurate knowledge of the electrical charges, as shown in Table 4.10.

Statement 2: ***Every house supplied with electricity is provided with a box of fuses so that…***

This question is testing the students' knowledge about the function of fuses. A fuse is a short length of wire designed to melt and separate when there is excessive current. Fuses are usually connected in series with the component(s) it is protecting from the excess current, so that when the fuse blows it will open the whole circuit and resist the current through the component(s). Fuse is used for protecting electrical appliances and installation from the excessive flow of current. Fuse is not only in electrical appliances but also present at home as a circuit breaker. The circuit breaker is the most common device uses for excessive current protection in high-current circuits today. Circuit breakers are switches specially designed that automatically open to stop current in the event of the too high current. Small circuit breakers, such as the one used in residential, commercial and light industrial service do operate thermally.

A residual current circuit breaker (RCCB) can perform different functions. It switches off the mains supply to an appliance when it detects leakage of current to earth or another circuit. For example, because of faulty insulation, an exposed metal part of an appliance may become ‘live.' Anyone touching that part conducts current to earth and receives a shock. The RCCB measures the current flowing along the live wire, and that is flowing through the neutral wire. Because of the leakage of some of the current (through the person) the live and neutral currents are unequal. The supply is switched off as the RCCB detects this state. It significantly reduces the chances of severe electric shock (Bishop, 2006). This question, therefore, is testing if the students know if the circuit breaker is a fuse that protects the electrical system.

From the table, 42% of the students got the question correctly before the intervention and only 19% after the intervention. Student’s response shows that the students’ knowledge of fuse is inadequate after the intervention. Group conclusion in Table 4.11 also indicates from the students’ discourse that they had a poor understanding of the fuse and its application.

Statement 3: ***According to Ohm’s law, the ratio V/I is constant for…***

This is testing students’ knowledge of Ohm’s law and the relationship between the three significant electrical quantities. Ohm’s law states that the electrical current in a conductor is proportional to the potential difference applied to it provided the temperature remains the same. According to Ohm’s law, there is a linear relationship between the voltage drop across a circuit element and the current flowing through it. If Ohm’s law is valid, it can be used to define resistance as:

$R = V/I$

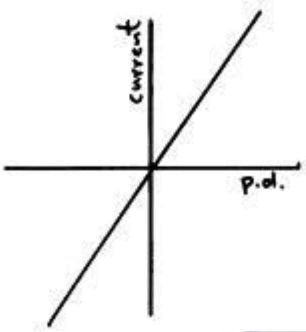
where R is a constant and independent of V and I.

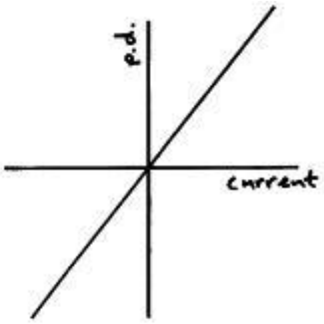
Students are expected to be able to use the equation given in the question to define resistance R for an electrical conductor. It is essential to understand just what is meant by these quantities. The current (I) is a measure of how many electrons are flowing past a given point during a set amount of time.

Therefore, the resistance R is viewed as a constant independent of the voltage and the current. In equation form, Ohm's law is:

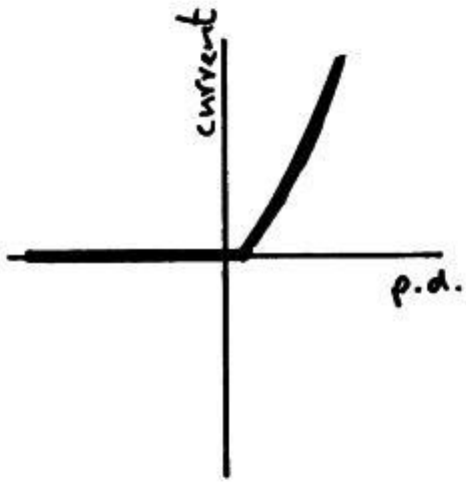
$V = IR$.

Here, **V** is the voltage applied to the circuit in volts (V), **I** mean the current flowing through the circuit in units of amperes (A), and **R** is the resistance of the circuit with units of ohms (Ω). This law gives a linear and perfect relationship between potential difference and current for Ohmic substance only. The plotting of the graph of potential difference against the current for an ohmic substance like silver gives a straight line graph as shown below.





For the non- Ohmic substance like a diode, the graph looks like the one shown below.



The students are expected to know the difference between any materials that obey Ohm's law like silver and any other materials that do not obey the law.

From Table 4.4, the students' knowledge before and after the intervention is indigent as only 8% of the students got the question correctly before the intervention and 11% after the intervention. The group conclusion during the dialogical argumentation also indicates that the students' understanding relating to this question is inadequate.

Statement 4: ***Which of the following is stored by a dry Leclanche cell?***

In electricity, a battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. The dry cell is one of many general types of electrochemical cells. A typical dry-cell battery is a zinc-carbon battery, which uses a cell that is sometimes called the Leclanché cell. This cell belongs to the category of a primary cell that once the stored energy is used up, cannot be recharged.

The focus of this question is testing if the students can distinguish between this cell and any other secondary cell. Secondary cells are those batteries that are rechargeable after the stored energy is used up.

Table 4.4 above shows that the students had an average knowledge of dry cell, because, 58% of the students got the question correctly before the intervention. However, the percentage of the students who got the question correctly reduced to 35% after the intervention. From the PIDAQ, only 23% of the students confessed they understood battery and battery-related concepts during the PI intervention which is evident from the EPA scores after the intervention.

Statement 5: ***The function of a 5A fuse included in a circuit supplying a household refrigerator with power is to keep the…***

A *fuse* is a small, thin conductor manufactured to melt and divide into two pieces to break a circuit in the event of excessive current. Fuses are rated regarding their voltage capacity as well as the current level at which they will blow.

Fuses are rated to blow if the current exceeds a stated amount. Always select the rating according to the device being protected. The current rating or rated current of a fuse is usually the maximum flow that it should withstand continuously, at the ambient temperature specified by the manufacturer (usually 25 degrees Centigrade). The ambient temperature refers to the immediate environment of the fuse, not the broader area in which it may be located. Ideally, a fuse should function reliably and indefinitely at its rated maximum amperage but should blow as reliably if the current rises by approximately 20% beyond the maximum.

The question tests the students' understanding of the application of fuse in a real-world situation. The students had been taught that a fuse could not accept any current beyond its rating. In this case, the fuse rating is 5A; the students are expected to know that any current above this value will be unacceptable by the appliance.

Table 4.4 above shows that only 19% of the students got the answer correctly before the peer instruction intervention, while 42% got it correct after the intervention. There was a considerable improvement in the students' knowledge of the application of the fuse after the intervention. The group conclusion reflected in Table 4.11 also indicates that students' understanding of the fuse concept was not adequate.

Statement 6: ***A short chain is sometimes attached to the back of a petrol tanker to…***

This is a question that deals with the application of static electricity. The question tested the knowledge of how to discharge static electricity. In the old-time, natural rubber tires would generate a significant static charge on the Chassis of the vehicle which caused numerous fires during fuel transfer operations.

From Table 4.4, only 12% of the student got the answer correctly before the intervention, while 23% got the answer correctly after the intervention. This indicates that the students' knowledge of this question is poor. Nevertheless, there was an improvement in the students' knowledge due to the PI intervention. The dialogical argumentation transcript indicates poor student understanding of charge related concept.

Statement 7: ***Power supply is transmitted at a high voltage and low current to…***

This question tested the students' understanding of the relationships between the fundamental concepts of electrical power transmission. These concepts are Voltage, current, power, and electrical energy. The students should know these concepts when talking about power transmission if not; they will not know the existing relationships. Knowing the relationships will help the students to get the question correctly.

Voltage: The voltage of a transmission line determines the line's ability to transmit electricity. This electric force, or electric potential, is measured in volts (V), or more typically in kilovolts (kV).

Current: The current through a transmission line is a measure of the amount of electricity that is moving through a conductor. Current flow through a conductor is measured in amperes (amps).

Power: Power flowing through a power station is measured in watts (W), or more typically megawatts (MW).

Electrical Energy: Energy is a measure of the ability to do work. The energy required by a load or provided by a generator is the product of power and time and is usually expressed in kilowatt-hours.

Power is directly proportional to the square of the current multiply by the resistance of the conductor. To, therefore, minimize power loss due to heat, power should be transmitted at high voltage and low current.

Power loses= current^2 x resistance.

Also, the low current in transmission lines restricts their power carrying capacity, which equals the product of current and voltage across a transmission line:
power = voltage x current.

From Table 4.4, 31% of the students got the question correctly before the Peer Instruction intervention and 39% after the intervention. The students' knowledge of this question is inadequate; nevertheless, the result shows an improvement of students' understanding due to the intervention. The dialogical argumentation discourse in Table 4.11 also shows the students had an inadequate understanding of electrical transmission.

Statement 8: ***In homes, electrical appliances and lamps are connected in parallel because…***

The students have been taught two types of electrical connection which are a parallel and series connection. The electrical connection in the home could only fall into any of these two categories. The question, therefore, tested students' knowledge in differentiating between series and parallel connection and the application to the electrical connection at home.

In a parallel circuit, there are several pathways for electron flow between the terminals of the battery. It is a connection with a set of elements which are directly connected by wire at both ends. Parallel connection carries the same voltage but different current. In a series circuit, there is only a single pathway for electron flow between the terminals of the battery. Each resistor in series has the same current but the different voltage.

The overall power rating is increased when two resistors are in parallel. All the household equipment are connected in parallel. The reason is that in parallel connection, components of voltage remain the same. The equipment used in households is of the same voltage rating. The wiring is done in such a way that equipment gets connected in parallel and has the same voltage across them. They are all in their conducting loop so you can turn one appliance off without affecting the others. For us to have control over the individual lamps or loads, they have to be wired in parallel.

For the students to be able to answer this question, correctly, the idea of critical thinking is imperative. The students should be able to reason beyond little guessing. Students are already aware that a parallel circuit carries equal voltage and home appliances are rated with the same voltage in Nigeria.

From Table 4.4, only 12% of the student got the correct answer before the intervention, while 15% got the answer correctly after the intervention. The students had an imperfect knowledge of this question both before and after the intervention. Table 4.11 of the dialogical argumentation transcript equally indicates students' inadequate understanding of connections of electrical appliances.

Statement 9: ***Which of the following materials has an increase in resistance with temperature?***

Resistance is directly proportional to the temperature and temperature enhances the amplitude of vibration of atoms also increase leading to more collisions between atoms and electrons. In an insulator, however, the situation is slightly different. Few free electrons hardly can permit the flow of any current. Almost all the electrons are firmly bound to their parent atom. Heating insulating material causes vibration of the atoms, and if the heat is sufficient enough, the atoms vibrate violently to liberate more electrons from the atom. The freed electrons become carriers of electric current. Therefore, the resistance of an insulator falls at high temperatures.

There is resistance because the charges bounce into and around atoms as they find their way through a material. Insulators' resistance, however, decreases with an increase in temperature. Materials used for practical insulators such as glass and plastic show drop in their resistance at very high temperatures. These materials remain good insulators overall temperatures they are likely to encounter in use.

A positive temperature coefficient happens in a material where the resistance increases as the temperature increases. A material where resistance falls with an increase in temperature is said to have a negative temperature coefficient. Conductors have a positive temperature coefficient, while insulators have a negative temperature coefficient.

The objective of this question is testing the students' knowledge about the concept of resistance and also the relationship between temperature and resistance. The students' response to the question shows poor students' understanding.

Table 4.4 reveals that 31% of the students got the question correctly before the peer instruction intervention and 46% after the intervention. The dialogical argumentation discourse also showed that the students' understanding of the resistance and temperature is not adequate. Thus, the students' knowledge of this question is inadequate after the PI intervention.

Statement 10: ***Capacitors are used in the induction coil to…***

A capacitor stores energy in the form of an electric field while the inductor is a coil which stores energy in the magnetic field. Capacitor and inductor are two passive and linear elements. Unlike the resistor which dissipates energy, ideal capacitors and inductors store energy rather than dissipating it.

The question examined the students’ knowledge about the uses of capacitor and inductor. The result indicates that the students’ knowledge of the capacitor and inductor was poor.

Table 4.4 shows that no single student got the correct answer to this question before the peer instruction intervention (0%). However, 27% of the students got the answer correctly after the PI intervention. The PIDAQ also revealed that students had the problem of the understanding capacitor and capacitance related concepts due to misconception.

Statement 11: ***Two lamps rated 40W and 220V each is connected in series. The total power dissipated in both lamps is…***

This is a question testing the problem-solving skills of the students. Electric power expresses the rate at which an electrical device is converting energy from one form into another. The students had been taught that the power of a device is proportional to the amount of current flowing through it. It is also proportional to the voltage that is driving the current. It implies that the bigger the current and the bigger the driving force, the bigger the power. This can be translated into an equation:

Power = current × voltage, $P= IV$

The question is testing how the students can use the knowledge of two different electrical connections (series and parallel connection) to solve a problem. Besides, the question tests how the students can apply the most appropriate equation to solve the problem of electrical power. Finally, the question tested how students can apply the classroom experience to solve the problem outside the class.

Table 4.4 above indicates that 35% of the students got the answer correctly before the intervention, while only 19% got the question correctly after the intervention. Both the dialogical argumentation transcript and the semi-structured interview also indicated poor students’ understanding of electrical power. The conclusion here is that both before and after the intervention, the students' knowledge was poor as regard electrical power dissipation. It is also absorbing to know that this question deals with the application of classroom experience in solving real-world problems outside the classroom. Therefore, with this analysis, it is apparent that the students are weak in using classroom experience in resolving the real-world problem.

Statement 12: ***A house has ten 40W and five 100W bulbs. How much will it cost the owner of the house to keep them lit for 10 hours if the cost of a unit is ₦5?***

This is a question of problem-solving skills which is testing students’ knowledge of the different units of electrical power and how to calculate it. The question tested the students' knowledge of applying classroom experience to solve a real-world problem. The students had been taught different units of power and how to convert one unit to another.

The underlying unit of measurement in electricity generation is the watt which is the smallest unit. The units are shown below.

1 kilowatt (kW) = 1,000 watts

1 megawatt (MW) = 1,000,000 watts

1 gigawatt (gw) = 1,000,000,000 watts

1 terawatt (TW) = 1,000,000,000,000 watts

The rate of electrical consumption is measured in kilowatt-hour (kWh). To, therefore, gets the cost of consumption for a particular period, the equation below is relevant.

Cost = power x time x rate,

Power is measured in kilowatt and time is measured in an hour.

Table 4.4 indicates that 30.8% of the students got the question correctly before the intervention, while 46% got it correctly after the intervention. Table 4.11 of dialogical argumentation transcript also indicates student's inadequate understanding of electrical power related concepts. The data reveals that there is an improvement after the intervention. The improvement can be attributed to peer instruction intervention. Nevertheless, with the improvement, the students' knowledge here is less than the average.

Statement 13: ***Two 50 μF parallel plate capacitors are connected in series. The combined capacitor is then connected across a 100-V battery. The charge on each plate capacitor is…***

This is another problem-solving skills question. The question tested the students' knowledge on how to draw the electrical circuit from a worded problem. Besides, the question tested the students' knowledge of differentiating between series and parallel combinations of capacitors.

Capacitors connected in series have the same voltage but different charges while that of parallel have different voltage but same charges. The calculation of equivalent capacitance or total capacitance for each is different. To obtain a total capacitance of capacitors in series require the sum of the reciprocal of the capacitance of each capacitor.

$$\frac{1}{Ctotal} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} +$$

For the capacitors in parallel, the total capacitance will be the algebraic sum of the individual capacitance of the capacitor.

Table 4.4 shows that 42% of the students got the answer correctly before the intervention, while 31% got it correctly after the intervention. The PIDAQ, the transcript, and semi-structured interviews indicated that the students have a limited understanding of capacitor and capacitance related concepts. Judging from this data, it is clear that the student's knowledge both before and after the intervention was not proper.

Each question has been analyzed. The next section focused on the analysis based on the category of the questions. The whole questions are divided into two classes of Electromagnetism I as indicated in Table 4.5. Electromagnetism I is divided into several branches of Physics; however, since this study is in the introductory phase and called Electromagnetism I, the study concentrates on two aspects, namely current electricity and electrostatics. Questions were therefore grouped into two broad aspects for consideration namely, Conceptual and Problem-solving skills. The conceptual and problem-solving skill in Physics is aspects of physics that are desirable in physics instruction (Docktor, Strand, Mestre & Ross, 2015)

Table 4.5 *Students' responses based on the Classification of Physics Questions*

No	Question Category	Scores in Pre-test	Scores in Post-test
1	Conceptual	24. 6%	29.3%
2	Problem-solving skill	26.9%	35.9%

Table 4.5 above reveals that students understanding in both conceptual and problem-solving are poor in Electromagnetism I. From Table 4.5, only 24.6% of the students got the conceptual questions correctly before the intervention while 29.3% got the questions correctly after the intervention. Students' knowledge of problem-solving is similar to that of conceptual in Electromagnetism I. Nevertheless, from the table, it shows that the students' knowledge in problem-solving is better than that of conceptual knowledge. 26.9% of the students got the problem-solving questions correctly before the PI intervention, while 35.9% got the questions correctly after. Although, the data obtained from the achievement test shows that the students in Electromagnetism I had a low critical thinking skill/ability. Students scored low marks in any question that does not have a direct interpretation. An example is question 10 in EPA where no one got the correct answer before the intervention. The case is similar to questions 3 and question 13, where the students scored low marks before and after the intervention. For instance, in question 3, only 7.7% of the students had

the correct answer before the intervention while 11.5% got the answer correctly after the intervention. These are higher other questions that demand the students to think critically about the questions.

Nonetheless, the transcribed discourse shows that the student critical thinking had improved based on the consensus after the argument. According to Herr (2012), Critical thinkers weigh evidence and arguments. The author further argued that the Critical thinkers break arguments into basic statements and draw logical implications. During the dialogical argumentation, the students had various contrary views about Ohm's law but later came up with the statement that "Metals are Ohmic material that perfectly follows Ohm's law." This statement indicates the level of improvement of these students in being able to think critically.

4.3.3 Results of Peer Instruction Dialogical Argumentation Questionnaire.

This study is using dialogical argumentation questionnaire to find out how students learned during the PI interactions because some believed student did not learn but copied the correct answer from the few who knew the answer. The study is not in any way a dialogical argumentation (DA) research; however, applying it in the study may be a novel idea.

95% of the students were hearing and participating in peer instruction in science class for the first time. All the students reported that the DA in peer instruction in science class is absorbing. However, only 77% of these students agreed that the DA in peer instruction was fascinating because it gave them a deeper conceptual understanding of Electromagnetism I. The students also agreed that it gave them a better knowledge of the application of electromagnetism in a real-world situation. The statement of these students is confirmed by question 5 in EPA on the fuse. Learning of fuse is a practical aspect of Physics that any student should be able to apply in a real-life situation. Only 19.2 got the answer right before the PI, but 42.3% got the answer correctly after the PI. It thus implies that the students can apply the electromagnetism in a real-life situation.

Only 54% of the students were able to get the correct answer to the ConcepTest after the group discussion. All the students agreed that the DA in peer instruction helped to understand many concepts in Electromagnetism I. The students' submission in this interview is apparent in the discourse transcribed because many of the consensuses show a better understanding of the argumentation. For example, table 4.10 shows student had correct understandings of Ohm's law, capacitor, capacitance, charges diode and many others during the dialogical argumentation.

62% of the students had more understanding of resistor and resistor related concepts when applied DA in peer instruction. 85% of the students had a deeper understanding of capacitor and capacitor related concepts. 54% of the students had an in-depth understanding of the concept of conductor and insulator through DA in peer instruction. Battery and battery-related concepts were more understood by only 23% of the students. 54% of the students understood better the concept of diode while 23% understood the electrical circuit and current better by applying DA in peer instruction.

Table 4.6

Students Response to Question Based on Electromagnetism Concepts

No	Concepts	Response in %
1	Battery and battery-related	23
2	Capacitor and capacitor related	85
3	Conductor and Insulator	54
4	Diode	54
5	Electrical circuit and current	23
6	Resistor and resistor related	62

85% of the students agreed they had many misconceptions in Electromagnetism I which they were able to overcome through DA in peer instruction. The common misconceptions the students overcame through the DA in peer instruction are the following: how insulator works, diode, resistor and resistance, electrical circuit, capacitor, and capacitance. 92% of the students agreed that the DA in peer instruction is necessary for science learning because it helped their learning in Electromagnetism I.

The students submitted that they not just copied the correct answer from the group but understood the questions through personal thinking, active involvement in the argument and considering others contributions.

It implies when a ConcepTest is posted; the students first think personally on the ConcepTest, actively participate in the discussions, listening to various other contributions as they argue among themselves, then decide on which answer is correct.

The next focus is the significance of the intervention on the academic performance of students in Electromagnetism I. Analysis of Covariance (ANCOVA) was employed for this analysis. The result of the above analysis could be subject to debate unless the covariate (pre-test score) is statistically controlled for using ANCOVA. Before running ANCOVA, there is a need to test for specific assumptions. The first assumption is Levene's Test of Equality of Error Variances.

Table 4.7 *Levene's Test of Equality of Error Variances*

F	df1	df2	Sig.
1.749	1	50	.192

From Table 4.7, the significant value is 0.192 greater than the probability of 0.05. It implies the variances are equal and therefore, the assumption is not violated. The next assumption is on linearity: a linear relationship between the dependent variable and the covariates for all the groups. Figure 4.1 shows the linearity of the relationship assumption.

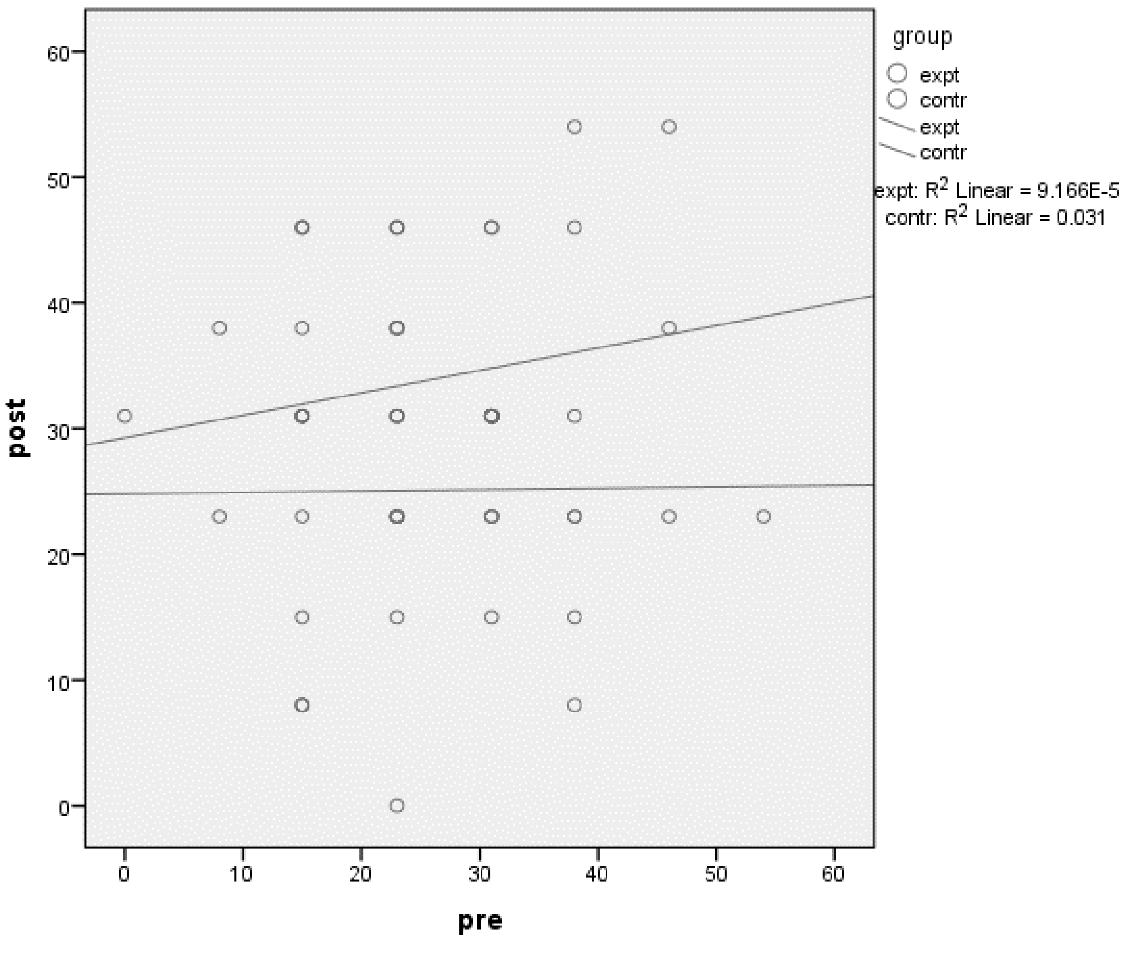


Figure 4.1. Linearity of relationship

In figure 4.1 above, the relationship is linear, so the assumption of a linear relationship has not been violated. The last is the assumption of the Homogeneity of regression slopes.

Table 4.8

Homogeneity of Regression Slopes Analysis

Dependent Variable: post

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1090.973[a]	3	363.658	2.544	.067
Intercept	4807.966	1	4807.966	33.634	.000
Group	32.851	1	32.851	.230	.634
Pre	47.283	1	47.283	.331	.568
group * pre	36.627	1	36.627	.256	.615
Error	6861.547	48	142.949		
Total	52911.000	52			
Corrected Total	7952.519	51			

a. R Squared = .137 (Adjusted R Squared = .083)

The significant value of ***group * pre*** is 0.615 higher than the probability value of 0.05: this implies that the interaction is not statistically significant. From this result, the assumption of homogeneity of regression slopes has not been violated. Having tested for the assumptions, it is now safe to run the ANCOVA analysis of the groups.

Table 4.9

ANCOVA Analysis

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1054.345[a]	2	527.173	3.745	.031	.133
Intercept	5288.417	1	5288.417	37.565	.000	.434
Pre	98.018	1	98.018	.696	.408	.014
Group	1012.579	1	1012.579	7.193	.010	.128
Error	6898.174	49	140.779			
Total	52911.000	52				
Corrected Total	7952.519	51				

a. R Squared = .133 (Adjusted R Squared = .097)

Table 4.9 shows there is a significant difference between the groups because 0.01 significant value is less than the probability value of 0.05. The eta squared value of 1.128 (12.8%) indicates a large size effect. The observed 0.408 level of significance of the covariate (pre-intervention EPA) is greater than 0.05 shows there was no relationship between the covariate and the post-intervention test. This implies that the students' scores before the intervention had no influence on the scores after the intervention.

One crucial aspect of this study is the understanding of how the students arrived at the correct answers. Thus, the importance of the dialogical argumentation in peer instruction to the study cannot be underrated. Therefore, the students' discourse during the dialogical argumentation in the peer instruction is transcribed and recorded, as indicated in the tables below.

4.3.4 Transcript of Dialogical Argumentation. The transcripts of views of the students during the group argument in the PI are presented below. These are individual conversations during the discussion and the group conclusions after the argument. The individual students' conversation, the group judgment and the remarks on the conclusion are recorded. The remark is accurate when the conclusion is considered to be an entirely correct response. It is not accurate when the answer is not wrong but not entirely correct. The EPA contains multiple-choice questions where only one option is considered the right answer for a question which is subject to guessing by the students. However, the problem of guessing is rectified through the dialogical argumentation because all students' submission is thoroughly discussed among themselves. Thus, a submission may either be accurate or not accurate, but may not be entirely wrong during dialogical argumentation as in the EPA. Therefore, the triangulation of the EPA data and the data in the transcript allay the fear that students copied themselves in the PI (Nielsen et al. 2012).

For easy understanding, the groups are sub-divided into sections, as shown in Tables 4.15 and 4.16 below. The discourse in group 1 and group 2 are in Table 4.15 while the conversation of group 3 and group 4 are in Table 4.16. The tables showing the conversation for only three students does not imply there were three students in a group. The researcher purposely picked three students in each cluster whose conversation differs from each other.

Table 4.10

Students' Conversation during Dialogical Argumentation in Group 1 and Group 2

Student	Conversation	Conclusion per group	Remarks
1	The transistor is one of the materials that obey Ohm's law.	**Group 1**	
2	The electrolyte also follows Ohm's law perfectly.	Metals are Ohmic material that perfectly follows Ohm's law.	Conclusion accurate
3	Both diode and transistor are Ohmic substances that obey Ohm's law perfectly.		
4	The capacitor is the same as the capacitance.	**Group 1**	
5	Capacitance is the ratio of charge to the potential difference.	The capacitor is an electrical device used to store charges.	Conclusion accurate
6	The capacitor is used in electricity.		
7	The insulator is the thing used to protect the wire.		
8	Conductor carries current in the wire.	Both conductor and insulator carry charges. Charges move in	Conclusion

		a conductor that is why it is a conductor. Charges in insulator do not move and cannot conduct current.	accurate
9	There are charges in conductor but not in the insulator.		
10	A semiconductor material that carries electrons is a diode.	**Group 1**	
11	Diode, capacitor and transistor work the same way.	The diode is a semiconductor material that conducts electrons in only one direction.	Conclusion accurate
12	Diode and resistor are the same.		
13	There is no particular arrangement of the resistor in a circuit than to connect where needed.	**Group 2**	
14	There is two arrangement of resistors which are the same.	The total resistance in the series arrangement is the algebraic sum of all the resistance.	Conclusion not accurate
15	There are parallel and series arrangement with the same total resistance but different current.		
16	The resistance of a material such as metal increases with the temperature.		
17	As for me, only the electrolyte's resistance increases with the temperature.	The resistance of material like wood increase with the temperature being a poor conductor of electricity	Conclusion not accurate
18	My thinking was that water and some liquids' resistance increase with the temperature.	**Group 2**	
19	The two parallel plates of a capacitor carry charges on them which may not be equal.		
20	The charges depend on the types of plates.	The plates carry equal, and opposite charges and the plates are separated from each other by an insulator called a dielectric.	Conclusion accurate

21	The separation between the plates is called an insulator.		

Table 4.11

Students' Conversation during Dialogical Argumentation in Group 3 and Group 4

Student	Conversation	Conclusion per group	Remarks
1	Fuse box installed at home is to confirm voltage.	**Group 3**	
2	Fuse box limits the amount of current used at home.	Fuse box prevents electric shock at home.	Conclusion not accurate
3	It allows the home to record the electricity used.		
4	The connection of lamps and electrical appliances at home should not be in series but parallel to avoid heating wires.	**Group 3**	
5	No! It is to allow the use of less current.	The reason for this connection is to use less voltage.	Conclusion inaccurate
6	I think it is for high voltage consumptions.		
7	Resistor and resistance mean the same thing.	**Group 4**	
8	The resistor is a disturbance to current.	Resistor and resistance are not the same. Resistance is the opposition to the flow of charge while the resistor is the material that opposes the flow of charge.	Conclusion accurate
9	Resistance is opposition.		
10	Two kinds of capacitor connection exist.	**Group 4**	
11	The charge is the same for the two connections.	The two connections are parallel and series, and it has a different connection. The charges and potential difference are not the same between the two connections.	Conclusion accurate
12	The connection between the two types is the same.		
13	The power supply is transmitted with a high voltage to allow it to pass through a transformer.	**Group 4**	

14	No! It is to increase power.	It is to prevent heat loss.	Conclusion not accurate
15	For me, it is to make power travel fast.		

Table 4.5 indicates that both before and after the intervention students' conceptual understanding and problem-solving skill are poor. However, the table shows the improvement after the intervention. Supported by Gok (2011); Lasry, Mazur, and Watkins (2008); Crouch and Mazur (2001) that peer instruction increased student conceptual learning in Physics. Similarly, the student shows a better understanding of problem-solving skills after the PI intervention. The result is consistent with Crouch, Watkins, Fagen and Mazur (2007); Hake (1998); Watkins and Mazur (2013) that interactive engagement strategy like peer instruction can be an effective way of increasing problem-solving test in Physics courses.

Students in PI are better in the understanding of conceptual electromagnetism I because of the integration of the dialogical argumentation. Argumentation may enhance conceptual understanding (Venville & Dawson, 2009). Gok (2014) also said the interactive engagement methods, had a more positive effect on students' conceptual learning.

The study revealed that students' understandings both in conceptual and problem-solving in Electromagnetism I are poor before and after the intervention. Nevertheless, the intervention had more impact on the problem-solving than the conceptual according to Table 4.5.

In light of the foregone, Physics teachers should utilize different methods to change students' alternative conceptions because it is difficult changing it (Baser, 2006). The understanding of conceptual substitution and cognitive conflict is imperative to facilitate conceptual change (Planinic, Krsnik, Pecina & Susac, 2005 as cited in Baser, 2006). Concept substitution is a conceptual change technique where some student's ideas may be correct, but these ideas are applied to the wrong concept. If this wrong concept is substituted with a scientifically accepted concept, the idea may become correct.

In cognitive conflict, students' experiences about some phenomenon are challenged to create a state of cognitive conflict in student (Baser, 2006). The students' problem in this study may likely be due to the conceptual conflicts between concepts like capacitor and capacitance; resistor and resistance; capacitor and inductor; and diode and resistor. It is evident from the interviews and the PIADQ. The perspective of Liang (2016) is that conceptual (cognitive) conflict takes place when there is a conflict between the new concept learned and the learner's prior understanding of the concept

Teachers need only to give correct but not well-organized information about a learning task and allow the students to navigate to the conclusion. It is one of the attributes of a constructivist teacher. Constructivism learning requires a problem-solving approach. Students should be able to construct new knowledge from limited prior information. Many Physics students who are deficient in problem-solving skills are easily recognized from the types of questions they often asked. Some of these students say the problems or questions to be solved are outside the syllabus. The truth is that these students are weak in problem-solving skills.

The problem-solving skill enables the students to solve a problem that has a brand-new content: the student has never encountered this situation before. There is no clear statement of the problem that tells the student what knowledge or technique or formula to use for solving the problem. For instance, in solving problems in EPA, no formula table was supplied, and no formula was written on the question paper. It was the responsibility of the students to find an appropriate formula to solve any of the problems in the question paper.

For students to be able to have a real mastery of Physics, they must be able to solve problems that are new to them in Physics. The teacher cannot be able to teach everything in the classroom. For instance, many questions in electromagnetism require the students to apply the formula. Not all the times the formula will be supplied to solve problems: the students, therefore, should be able to apply appropriate formula.

The problem-solving skill enables the students to understand many valid approaches to solving a problem. For instance, electrical power has many formulas that can be used by the students to solve problems. The choice depends on the students' knowledge. A student who has an excellent problem-solving skill will consider specific parameters in the question before applying any formula.

The problem-solving skill requires that the algorithm for solving the problem be unclear. There is no logical step-by-step procedure for solving a mathematical problem. Many students are exquisite at mastering step-by-step problem-solving in a textbook, but this does not make him or her right in problem-solving skill. The textbooks guide such students, and once the textbook is not available, he or she may find it challenging to solve a problem independently. Given the triangulation of data both from the quantitative and qualitative perspectives, the table below is germane to shed light on answering the research question 1.

The table selected some concepts of the Electromagnetism I and merged data from the quantitative and qualitative analysis. The data from the quantitative is from the achievement test scores of the EPA. The study considered the achievement gain as the difference between the post-test and the pre-test scores of the participants who attended the PI class. The data from the qualitative is from the transcript of the dialogical argumentation.

Table 4.12

Summary of Concept understanding based on the Mixed-method Evidence

Serial No	Concepts	Quantitative evidence Achievement gain (%)	Qualitative evidence
1	Ohm's law	3.8	Accurate Understanding
2	Fuse	23.1	Accurate Understanding
3	Charges	11.6	Accurate Understanding
4	Temperature resistance	15.4	Accurate Understanding
5	Capacitor	26.9	Accurate Understanding

4.4 Current Electricity

Electricity is an aspect of Electromagnetism I that students offer at all level of Physics education in Nigerian schools. The curriculum of Physics indicates that students in Senior Secondary Schools in Nigeria start learning of electricity from SSS1 (Awolola, 2004). However, the literature shows that students' academic performance in this branch of Physics is poor because of many reasons. One of these grounds is attributed to the misconceptions by both the teachers and the students. Many times, profound misconceptions prevent students from getting a firm knowledge of fundamental concepts in electricity (Urban-Woldron, 2013).

From Table 4.5 above, it shows that the students' knowledge both before and after the intervention is very poor. Only 27.8% of the students answered current electricity correctly before the intervention while 26.3% after the intervention. This result confirmed several research studies that had been carried out on the current electricity. According to Kollöffel and de Jong (n.d), the concept of electricity is abstract and difficult to grasp. Electricity's intangible nature does not allow many students, even those who have completed a Physics course, to have the right ideas about it and the behaviour of electrical circuits.

The research conducted and published in 1992 by McDermott, Shaffer and the Physics Education Group at the University of Washington identified specific student difficulties with learning about electric circuits. The research work gave details analysis of these problems arising during the instruction of electricity. The result of McDermott, Shaffer, and the Physics Education Group is germane to the present study.

Electricity is an essential and challenging Physics topic at all school levels, where students often have many difficulties in learning electricity (Jaakkola & Nurmi, 2004). McDermott and Shaffer (1993), much research studies conducted on the understanding of electricity revealed that students had difficulties in conceptual understanding. McDermott and Shaffer identified three areas of students' difficulties in current electricity. The areas are the inability to:(1) apply formal concepts to electric circuits, (2) use and interpret formal representations of an electric circuit, and (3) qualitatively argue about the behaviour of an electric circuit.

The students had a problem when it comes to applying formal concepts to interpret electrical circuit. Many of these students had poor knowledge of the two types of circuits-parallel and series circuits connection. This has been an age-long problem as McDermott et al. (1993) said students had the problem of recognizing parallel branches when not directly connected to the battery. This problem reflected in question 8 of the EPA. The question required the students to use their knowledge of the type of circuit connection to answer the question. The students had a poor understanding of this question both before and after the intervention. Only 11.5% of these students got the question correctly before the intervention, while 15.4% got it correctly after the intervention.

Concepts of voltage and current in electricity have often appeared foreign to students since they are measurable but not directly visible (Graff, Leiffer, Niemi & Vaughan, 2007). This is the reason some attributed poor knowledge in electricity to its abstract nature. Mulhall, McKittrick, and Gunstone (2001) in their perspective, believe electricity concepts are abstract and challenging to teach.

Several research studies attributed poor understanding of students in current electricity to the misconceptions by both the teachers and the students. Classroom experience in the current electricity revealed that it is a topic that students had many misconceptions.

Students' responses to the PIDAQ and personal interaction during the intervention revealed many misconceptions students had. The questionnaire indicates students had misconceptions in resistor and resistance; insulator and conductor; and diode. In one of the interactive class during the intervention, a student asked this question: *What is the difference between diode and resistance?* This question indicates there was a misconception held by this student. The question should have been the difference between a *diode* and a *resistor*. This question is consistent with the submission of Mulhall et al. that students formed specific ideas about concepts in electricity before formal learning takes place. These ideas should be the focus of the teacher to ensure that there are conceptual changes. Physics educators need to seek different ways to change students' alternative conceptions (misconceptions) as since they may be resistant to change (Baser, 2006). The misconception of the students about the resistance is reflected in the way they answer questions related to resistance and resistor.

Question 3 in EPA tested the students' knowledge of Ohm's law. The three quantities in this law are current, voltage and resistance. Only 8% of the students got the answer correctly before the intervention and 11.3% after the intervention. This is evidence that the students lacked a proper understanding of resistance, which may be attributed to the misconception. Similarly, another question that required the knowledge of resistance is Question 9. Analysis of this question shows that only 31% of the students got the answer correctly before the intervention; however, there was an improvement after the intervention.

Confirming the personal experience of the researcher during the interactive class in PI, McDermott et al. said resistance is one of the misunderstood concepts in electricity. Students had many difficulties and misconception in electromagnetism, in particular on a topic like current electricity. This is indicated in the outcome of this study as students understanding both before and after the intervention was inadequate. In support of this observation, Engelhart and Beichner (2003) reported that significant difficulties and misconceptions are still widespread in students studying electricity. Because concepts in direct current electricity are abstract, students develop different types of alternative conceptions (misconceptions) related to current, potential difference, a complete circuit, and power dissipated within circuit element (Baser, 2006).

The method of instruction is another challenge of poor understanding of current electricity in Physics. The method of instruction does affect students' understanding of concepts in electricity (Engelhart & Beichner, 2003). Mulhall et al., (2001), put it that conventional instruction has little effect on changing students' understanding of learning of electricity. This may have reflected in the outcome of this study because instead of improvement in the students' knowledge after the intervention, the reverse was the case.

Students' misconception in Physics has been attributed to many sources. Some authors argued that textbooks, language and the teachers' lack of conceptual understanding are significant sources of Physics students' misconception (Eraikhuemen & Ogumogu, 2014). This could have been the reason Mulhall et al., (2001) posits that the problem of electricity is the confusion in the use of electricity concepts and terms as they appear in Physics textbooks.

The authors observed that the potential difference, voltage, voltage drop and electromotive force (emf) are given a different meaning in various textbooks.

Table 4.5 above gives a summary of the student's knowledge in the current electricity before and after the intervention. The table reveals that 28% of the students had correct answers to the electricity questions before the intervention and 27% after the intervention. This shows there was no improvement in the students understanding even with the PI intervention. Therefore, it could be concluded that students' knowledge in the current electricity before and after the intervention was weak. The second aspect of electromagnetism which is electrostatics is the next focus.

4.5 Electrostatics

Electrostatics is the second selected area of interest for discussion. The teaching of electrostatics is a challenging task due to its complexity and degree of abstraction (Chang, 2007). One of the great difficulties in teaching electrostatics is the abstract nature of the subject (Bonham & Risley, 1999). Guisasola, Zubimendi, and Zuza (2010) explain that difficulty in learning electrostatics may hinder the learning of more advanced topic in Physics. There are many concepts in electrostatics that students find challenging to learn because the students cannot visualize those concepts. How will a teacher make students feel electric field, vector, and flux density? The teacher could only explain it, or at best demonstrate it. Many problems of the students in electrostatics arise from conceptual difficulties with vector superposition (Meredith & Marrongelle, 2008).

Students learn best when they see and feel what they are learning. Kola (2007) argued that what a student heard can easily be forgotten but what is seen by he/she is quickly remembered. Because the students cannot visualize these concepts, they disagree with any scientific model put forward to explain the concepts. Students have a problem in learning electrostatics because of ideas and conceptions that do not agree with the scientific models they had (Castells, Konstantinidou & Cerveró, 2014).

Many authors believe that Physics is challenging to learn because it is abstract; this does not connote that all aspects of the subject are abstract. However, electrostatics is believed to be the most abstract aspect of Physics. It is one of the most challenging areas of Physics to learn and to teach this is due in large part to the highly abstract nature of the topic (Bertrand, 2007).

Table 4.5 above it shows that 29.8% of the students got questions on electrostatics correctly before the intervention and 34.6% got it correctly after the intervention. The data indicate that students had more understanding of the electrostatics after the intervention. In other words, PI improves students' knowledge in electrostatics.

The overall analysis indicates that the PI improves students' knowledge in electrostatics. Nevertheless, questions 1and 13 of EPA seems to be contrary. 65% of the students got question 1 correctly before the intervention, but the percentage reduced to 58% after the intervention. The question tested the students' knowledge about the movement of charges through different substances. Though, with the reduction in the number of the students who got the question correctly after the intervention: it could still be inferred that the students' knowledge about the question is right.

Similarly, 43% of the students got to question 13 correctly before the intervention, but only 31% got the question correctly after the intervention. The question tested the students' knowledge on how to draw the electrical circuit from a worded problem. In Physics, it is reasonable to give the problem to students in a schematic circuit diagram or worded form: whichever way students should be able to interpret and solve the problem. Question 13 is in the latter format. The outcome of this analysis shows that the students' knowledge of this question is inadequate. This result is consistent with Casperson and Linn (2006) that students struggle to employ their understanding of electrostatics to explain the behaviour of electric circuits. Similarly, Baser explains that students have a problem in understanding electrical diagrams and interpreting a short circuit.

Question 6 tested the students' knowledge of how to discharge static electricity. 11% of the students got the question correctly before the intervention and 23.1% after the intervention. The PI intervention improved the students' knowledge. This indicates the students may have adequate knowledge of charges and movement, but the knowledge of the application is frail both before and after the intervention.

The PIDAQ reveals several misconceptions held by the students in electromagnetism I. The capacitor is one of the areas of students' misconceptions, and the capacitor is from electrostatics. Meredith and Marrongelle (2008) asserted that students had learning difficulty in the capacitor. The outcome of Question 10 cannot be separated from this assertion. The question tested the students' knowledge about the use of capacitor and inductor. No single student got the question correctly before the intervention, but many students got it correctly after the intervention. This implies that the PI intervention improves the students' knowledge about this question.

The summary of the students' knowledge in electrostatics is represented by Table 4.5 above. 29.8% of the students got all the questions in electrostatics correctly before the intervention and 34.6% after the intervention. This implies that the PI improves the students' knowledge of electrostatics. However, the conclusion is that the students' knowledge both before and after the intervention was weak.

4.6 Misconceptions in Electromagnetism I

From the analysis of PIDAQ, there was a revelation that the Physics students in this study held on to some misconceptions before the intervention. The revelation is in support of Eraikhuemen and Ogumogu (2014), who states that the weakness in students' knowledge of Physics is due to several misconceptions the students had. This finding also corroborates the earlier works of Raduta (n.d), Koudelkova and Dvorak (2014); Smail and Rowe (2012) on misconceptions in Electromagnetism.

The PIDAQ contains structured, and unstructured, open-ended questions to explore students personal experience with PI. 85% of students agreed they encountered many misconceptions of Electromagnetism I which they were able to overcome through PI. Besides, evidence emerged during the intervention that the students had lots of misconceptions from the types of question they asked. Many of the students could not differentiate between capacitors and capacitance; between resistors and resistance and asked questions such as: what is the difference between capacitor and capacitance? What is the difference between resistance and diode? The second question had shown the students' misconception because it should not be resistance but resistor

These students agreed that they had and overcame misconceptions in the following areas of electromagnetism: how insulator works, diode, resistor and resistance, electrical circuit, capacitor, and capacitance. The students' question shows they do not recognize that both the capacitor and the resistor are electrical devices. The students also do not know that capacitance and resistance are the properties of the electrical devices mentioned above, respectively. However, as a result of the peer instruction dialogical argumentative the students had realized that the capacitor and resistor are tangible and real electrical materials while the electrical functions they performed are capacitance and resistor respective. This is evidenced by the transcript. For instance, students in table 4.10 concluded that a capacitor is an electrical device used to store charges. Other students also concluded that resistance is the opposition to the flow of charge while the resistor is the material that opposes the flow of charge.

4.7 Social Constructivism, Controversy Constructive and Students' Knowledge of Electromagnetism

The pre-service Physics teachers in this study came from secondary schools. The personal survey of their Physics academic record indicates they had a knowledge of electromagnetism from SSS 1. This tells that they came into this research study with the background knowledge of electromagnetism. Therefore, that knowledge is constructed based on their previous understanding of electromagnetism is not an assumption but a reality. According to Garbett (2011), Constructivism emphasis is on the importance of the knowledge, beliefs, and skills that an individual brings to the experience of learning (p.37). New information is linked to prior knowledge. Thus mental representations are subjective. The learners in this study were not blank slates (*tabula rasa*) but came in with knowledge of electromagnetism they had from the secondary schools. Electromagnetism is an aspect of Physics included in current electricity that is taught at the Senior Secondary Physics (SSP) in Nigeria.

PI is relevant in constructivism domain. Presenting a ConcepTest on a topic entirely new and foreign to the students would almost be tantamount to presenting the beauty of colours to a blind person. Therefore, the students in the PI class have prior knowledge which serves as a springboard on which the new knowledge is constructed. In constructivist learning, students engage in active cognitive processing, such as paying attention to relevant new information, mentally organizing new information into a coherent representation, and mentally integrating new information with existing knowledge (Mayer, 1999).

PI is an interactive and cooperative learning paradigm. Thus the students are engaged in the social activity of learning. Through active participation, the students are encouraged to construct their knowledge based on their current understanding. Social constructivism as developed by Vygotsky argued that learning is a social and collaborative activity where people create meaning through their interactions with one another (Schreiber & Valle, 2013). The students are always interacting throughout PI intervention. Learning is a process of interaction through which the learners develop their understanding by assembling facts, experiences, and practices (Educause Learning Initiative, 2005). The social constructivism theory believes in the social interaction of students in the classroom along with the critical thinking process.

One aspect of this study that is novel is the integration of dialogical argumentation instruction into the PI. The essence of the integration, as already stated in the conceptual framework section, is to resolve the issue on how students learn in the PI.

This issue of argumentation in science learning is not new and underpinned by the constructive controversy theory. The students' arguments transcribed indicate that there was an improvement in students' understanding of Electromagnetism I. According to Jimenez-Aleixandre and Erduran (2007), the argumentation approach to teaching science has gained momentum in recent years. Aydeniz and Ozdilek (2015) said argumentation had received such significant attention because it is believed that learning science through argumentation help students to develop an improved understanding of the nature of science. Acar (2015) found that students who received argumentation-based instruction developed their scientific reasoning.

Most of the arguments transcribed corroborate the PIADQ on the problem of students' misconception in Electromagnetism I. Cross et al. (2008) cited in Garcia-Mila, Gilabert, Erduran, and Felton (2013) said argumentation facilitates students' review of their prior knowledge, and help them to overcome misconceptions. Argumentation-based learning lowers the level of students' misconception (Sekerci & Canpolat, 2014).

The case of students 7, 8 and 9 in Table 4.16 indicates that the students in group 4 lacked a proper understanding of resistor and resistance. It also confirms Goodman (2015) that the Dialogical Argumentation Instructional Model improved the learners' conceptions of the capacitor when exposed to the model. All the conversation recorded also shows that most of the students understood the ConcepTest as against the fear that students copied themselves.

The argumentation assisted the students understanding, and it reflected in their scores in EPA. The discourse of students 1, 2 and 3 in Table 4.10 shows that the group conclusion on Ohm's law during the argument was accurate. The outcome of this study shows that instruction based on argumentative practices is useful in teaching concepts in science education. (Kaya, 2013)

The students' discourse, as evidenced by the transcripts, confirms the views of Aufschnaiter, Erduran, Osborne, and Simon (2008) that students learn science while arguing. The author asserts further that the increase in students' conceptual understanding occurs when they are exposed to argumentation. The evidence of this submission is seen in the various groups shown in Tables 4.10 and 4.11. For example, in Table 4.10 among group 1, the discourse of students 4, 5, 6 and the group conclusion shows an improvement in the conceptual understanding of the capacitor. Also, in Table 4.11, the argument of students 13, 14, 15 and the group conclusion indicates an improvement in the conceptual understanding of the electrical power supply.

This is evidence in a question related to electrical power in the EPA, as recorded in Table 4.4. The pre-test students' scores before the students participate in the dialogical argumentation were 31% and 39% after the argument. The same applies to a question on the resistance and temperature: pre-test score was 31% while the post-test was 46%. This indicates an improvement in the scientific reasoning ability of the pre-service teacher as supported by Acar (2015) that argumentation-based learning enhances students' scientific reasoning.

Argumentation is thought to be a constructivist teaching method because students' discussion and reasoning are at the center of this type of instruction. Scientific argumentation is considered to be *individual* activity when the learner is involved in a reasoned discourse which maybe by thinking or writing or a *social* activity within a group (Driver et al., 2000) Argumentation is described as the process where two or more people are trying to challenge one person's claims to knowledge through questioning, while the proponent is trying to justify and defend his/her claim to knowledge through reasoned discourse (Aydeniz and Ozdilek, 2015). This submission is confirming the position of constructive controversy as a theory adopted for the study. The examples supporting these authors are shown in Tables 4.15 and 4.16, where the arguments of three students in each group are recorded. For argumentation to take place, students need to be able to work in groups, listening to each other and articulating their ideas (Simon, Erduran, and Osborne, 2006). Beside students working in a group, the teacher must be knowledgeable in scientific argumentative instruction. According to Aina (2017c), the success of implementing the dialogical argumentative-based instruction lies significantly on the teacher.

Given the results of the transcript, it was clear that the scientific argumentation plays a crucial role in science learning. Thus, supported by Sampson and Grooms (2009) that scientific argumentation should play a more central role in the teaching and learning of science. The scientific argumentation was based on the contradictory ideas among the pre-service teachers in the PI class. Peers' discussion of conflicting ideas has been proven to promote students' learning (Larrain, Howe & Cerda, 2014).

What is done in scientific argumentation is a deliberative attempt to solve problems. It is like there is a controversy in learning that must be resolved through dialogical argument. Thus, there are conflicting opinions and ideas among the students regarding the subject under discussion. This is not a debate, nor is it an individualistic approach to a controversial issue but a procedure for cooperative learning.

PIDAQ reveals that before the peer instruction intervention the pre-service Physics teachers held many misconceptions in Electromagnetism I. The common misconceptions the students had before the intervention are: how insulator works, diode, resistor, and resistance, electrical circuit, capacitor, and capacitance.

However, after the intervention, data collected through the questionnaire reveals that the students got rid of all these misconceptions. A misconception in Physics is another problem of learning in Nigerian schools. According to Stein, Larrabee, and Barman (2008), science educators expected to challenge students' common misconceptions at the right stage to avoid becoming a permanent problem. Gooding and Metz (2011) opined that if misconception is unchallenged for an extended period, it may become entrenched. To solve the problem of students' misconceptions, teachers must first identify those misconceptions (Gooding & Metz, 2011). In other to address the problem of misconception, it is vital to discuss critical thinking about the students' knowledge in electromagnetism.

4.8 Critical Thinking and Students' Knowledge of Electromagnetism I

Students' knowledge in Electromagnetism I as revealed in this analysis was weak, though, with a little difference after the PI intervention. The reason for this poor knowledge may be many; however, it is apparent from the students' responses to the questions in EPA that there was a learning gap. This gap is hinged on the absence of intense critical thinking by the students. The evidence of poor critical thinking ability could be seen in the transcript of the dialogical argumentation discourse. For instance, in Table 4.16, student number 9 said *resistance is opposition*. This is unthinkable for a student who had study Physics for three years in secondary school. The student just gave the literal meaning of the resistance. According to Rodrigues and Oliveira (2008), critical thinking is crucial to Physics learning. Students usually encounter difficulties in most of their science subjects because they were not exposed to thinking at a higher level (Saingan & Lubrica, 2008). Rodrigues and Oliveira concurred that critical thinking level is a predictor of the students' academic performance in Physics because developing students' critical thinking contributes to improving academic performance in Physics.

In this study, the result of EPA indicates the student does not have a deep understanding of the Electromagnetism I. Physics is considered as a higher-order thinking subject. Therefore, there is a need to foster critical thinking skills in the Physics classroom (Ramos, Dolipas & Villamor, 2013).

At this juncture, it is correct to summarize the research question 1, which says: What is the understanding of Electromagnetism I by the pre-service science teachers' before and after peer instruction intervention?

4.9 Summary of findings to Research Question 1

The independent variable was the type of intervention (peer instruction), and the dependent variable consisted of scores on the EPA-administered after the intervention was completed. Participants ‘scores on the pre-intervention administration of the EPA were used as the covariate in this analysis.

Descriptive statistical analysis indicates that integrating PI into DAIM has impacted the students understanding of Electromagnetism I. Independent t-test shows that both the students in the control group and the experimental are on the same academic level in Electromagnetism I. To control for the effect of the covariate on the outcome of the result and also the effect of contamination, ANCOVA was performed.

Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measurement of the covariate. After adjusting for pre-intervention scores, there was a significant difference between the two groups on post-intervention scores on the EPA, F (1, 49) = .72, p = .010, partial eta squared = .13. There was no relationship between the pre-intervention and post-intervention scores on the EPA, as indicated by a partial eta squared value of .0.014.

Given the detailed analysis above, current electricity and electrostatics are the two aspects of Electromagnetism I investigated in this study. It was revealed that the students' understanding of current electricity and electrostatics was poor both before and after the intervention. Besides, the students had misconceptions about how insulator works, diode, resistor and resistance, electrical circuit, capacitor and capacitance before the intervention. The study also revealed the improvement of the students' understanding after the intervention whereby problems in misconception were resolved. Therefore, the following are the conclusion arrived at on the research question 1:

- Students' knowledge of current electricity does not improve after the PI intervention
- Students' knowledge in electrostatics improved after the PI intervention
- Students' understanding of Electromagnetism I was poor both before and after the PI intervention
- Students had misconceptions in Electromagnetism I before the PI intervention but were got rid of after the intervention.

- Through the incorporation of the dialogical argumentation, the study indicates that students learned in PI by interaction not by copying the correct answer from another student.
- Finally, the incorporation of PI into the DAIM has an impact on the students' understanding of Electromagnetism I.

4.10 (RQ 2) Research Question 2: Is there any gender impact of PIDAIM on the pre-service science teacher in the learning of electromagnetism I?

The students who participated in the intervention are divided into male and female: fifteen males and eleven females. The achievement test scores of these students in the EPA were analysed using ANOVA and independent-samples t-test. The study used these statistical tools because it compares the mean scores of two different groups of people. Before the study runs the analyses, it first checked for the assumption of equal variance to ensure the t-test is the appropriate tool for the data analyses.

Table 4.13

T-test Analysis of Gender Academic Performance in Physics

		Levene's Test for Equality of Variances						t-test for Equality of Means		
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	95% confidence interval of the difference	
									Lower	Upper
Score	Equal variances assumed	0.01	.970	2.31	24	.030	11.13	4.809	1.203	21.052
	Equal variances not assumed			2.32	22.049	.030	11.13	4.787	1.200	21.054

Table 4.13 shows the non-violation of the assumption of equal variance because the observed 0.970 level of significance is higher than the probability value of 0.05. The t-test for the equality of mean value has 0.030 (2-tailed) which is less than the probability value of 0.05: this implies that there is a significant difference between the groups. With the calculated eta square of 0.18 (18%) indicates the effect size is large. The substantial size effect implies

that the difference that exists between male and female in Electromagnetism I is not by chance.

Table 14

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PIDAIM_Perf	Sphericity Assumed	205.856	1	205.856	2.248	.147
	Greenhouse-Geisser	205.856	1.000	205.856	2.248	.147
	Huynh-Feldt	205.856	1.000	205.856	2.248	.147
	Lower-bound	205.856	1.000	205.856	2.248	.147
PIDAIM_Perf * sex	Sphericity Assumed	248.779	1	248.779	2.716	.112
	Greenhouse-Geisser	248.779	1.000	248.779	2.716	.112
	Huynh-Feldt					
	Lower-bound	248.779	1.000	248.779	2.716	.112
Error(PIDAIM_Perf)	Sphericity Assumed	248.779	1.000	248.779	2.716	.112
	Greenhouse-Geisser	2198.164	24	91.590		
	Huynh-Feldt	2198.164	24.000	91.590		
	Lower-bound	2198.164	24.000	91.590		

Table 14 shows that interactions within the groups are not significant because of the observed significant value of PIDAIM.Perf (0.147) that is higher than the probability value of 0.05. The implication of this is that scores of the control group do not affect the scores of students in the experimental (treated) and vice-versa. This result also allays the fear of the contamination effect.

Table 15
Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	48327.712	1	48327.712	313.712	.000
Sex	187.097	1	187.097	1.215	.281
Error	3697.230	24	154.051		

The statistics in Table 15 indicate that there was no significant main effect of gender (Sig. < 0.05). It thus implies that gender does not affect academic performance in the PIDAIM intervention.

Table 16
Descriptive Statistics

	Sex	Mean	Std. Deviation	N
Control	Female	29.1333	7.78154	15
	Male	28.5455	8.48957	11
	Total	28.8846	7.92630	26
Treated	Female	28.7333	13.29590	15
	Male	37.0000	13.60882	11
	Total	32.2308	13.79944	26

The table shows the gender descriptive statistics in PIDAIM. It indicates that the mean score of female students with no treatment is slightly higher than their male counterparts. However, after the intervention, the male students that received treatment have higher mean scores than the female students. This outcome suggests that the intervention enhanced the male students understanding of Electromagnetism I more than the female students.

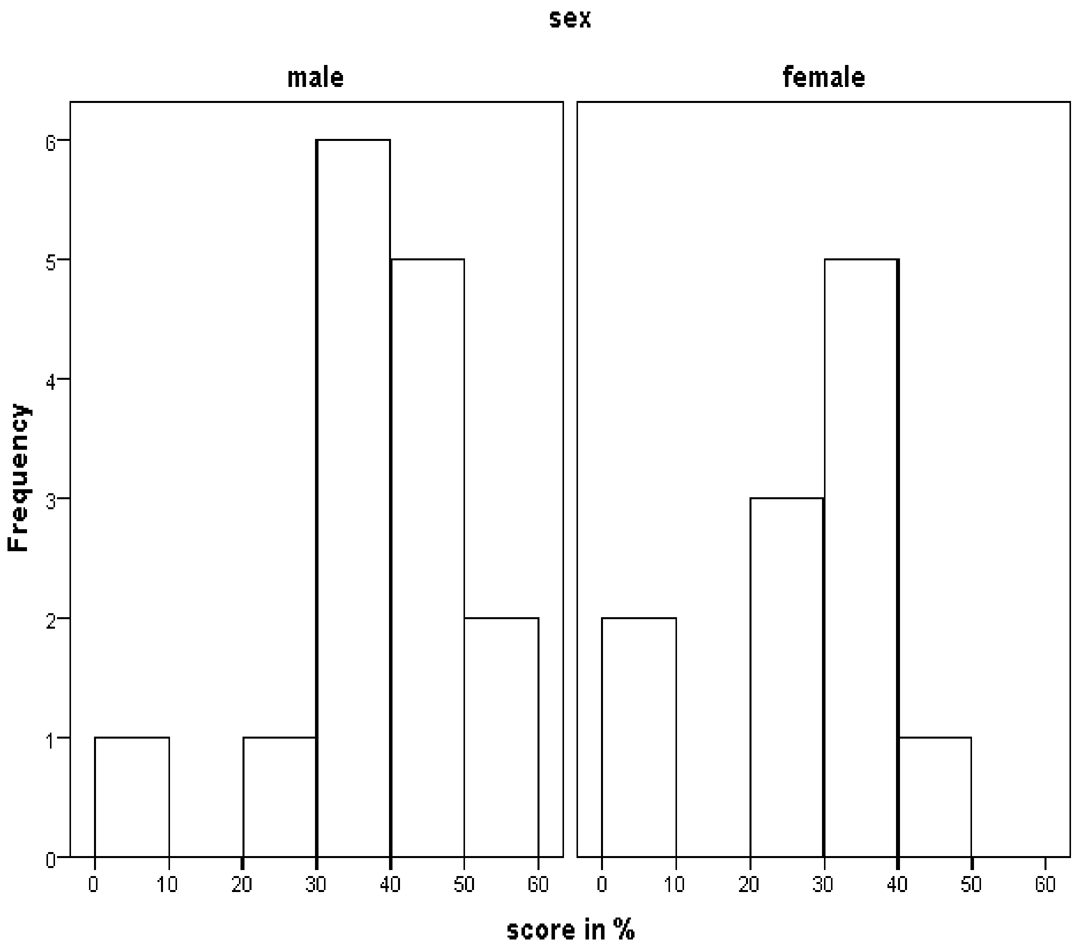


Figure 4.2. Gender score in EPA frequency distribution.

Figure 4.2 above shows the distribution of the scores among the students based on gender. The Electromagnetism I lowest mark recorded was among both male and female students. However, the number of students with the highest score was recorded among the male students as revealed by figure 4.2.

Table 4.13 shows there is an achievement gap between the male and female students who participated in PIDAIM intervention. This gap is in favour of the male students. However, comparing the performance of students in the control group with those in the experimental (Treatment) suggest that the PIDAIM does not enhance the female students' understanding.

The reflection of the distribution is not new but confirms several other studies earlier conducted as regard gender disparities in Physics academic performance. The gaps between boys' and girls' achievement in Physics are not a Nigeria problem alone. Andam, Amponsah, and Kaufmann, (n.d) in their research study observed that boys in Ghana performed better in Physics than their girl counterparts. Ngetich (2014) had noted that the performance in Physics by girls in the national examination has not been impressive in Kenya. It appears that teachers fail to develop and use a mode of communication which takes into account the unique learning needs of female students (Ngetich, 2014). The argument of the author might be right. However, the particular learning needs of female students are not known here.

Akweya, Twoli, and Waweru (2015) in support of Ngetich argued that a study show teacher characteristics, students' attitude, and learner's ability affect girls' performance in Physics in public schools. In another instance, Amunga, Amadalo, and Musera, (n.d) registered a gender percentage gap of 4.5% between boys and girls in a national Physics exam in Kenya. The outcome of this study suggests a new finding that gender does not affect students' academic performance of electromagnetism in an interactive-engagement. This is in contrast to Gok (2014) that teaching with interactive strategies increases the comprehension of both genders. Also, contrary to Stephen (2010) that there is a gender influence on students' learning in physics. There is no consensus about gender achievement in science. There two trending schools of thought on this issue: one school holds the view that male students are better than female while another is on the contrary.

Therefore, the significant difference in performance experience in Table 4.13 has nothing to do with gender. The reasons for the disparities in achievement may be due to many factors according to literature. Sawe (2010) observed that teachers and the girls' attitude, including resources like laboratories contributed to the performance of female's academic performance in Physics. **Girls are not rewarded for the efforts made in Physics which subsequently affect their academic negatively in the subject (Hofer, 2015). The reward is valuable in learning which can be in the form of motivation.** Rehman and Haider (2013) posit that without motivation, learning may be impossible. Thus, teachers should always motivate girls in Physics. According to Mujtaba and Reiss (2013), girls received less encouragement to learn Physics than the boys. Also, the girls had less positive experiences of their Physics lessons and Physics education than did boys.

The consequence of the gender disparities existing in Physics achievement is that it reduces the number of girls seeking for Physics-related careers. The performance and perceptions of the difficulty of Physics are determinants of students' decisions about whether to continue to study Physics (Murphy & Whitelegg, 2007). This according to the authors, informed the reason girls, relative to boys, continue not to see a future self-engaged in Physics and Physics-related careers. Murphy and Whitelegg observed that the content, context and ways of approaching and investigating the problem in Physics is more closely reflecting that of masculine than feminine which exerts a negative influence on girls' performance.

In this female study, students are better than the male students in applying Ohm's law to solve the problem as related to the three necessary electrical quantities (current, voltage, and resistance). Additionally, it also suggests that female students are better than male students in word problems and capacitor related problems. It is common in Physics to present problems to students in word format, and students are required to interpret the question by drawing circuits diagram in other to solve the problem. The female students scored zero in three questions even with the PI intervention. This is supporting the outcome of Table 15 above that performance in PIDAIM is no gender bias.

The general analysis indicates a significant difference between male and female academic performance in Electromagnetism I. The mean the difference in students' academic performance in electricity, an aspect of electromagnetism shows a wide gap in performance.

Analysis of conceptual question indicates that male is superior in academic performance to the female students as explained by figure 4.3 below. Female students scored zero in three conceptual questions.

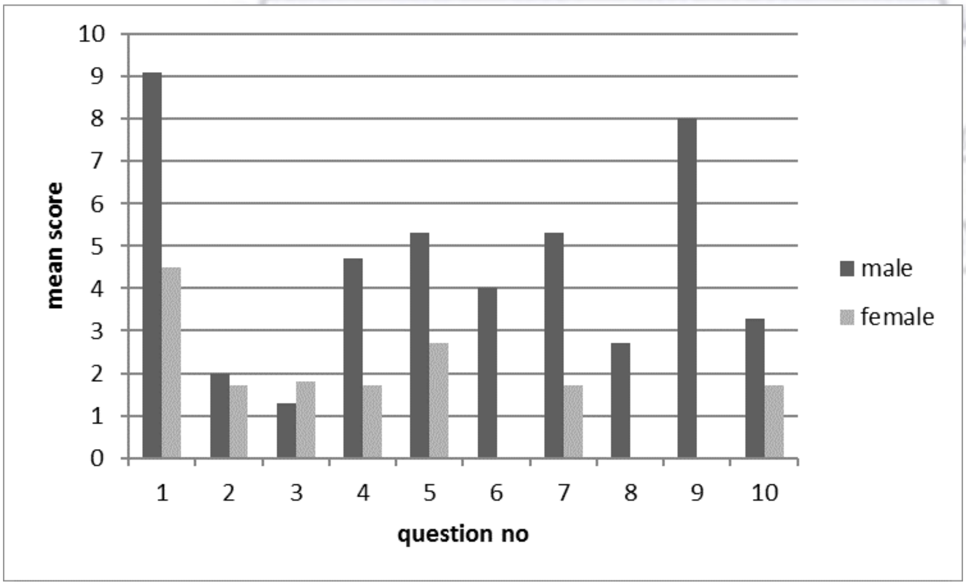


Figure 4.3. Chart of students' achievement in conceptual questions

The focus of the table below is to compute the achievement test scores of the male and female students in the problem-solving skill questions. The EPA contains only three problem-solving skill questions. The reason is that the contents of the Electromagnetism I contain more of conceptual Physics learning than the problem-solving. Thus, to accurately answer the research question 2, it is essential to investigate the impact of the PI on the students' academic performance in the problem-solving skill based on gender.

Male student shows superiority over female students in the problem-solving skill questions. This outcome is consistent with Gok (2012) that male student is better in academic performance in problem-solving skill in Physics than the female student.

Hazari and Potvin (2005) explained that female students do not show interest in physical science, especially Physics. Interest is vital in learning; once a student lost interest in a subject, he/she may no longer do well on such a subject. According to Baram-Tsabari and AnatYarden (2008), boys develop an interest in Physics with age while girls do not develop such an interest to the same degree. Aina and Adedo (2013) have once attributed low enrolment in science subject like Physics to lack of interest. Research also suggests that the rate of attrition in Physics is higher among female students (Hazari, Tai, & Sadler, 2007). The study indicates a wide gap in academic performance between male and female students who participated in the PI intervention. This is evidenced by the significant size effect of calculated eta square. This outcome is relevant to Gok (2014) that teaching with interactive strategies increases the comprehension of both genders but that more study is required on the gender differences in Physics education.

Because of the lack of interest, students shun sciences, particularly Physics when given an option, and this especially applies to girls (Olufunke, 2012). Thus, there are studies with evidence of differences in enrollment and performance in Physics between male and female (Hazari & Potvin, 2005; Semola, 2010; Greeberg, 2006). The present study is consistent with volumes of studies as regards the superiority of male students to female in academic performance in Physics. However, the likely reasons for the difference need to be discussed.

Some of the reasons the female students are behind male students in academic performance in Physics, as indicated by research studies are interest, academic self-concept, attitude, and socio-cultural.

Research abounds that students do better on any subject they show interest. Many female students have not been showing good interest in learning science including Physics in schools today. These students enrolled in Physics because it is a requirement that must be satisfied before graduating in other courses. According to Garwin and Ramsier (2003), interests in learning Physics is decreasing among students in higher school and subsequently result in low achievement in the subject. Olufunke (2012) contended that students' interest would determine what they can learn and how well they may learn. According to this author, interest also determines how well a student can apply what he or she has learned. Thus, Taale (2013) suggests that Physics teachers should make Physics enjoyable to the students using a variety of teaching and learning strategies.

Agbaje and Alake (2014) in their study on “The student variables as a predictor of secondary school students’ academic achievement in science subjects” concluded that students’ interest is vital to learning. Agbaje and Alake concurred that students’ interest and attitude are crucial to academic performance in Physics.

Due to a lack of interest in Physics by many female students, they, therefore, show negative attitudes to the subject. Negative attitude to Physics by female students has resulted in the poor academic performance of the students (Thomas & Israel, 2013). Teachers alike demonstrated negative attitudes toward the female students having the notion they cannot study Physics. Whyte (1986) explains that some teachers have the attitude that a girl-child cannot do well in mathematics and the abstract nature of Physics is well beyond them. Victoria (2011) faulted the teacher for failing to inculcate in the female learners the critical thinking to make studying Physics easy.

Research has shown that students’ interest will make them study and learn Physics better and, choose to study Physics as a course at the higher level of education (Lavonen, Byman, Juuti, Meisalo & Uitto, 2005). The study conducted by Lavonen et al., on pupil interest in Physics in Finland, indicates that girls’ interest in Physics is lower than that of the male. This study is consistent with Hoffmann’s (2002) that male students have an interest in Physics lessons than their female counterparts.

Physics is traditionally regarded as a male subject. Limprecht, Janko, and Gläser-Zikuda (2013) cited Milhoffer (2000) that female students rate their abilities and performance on a lower level compared to male students. Wodzinski (2007) Physics teacher instruction is predominantly related to the learning demands of boys which probably caused the girls to feel slightly insecure in Physics lessons and fear Physics as a subject. According to Limprecht, Janko and Gläser-Zikuda (2013), this may have impacted the girls to underestimate their learning achievement in Physics. To Lupart, Cannon, and Telfer (2004), the girls tend to underestimate their competencies.

Hoffmann asserted that girls grow old and find Physics as a school subject to be less and less attractive. The author observed that research shows that Germany girls get less support and encouragement from their parents to work in the areas of Physics.

Self-concept is an educational construct that is critical to students’ success in any subject. Self-concept is the perception a student has about his or herself. The moment a student has the perception that he cannot succeed in any subject based on any reason best known to him or her, it may be difficult to change such student. Clarke (2005) argued that how a student perceives his or her ability can hinder or enhance his/her learning experience. According to Dupe (2013), the way a learner feels about his/her abilities may impact his/her academic performance. Another educational construct is self-efficacy. Bandura (1986), a proponent of social learning theory describes self-efficacy as the set of beliefs a person holds regarding his or her capabilities to produce desired outcomes and influence events that affect his or her life. Kpolovie, Joe, and Okoto (2014) assert that many of the factors that influence students learning might include self-efficacy, students‘ attitude towards school, interest in learning, and study habit.

Many of the female students in Physics have a low self-efficacy because they lacked self-concept. Dupe views the academic concept like an individual’s perception of self-efficacy in a subject. A female student with high self-efficacy will persist in her study even in the face of learning difficulties. A female student who has low self-efficacy will not be willing to go the extra mile in his or Physics learning. Beside self-efficacy, socio-cultural issues are another strong factor that inhibits female academic performance in Physics.

Aina (2014) explains that some of the causes of poor performance among female Physics students in Nigeria are religion and early marriage. In Nigeria, a particular religion prohibits formal education for female children: any female who defies this religion prohibition does that at her risk. Many of these female students are always psychologically imbalance because of fear. Norton and Tomal (2009) reported that religion adversely affects female education. The present study was carried out in a community that is very sensitive to religion. Due to early marriage in some part of Nigeria, it is ubiquitous to see a female student in Physics class nursing a child. The researcher has witnessed students in Physics class nursing children, and this is worrisome because such students always dropped out of Physics class as a result of poor academic performance. These students already had divided attention to learning and their babies. There is the burden of child-rearing and that of reading about a girl who has put to bed while in school. International Labour Organization [ILO] put it this way:

> Women and girls often spend significantly more time on household chores and caring duties, such as child-rearing or attending to the sick, than do their male counterparts. The obligation to undertake household chores

inevitably limits the time available for education and other activities (p.20).

Therefore, it should not be strange to anyone if male students are academically better than the female students in Physics. Therefore, the present study indicates that there is a significant difference between male and female students' academic performance in Physics and the size effect is large.

4.11 Summary of findings to Research Question 2

An ANOVA and independent-samples t-test was conducted to compare the academic performance of male and female students. There was a significant difference in scores for males (M = 38.40, SD = 12.25) and females (M = 27.27, SD = 11.91; t (24) = 2.31, p = 0.03, two-tailed). The magnitude of the differences in the means (mean difference = 11.13, 95% CI: 1.20 to 21.05) was large (eta squared = .18).

Given the results of the different analysis, a significant difference exists between the male and female students' academic performance after the intervention. The finding indicates that the difference between male and the female academic performance after the intervention was significant with a substantial size effect. The male student shows superiority over the female students in current electricity and electrostatics. The finding also indicates that male students were better than female students in both the conceptual and problem-solving skills in Physics. However, the ANOVA analysis indicates that gender does not affect the students' academic performance when both the control and experimental groups are put together.

The following conclusion was reached on the research question two:

1. A significant difference exists between male and female academic performance in Electromagnetism I who participated in the PIDAIM
2. Male pre-service teachers are academically better than their female counterparts in both current electricity and electrostatics for those in PIDAIM
3. Male pre-service teachers are academically superior to the female pre-service teachers both in the conceptual Physics and problem-solving skill in Physics PIDAIM.
4. Finally, there is no main interaction effect of gender on the academic performance of students' of Electromagnetism I.

4.12 (RQ 3) Research Question 3: Is there any correlation between authentic learning classroom and the constructivist classroom based on the students' academic performance of Electromagnetism I?

The triangulation of data was employed to answer this research question. The data obtained through the achievement test conducted using EPA, the result of the semi-structured interviews and the transcript of dialogical argumentation were triangulated.

Analysis of EPA reveals that the questions of this instrument were grouped into conceptual questions, problem-solving (see Table 4.5), and questions related to authentic learning (real-world problems). Questions 2, 6, 8, and 12 are real-world problem relating to authentic learning.

30% of the students got the right answer for question 2 at the pretest while the percentage drops to only 13% at post-test. Similarly, 15% of the students got the correct answer for question 6 at pre-test and dropped to 6% at post-test. For question 8, no student got the right answer at pretest, but at posttest, 19% of the students got the question correct. The percentage of students who had the correct answer to question 12 was 23% but dropped to 19% at the post-test. The figure below summarizes the analysis.

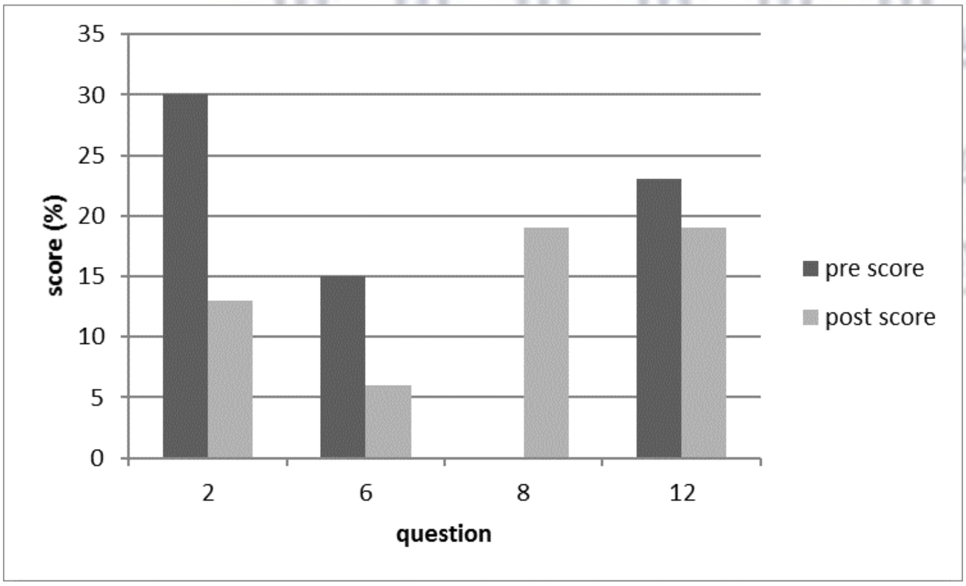


Figure 4.4. The authentic learning questions

Figure 4.4 above shows that students' scores in question 8 increased from 0% at pre-test to 19% at post-test. This is an indication that the students' ability in applying classroom experiences to solve the real-world problem had increased. It must, however, be highlighted that the increase is minimal because it was only observed in one question out of four. This confirmed Rule (2006) and Lombardi (2007) arguments about the authentic learning reviewed earlier.

The semi-structured interview with the students reveals lots of understanding about the authentic learning experience of the students. The interview was conducted only for the students in the experimental group. The interviews centered on finding out the students' experience on (1) peer instruction, (2) dialogical argumentation and (3) the authentic learning based on the nine fundamental elements highlighted in the literature. See the appendix for the interview protocol used in the study.

All the students commented that peer instruction is impressive. A student said, *"I learned well and understood many things in Electromagnetism I never knew before."*

More than 90% of the students agreed that they learned better in the peer instruction class than using textbooks and the lecture method. A student said she learned by herself in PI. Another one put it like this *"I find it easy to retain what I learned in PI than in traditional lecturing."*

The students agreed they enjoyed higher collaboration in learning during peer instruction than in traditional lecturing. One student said she listened to different opinions and interacted with different students to get correct answers. Another student said, *"If I had the wrong answer before group discussion, I find it easy to adjust during group discussion to the correct answer."*

Over 90% of the students commented that group leader presentation after group discussion helps their confidence in the public argument of the personal idea. Only one student commented that there was no benefit in the group leader's presentation. However, many believed they benefitted from the group leader's presentation. A student put it thus *"before now, I cannot stand up in public to talk, but now I can do."*

All the students reported that classes in PI were fascinating more, especially with the scientific argumentation during the PI.

Many kinds of literature had it that the purpose of learning is to be able to apply what is learned to solve the real-life related problem. Some regard it as being able to transfer theory to practice. The outcomes for teacher education courses must go beyond knowledge of the theoretical notions encountered in education classes (Herrington, Herrington & Glazer, 2006). It implies that students should be able to transfer their knowledge and skill learned at school into their everyday lives outside of school (Mims, 2003). Learning of electromagnetism laws and formulas are useless if students cannot solve the life-related problem with such laws and formulas.

Analysis of EPA indicates that out of the four questions relating to using classroom experiencing to solve a real-life problem: PI students' understanding increase only in one question. Question 8 deals with using the knowledge of Ohm's law and electrical power to solve domestic electrical connection. The result shows the students scored 0% at the pre-test but after the PI intervention post-test increase to 19%. This indicates the students had improved in the application of Ohm's law and electrical power knowledge.

The Students are required to learn not only the ideas of Physics but also the strategies used by expert problem solvers (Crouch & Mazur, 2001). The expert problem-solving approach is what the authentic learning experience demands. Authentic learning requires that students can apply scientific laws and principles to solve a real-life problem. This aligns with Mazur (1997) that students learned laws in Physics are unable to address simple problems as they emerge anywhere in the world.

The outcome of this study indicates that students' ability to use laws and formulas to solve real-life related problem improved after the PIDAIM intervention. However, the improvement witnessed here is weak, according to figure 4.4 above. According to Herrington (1997), in authentic learning student learn conditions for applying knowledge. One fundamental purpose of the PI was for the Physics students to solve real-life problems using their classroom experience.

One of the primary features of the authentic learning environment is the students' interest. Mims (2003) put it that learning is centered on authentic tasks that are of interest to the learners. One major problem with the traditional lecture method is the lack of consideration for the students. The teacher is only interested in completing the coursework within a specified time. The need to rush through the Physics content placed students in a passive role as receivers, rather than constructors, of knowledge. The learning environment in PI resembles the authentic context because it involves ill-formulated problems and ill-structured conditions; involves cooperative relations and shared consequences (Herrington, 1997). The central purpose of the study was not to complete Electromagnetism I content outline but ensure students are the active constructor of knowledge themselves.

The ConcepTests used in PI are not well-defined task: it only introduces the students to what they are to learn. Subsequently, the students through discussion and collaboration were able to learn many things not specified by the ConcepTest. For instance, none of the

ConcepTests used mentioned diode, insulator, and an electrical circuit. Nevertheless, from the interviews, the students commented that they were able to understand these concepts well. The learning context reflects the way knowledge was used in real life. During the PI intervention, the researcher made use of no textbook or any prepared scheme of work, but the cynosure to the learning was the ConcepTest.

What is presented to the students in the PI class that is similar to authentic context are many based on the nine fundamental elements of authentic reviewed in the study. The multimedia used during the intervention affords the students of the opportunity to watch video on Electromagnetism I. The students were presented with a real-life experience of the application of electromagnetism. The students were able to access some abstract concepts of Electromagnetism I through the multimedia. For example, many Physics students in de-contextualized learning find it difficult to comprehend what is called *flux* in electromagnetism. In this study, using the multimedia, the students visualized the real-life situation of what is called *flux* in electromagnetism.

Many students commented that the intervention gave them the real-life experience of learning they have not witnessed before in Physics. Another one said the programme made the learning of Electromagnetism I real as against the use of the textbooks and the passive classroom lecturing.

One excellent feature of the study well appreciated by the students as against the traditional way of learning is relevant to real-life in the PI. The students were all happy throughout the intervention, and that could be seen on their faces and the type of questions they asked. The interview also revealed the mind of these students. The study made learning to be real for the students. Another example of real-life experience in the study was that many concepts of the Electromagnetism I was made real to the students. The application of the *fuses* in the electrical installation and appliances were made real to the students during the intervention. It was presented to the students in a way to have real-life relevance.

Students learning by themselves are typically representing the authentic learning experience in nature. Here the students had control over what they learned, which represent an authentic learning environment. According to Watters and Ginns (2000), any authentic learning environment should establish a sense of personal control over what and how the learner learns. In this study, students were given enough opportunity to learn by themselves.

The authentic activities were designed for the students to complete as they interact in the PI class to enable them to incorporate the feature of real-life tasks. Authentic activities comprise complex tasks to be investigated by students over a sustained period, requiring a significant investment of time and intellectual resources (Lombardi, 2007). The activities were not well-defined and not structured; these activities required students to find as well as solve the problems, and it provided opportunities for the students to identify the relevant and irrelevant materials. The activities demand that the students take some hours to complete them.

The ConcepTests used as the backbone of the PI was not well defined. All the ConcepTests were just statements that introduce the students to concepts in Electromagnetism I. The ConcepTest on itself cannot help the students to understand the details of the topic or concept under discussion except they follow the PI procedure. The activities being ill-defined was not a problem because the students were not a blank slate. Social constructivist belief the students had the knowledge they enter into learning with, and as they interact socially, new knowledge is constructed using the prior knowledge.

The students spent the time to make exploration as they collaborated to get problems solved. The students in each group are actively involved in identifying the requirements needed to solve problems presented through the ConcepTests. Besides identifying what it requires to solve the problems, students broke the problems into sub-topics with everybody participating and get the problems solved. The lecturer (researcher) investigates as he moves around the groups indicate that the students divide the questions into sub-topic before solved. The general submission of the students during the interview could best be reported by a student thus:

There were different opinions during the group discussions through which I arrived at the correct answer, even if I was wrong in my first answer.

During the intervention, as the students were busy with the authentic task, they had the opportunity to identify both the relevant and irrelevant information. For example, a ConcepTest possesses irrelevant information, like information on the diode in a question of electrostatics, is irrelevant. Many of the topics were investigated for an extended period. For example, current electricity was examined for more than one week to give the students an in-depth knowledge of the topic—most of the problems overlapped to the week that follows. Herrington and Kelvin (2007) said the authentic activities or tasks reflects the kind of activities that people do in the real world, and are completed over a sustained period.

One essential characteristic of authentic learning is that it could be applied in another discipline. This could be likened to an apprentice who learned carpentry and could use his knowledge in differing ways. Most of these students during the interviews agreed to replicate the knowledge of Electromagnetism I acquired in other courses.

The learning environment in authentic learning resembles that of the real-world where students talk to the teacher and talk to one another. Students connect with others who share their passions and collaborate for a higher purpose (Hilt, 2011). The author explained further that the authentic learning environment encourages and nurtures the open sharing of ideas.

The presence of material such as multimedia, camera, and computers (laptops) makes the class resembles a real-life situation. Multimedia makes it possible for students to explore new fields, meet people and use a variety of tools to gather information and solve problems (Gulikers, Bastiaens & Martens, 2005, p.7). These materials were not just provided but integrated into the PI classes for the benefits of learning.

According to Anderson and Anderson (2005), Authentic learning is built on participation, genuine interest, and interaction with more experienced people. Students participated in group discussions to share ideas during the intervention. Authentic activities are relatively undefined and open to multiple interpretations, requiring students to identify for themselves the tasks and subtasks needed to complete the primary task (Lombardi, 2007). Authentic activities are crucial because it helps students to understand the complexity of the world outside the learning environment (Hui & Koplin, 2011).

In this study, learners directed their learning. PI indeed uses ConcepTest but the learners have every opportunity to revisit any ConcepTest when it is not understood. Learning in PI is personal, the teacher only provides the information through the ConcepTest, but the individual learners make choices. Rule (2006) asserted that in authentic learning, problems must have a personal frame of reference and be open-ended. PI does not restrict or limit students' response to ConcepTest: students' discussion on any learning task was not restricted. Students made their choices of interpretation in PI. Personalizing instruction by allowing the learner to choose from the wide variety of pathways is an essential characteristic of authentic learning (Rule, 2006). The students exercise higher levels of thinking. In this study of PI, no direct principle or formula was given to solve any problem. The questions were given, and the students were expected to provide answers through thinking skill and inquiry. All the options provided in the ConcepTest were related to the topic under discussion. Therefore, whichever option choosing leads to the learning of Electromagnetism I. In other words, the submission of the Hidden Curriculum (2014) that authentic learning is assumed to be designed around open-ended questions without a clear right or wrong answers was valid in this study.

Authentic learning focuses on connecting what students are taught in school to real-world issues, problems, and applications (Rule, 2006). Authentic learning means learning, which happens by actually participating and working on real-world problems; it engages learners by the opportunities of solving complex real-world problems and finding out solutions (Har, 2013, p.1). Authentic learning is a concern with the experience of linking the real-world to the classroom (Hui & Koplin, 2011). To be able to connect what is learned in the classroom to solve the real-world problem, there must be higher retention. The testimonies of the students in this study were that of higher retention than it used to be in the lecture method. Meaningful learning should not be only to acquire knowledge but be able to apply the knowledge. Experience shows that learning in Physics is through memorization. Thus, the students were unable to apply the knowledge adequately outside the classroom (Mazur, Watkins, 2009; Brown, Collins & Duguid, 1989).

Meaningful learning occurs when students build the knowledge and cognitive processes needed for successful problem solving (Mayer, 2002, p.227). The students explain that the learning of Electromagnetism I through the PI was impressive as they had the time of learning to themselves. In other words, learning through the PI was meaningful to them as many misconceptions were discovered and removed. Learning in the PI is not about acquiring factual knowledge but about the students themselves. Meaningful learning requires that instruction is beyond the mere presentation of factual knowledge; it requires more of students than merely recalling or recognizing factual knowledge (Bransford, Brown & Cocking, 1999; Lambert & McCombs, 1998).

During the peer instruction class, the students worked together in small collaborative groups of 3-5 students in a group. It might not be new to the students because they were familiar with working together in groups in the Physics laboratory for practical works. The grouping was not gendered bias as both male and female worked jointly in any group. However, the grouping was done by the students themselves. Working collaboratively together is very advantageous in learning, as commented by the students. A female student has this to say:

During the group discussion, I listened to different opinions and which helped me in knowing the correct answers to ConcepTests. Another one says: *when my answer was wrong, or I had the wrong idea about a ConcepTest at the beginning of the class; everything changes after the collaborative discussions.*

The advantages of collaboration are significant and crucial to the authentic learning experience. One of the benefits of collaboration that is evident in the study is joint problem-solving. Throughout the intervention period, students were seen arguing and dialoguing together to get the problem solved. This exemplified the belief of the constructive controversy theory, as reviewed in Chapter Two of the study. A question that was asked to establish this advantage during the interviews is “did you choose a leader to teach you in your group or how did you learn in your group”? All the students agreed that they were all teachers in the group. In other words, no single person was a teacher; they all worked together to get the problem solved. It was equally discovered that there was no division of labour at this time. The tasks were divided into sub-topics, but the students worked on each topic together not that a topic is given to an individual. The students sought for information on the same topic and later met to harmonize based on the constructive controversy theory.

The preceding relies on the fact that each person comes into the learning environment with his/her personal experiences. It is the experience that is capable of contributing to the completion of the task in his or her unique way. Therefore, it could be seen that all the groups engaged in collaboration, not just cooperation. Katz and Lesgold (1993) concisely argued that collaboration was not just cooperation because collaboration is synchronous, but cooperation may be synchronous or asynchronous.

A frequently mentioned advantage of students collaboratively working together was that the partner often helps by telling or explaining something that the student did not know or understand (Herrington, 1997). It was observed that the students understand themselves better than they understood their teachers. The students in this study explain the thing to themselves more clearly than the teacher could do. Going to the groups, the lecturer sees the students explaining to themselves concepts and principles in Electromagnetism I (see Appendix H).

Collaboration is very vital because it has the features of other elements of authentic learning such as reflection, articulation, coaching, and scaffolding. Students working in a collaborative group have the advantage of articulating their knowledge to their partners. What is done in the study is seeing a student explaining something to another student in Electromagnetism I. Articulation in collaborative groups was seen as a significant advantage of working with others (Herrington, 1997, p.193).

In this study, students helped each other to learn as they collaborate with each group. The students supported each other to extend the understanding of concepts and principles.

All the students interviewed testified that they had a good time for collaboration during their PI classes. Collaboration is an essential element of authentic learning because it is integral and required for task completion (Har, 2013). Collaboration and the opportunity to collaboratively construct knowledge is an essential ingredient of authentic learning (Herrington, 1997). Collaboration is not just to put students in the group and discussed together but must solve the problem together. In this study, students put their heads together to solve many electromagnetism problems. Collaboration allows students to 'put their heads together' on problems, and to fully articulate their progress as they go about the task (Herrington & Kelvin, 2007, p.9).

It has been argued by Edelson (1997) that science is not just an investigation but the sharing of results, concerns, and questions among a community of scientists. In other to corroborate, the argument is to agree that students in PI share their ideas and concerns in different groups through collaboration. When students share ideas during collaboration, it is always tricky for students to forget such ideas very quickly. Notably, when a student fully participated in the group collaboration, this view was agreed upon by Kola (2007), that students remember easily any activity he/she were actively involved.

Osborne et al. (2013) referred to the works of some social psychologists that there is increasing empirical evidence that the knowledge and understanding of learners can be facilitated by collaborative dialogue between peers. During the dialogical argumentation, students collaborate to reach a consensus. The transcript in Tables 4.10 and 4.11 exemplifies this collaboration. A few examples of the Tables are given below.

Students number 1, 2, and 3 in Table 4.10 collaboratively dialogued together to solve the problem of materials that obey Ohm's law. Students number 7, 8 and 9 in their collaborative dialogue resolve differences between electrical conductor and insulator. In Table 4.16 student number 7, 8, and 9 in group four collaboratively dialogue to solve the problem of the resistor and resistance. This underscores the position of constructive controversy as a supporting theory.

Collaboration has been observed as one essential element of authentic learning (Herrington, 1997). Collaboration is expressed in classrooms when students actively participate in discourses with each other as they attempt to make sense of their experiences and construct knowledge (Bell, Maeng & Binns, 2013). The veracity of these authors' statement could be seen in the transcript of dialogical argumentation given in the above examples.

Each week of the intervention students was divided into new groups different from the previous week. The students worked on two or three assignments as prescribed by the ConcepTests. The lecturer (Researcher) supervised the class to ensure maximum participation in every group. The group leaders were given time to tell the class the outcome of their group investigation.

Students articulated their understanding of Electromagnetism I in peer instruction in two ways: the discussion with their partner during the intervention and the group leader's presentation. The students being able to verbalize what they have learned are consistent with Lave and Wenger (1991) that being able to speak the vocabulary and tell the stories of a culture of the practice is fundamental to learning.

It was common during the intervention to see more knowledgeable students articulating their understanding by explaining facts to their partners. Experience had shown that words spoken out are not quickly forgotten like those not spoken out. Some students believed to be able to remember a memorized law and principle in Physics quickly is to recite many times in the presence of their colleagues. In this study, even students who are not sure of the correct answer to a question struggled to say something to other group members.

Articulation of idea has been observed to be one of the discourse patterns in which students can potentially engage during scientific argumentation (Darner, Callis & Wolf, 2013). For instance, student number 5 and 6 in Table 4.16 articulated their ideas about the connection between lamp and electrical appliances during the dialogical argumentation.

Student number 5 said "*No! It is to allow the use of less current.*" Student number 6 said, "*I think it is for high voltage consumptions.*" This represents a real authentic learning situation. The learners were free to articulate their understanding without any molestation or fear. Articulation is an essential element of authentic learning.

Another example of articulation can be seen in Table 4.10, where student number 17 and 18 articulated their understanding of resistance and temperature. Student number 17 put it thus: *As for me, only the electrolyte's resistance increases with the temperature.* For student number 18: *My thinking was that water and some liquids' resistance increase with the temperature.* Students 14 and 15 in Table 4.11 articulated their understanding of power supply through voltage thus: *"No! It is to increase power"* (student number 14).

"For me, it is to make power travel fast" (student number 15)

The group leaders' presentation is another means of articulating students' understanding in peer instruction. After many minutes of collaborative discussions, a group leader from any of the groups was picked to defend their group consensus. During this period, any member of the class can contribute to the presentation either to support or not with evidence. This has been very helpful as revealed by the interviews. Many of the students commented that the group leaders' presentation helped them gained more confidence in the public presentation of their understanding of Electromagnetism I.

More than 90% of the students reported that this helped them in the public presentation of their ideas in Electromagnetism I. Articulation is an essential element of authentic learning. Articulation provides students with an opportunity to speak and write about their growing understanding (Herrington, Reeves & Oliver, 2010). Articulation enables the student to be able to make a public presentation to defend his or her position and ideas. The students' opportunity to verbalize their thoughts in pairs enabled them to be aware of their learning and to make appropriate links to incorporate it into their cognitive frameworks (Herrington & Oliver, 2000).

The role of a teacher in authentic learning is that of coaching and scaffolding. The teacher only provides the skills, strategies, and links that the students were unable to provide to complete the task not to take over the whole teaching (Herrington, 1997). In this study, the teacher gave support to the students when needed and allow the students to take full responsibility for their learning.

During the intervention, the students were often encouraged to write down relevant information as the lecture progresses. The essence of note-taking was for the students to be able to reflect on what they have learned. Students asked questions from the lecturer (researcher) and another trained research assistant. The students after studied the written down notes then come to class and ask questions. For example, a student asked this question after studying his notes: *what is the difference between a diode and a resistor?*

Reflection is an essential element of authentic learning. Many learning opportunities in school are wasted when students are not given a chance to reflect upon and consolidate their learning (Herrington & Kelvin, 2007, p.9). The students had a chance to share their experience at the end of each class, besides; they also share ideas with their senior Physics students.

The first opportunity to reflect is that students had the chance to revisit any ConcepTest they have learned at any time of the intervention. The collaborative process also facilitates students' reflection with each student contributing their experiences and anecdotes to enlighten each other's. The note-taken opportunity for the students helped them to be able to make a connection between the existing prior knowledge and the new one.

The students in this study worked together in collaborative groups, as already discussed. The lecturer (researcher) was present to provide coaching and scaffolding in addition to what is provided by the partners in each group. At the beginning of the lesson, the teacher introduced the use of ConcepTest and gave short instructions to students on how to use ConcepTest. As soon as the students start working in groups, the lecturer makes himself available to the students for any assistance. The lecturer moves around the class to encourage the students to seek any assistance but not enforced it on them to seek such assistance. The students on many time consulted with the lecturer and the other research assistants for help and clarifications.

A student in each collaborative group equally offers assistance to partners. The lecturer observed this as he moved around the class to monitor the collaborative group discussion. Where students are not satisfied with their partners, help they called on any of the research assistants. Three of the research assistants were from the Physics department who were experts in Physics and capable of assisting the students. The most common areas of aid are the announcement, social and procedural matters.

Observation and interaction with the students showed that they were euphoric with the procedural assistance: this deals with the general procedure of the peer instruction. The procedural problems are usually solved by the lecturer (researcher) himself. Assistance relating to the subject matter was not often sought by the students. Nevertheless, where such assistance is requested for, the lecturer did not supply the solution but gave enough guides to lead the students to the next stage.

From the preceding, six elements of authentic learning were identified, which are the authentic content, authentic activity, collaboration, articulation, coaching and scaffolding, and reflection. Therefore, PI helps students' authentic learning experience in Physics.

Table 17

Correlations between Authentic Classroom and Constructivist Classroom

		Authentic	Constructivist
Authentic	Pearson Correlation	1	142
	Sig. (2-tailed)		.315
	N	52	52
Constructivist	Pearson Correlation	142	1
	Sig. (2-tailed)	.315	
	N	52	52

Table 17 shows a correlation between authentic learning classroom and the constructivist classroom with a correlation coefficient of 142. The reason for this is that constructivist learning is a student-centred (Brandon & All, 2010) and also the authentic learning. According to Hidden Curriculum (2014), Authentic learning is closely related to the concept and theory of constructivist teaching, and in some cases, it may be synonymously used.

According to Savery and Duffy (2001), constructivism is about understanding or knowing. Authentic learning is a concern with the experience of linking the real-world to the classroom (Hui & Koplin, 2011). For Powell and Kalina (2011), an active classroom, where teachers and students are communicating optimally, is dependent on using constructivist strategies, tools, and practices (p.241).

Students' construction of knowledge (Kirschner, Sweller & Clark, 2006) by themselves is central to the constructivism: this is done through active participation in the learning task. Supporting this is Prawat and Floden (1994) that constructivism is based on the idea that the students actively construct knowledge. The teacher only acts as a facilitator but not the provider of the knowledge. The basis of authentic learning has been to give the students enough opportunity to control their learning while the teacher plays coaching and scaffolding role.

According to Brandon and All (2010), constructivism theory is founded on observation and scientific study about how people learn. The theory emphasizes that learning should be an active process in which learners construct new ideas or concepts based upon their current or past knowledge.

The constructive theory model sees constructivism as a spiral with the students at the center of the spiral, making students the center point of learning. Within the ring, students interact, constituting a group (All, 2010) that interacts with their teacher. The participants in this study work in different groups where they learned from one another through questioning and argument. Through the process of questioning, students learn the strategies that help them become expert learners in Electromagnetism I. The process of active learning gives students the ever-broadening skill of lifelong learning.

According to Brooks and Brooks (1993), a constructivist teacher should encourage student critical thinking and enquiry by asking them thoughtful, open-ended questions, and encourage them to ask questions from each other. Encourage communication between the teacher and the students and also between the students. Make sure to wait long enough after posing a question so that the students have time to think about their answers and be able to respond thoughtfully. The ConcepTests in PI were usually posted and give enough time for the students to respond. Constructivist theories have their roots in Piaget and focus on the dynamic character of the learner, interacting with the environment either singly or with others (Packer & Goicoechea, 2000). Learners' interaction was the primary focus of this study. Learning is a social activity. Learning is intimately associated with other human beings, teachers, peers (Hein, 1991). Biggs (1999) argues that constructivism holds the belief that meaning should not be imposed or transmitted by direct instruction, but allows the students to generate information created by learning activities. In this study, the researcher did not impose any instruction on the learners, but they generate information by themselves. For instance, many of the concepts in Electromagnetism I are not directly reflected in the ConcepTests, and yet both the interviews and the transcript show that students learned these concepts. Examples of such concepts are an inductor and Ohmic substance. This implies that the students generated the learning information for these concepts by themselves.

Kroll (2004) suggests that in a constructivist classroom, students should be able to construct for themselves an articulated vision of learning, teaching, development, and knowledge. According to Huang (2002), constructivism stresses the evolvement of learners' ability to solve their real-life problems. The ConcepTests and the EPA were designed to give the pre-service teachers a real-world experience. The students' tasks were those that had a real-life resemblance. The kernel of the authentic learning is for students to have learning experiences that will enable them to solve a real-life problem.

In an authentic learning environment, teachers' knowledge and textbooks are severely discouraged from allowing students to direct their learning. The learning task is ill-defined. Brandon and All emphasized that constructivism believe that instead of using the teacher's knowledge and textbooks for solving problems, the student invents solutions and constructs knowledge in the learning process.

Learning Physics requires that students should be able to gather information independently, analyze the information critically, evaluate it and be able to develop a new framework through the information. This is the only way to produce a Physics graduate (Physics teacher) with critical thinking skills. Electromagnetism Physics teacher with critical thinking skills will be difficult to produce through the traditional teaching method where the teacher is the information provider. The school syllabus content-laden guides the traditional lecture method instead of concepts learning guided by active-learning strategies. Authentic learning is a student center model, interactive, and innovative curricula, which correlates with constructivism.

According to Powell and Kalina, constructivism requires classroom situations and activities that promote individual learning (cognitive) and interactive learning (social). The kernel of authentic learning is that students can learn both individually and also collaboratively. Constructivism has the belief that learners have an active role in constructing meaning on their own (Cornu & Peters, 2005).

Constructivism posits that people experiencing things and reflecting on those experiences is good, but need to construct their understanding and knowledge of the world (Thirteen Ed Online, 2004). Constructivism, as a learning theory believes that learning is an active process; knowledge is constructed from experience and a personal interpretation of the world (Christie 2005). According to Christie (2005); Honebein and Peter (1996), it also emphasizes problem-solving and understanding use authentic tasks, experiences, settings, assessments, and content presented holistically –not in separate smaller parts. Christie (2005); Honebein and Peter (1996) further emphasized that constructivism provide multiple modes of perspectives on content; new understandings are created via coaching and moderating. The authors also argued that testing should be integrated with the task and not a separate activity.

Collaboration is an essential aspect of constructivism; hence Christie said it involves collaboration between instructors, students, and other learners. It is tailored to the needs and purposes of individual learners and features active, challenging, authentic and multidisciplinary learning.

Constructivism benefits students in many ways as asserted by Christie (2005) that it helps students pursue personal interests and purposes; use and develop learners' abilities; build on the learners' prior knowledge and experiences and develop life-long learning.

Applying constructivism correctly in the classroom is essential. ThusThirteen Ed Online suggest that constructivist teacher should take note of the following:

- problems asked must be relevant to students
- learning must be structured around essential concepts
- know that students' points of view are windows into their reasoning
- teaching must be adapted to address students' suppositions and development
- students' learning should be assessed in the context of teaching

The five suggestions mentioned above acts as a cynosure for this study, and that makes it capable of producing students with an authentic learning experience in Electromagnetism I.

Authentic learning environments provide students with rich experiences and opportunities to construct knowledge, and in ways that make sense to their existing knowledge which is based on prior experiences (Cox-Petersen & Olson, 2000). The teacher would not be seen as "the knower," but would depend upon a resource-based approach where students would generate their investigations which would require access to various and copious amounts of current and static data (Cey, 2001).

The argument of Cey that constructivism made students gain much in learning when they work together supports collaboration as an essential element of authentic learning, as seen in the study. The students worked together throughout the intervention period. The author argues that students be able to reflect on and elaborate not just their ideas but those of their peers as well. The interview result indicates that pre-service teachers reflect much on group ideas than personal ideas.

Scheid (1995) viewed the learning that is captured within a constructivist environment as student-centred, collaborative, authentic and action-packed. The teachers in the authentic learning do not only do scaffolding; there is also scaffolding among the students. Cey thus asserts that constructivist classroom teachers must create opportunities for peer scaffolding and teacher-directed scaffolding which is the process of allowing interaction that stimulates knowledge building. The researcher and the research assistants gave the students much time to help one another where there are challenges: this is done through peer scaffolding.

Learning occurs when the learners are actively involved in the construction and reorganization of concepts only (Chen, 2003). Learning is a process of knowledge construction rather than the absorption of knowledge. Learner constructs knowledge based on how he/she perceived and conceived his environment. The situation in the dialogical argumentation exemplifies this as recorded by the transcript. Learner, therefore, construct knowledge individually, this might make it impossible for the teacher to transmit concept through lecturing to learners. Knowledge cannot be transmitted directly from person to person, but instead is individually and idiosyncratically constructed or discovered (McInerney & McInerney, 2002).

Learning has to do with the environment where the student had the experiences and constructed knowledge. That is why Chen argues that constructivists emphasize cognitive experience in authentic activities. Constructivism believes that constructing understanding demands that the students have the opportunities to articulate their ideas and to test those ideas through conversation, (Dykstra, 1996; Julyan & Duckworth, 1996). For instance, during the dialogical argumentation, a student said: *"resistance is opposition." "*This was the knowledge of electrical resistance he brought into a learning environment which helped him during the discourse. For Chen, the opportunity for students to discuss and clarify their experiences is paramount because it encourages self-organization and reflective abstraction.

According to Fox (2001), constructivism supports the active participation of learners rather than the passive perception, memorization, and all the mechanical learning strategies in traditional didactic lecturing. Learning is enhanced by challenge and inhibited by threat, which is why the classroom climate should be challenging but not threatening to students. This idea suggests the need to make the classroom fascinating to the students, as observed in this study. The interview indicates that the students showed interest in peer instruction. However, there were challenges the used of the ConcepTest posed to the students. The students overcoming these difficulties of the ConcepTest by themselves are another way of experiencing authentic learning.

In conclusion, both the Piaget Cognitive Constructivism (PCC) and the Vygotsky Social Constructivism (VSC), the constructivist classroom and authentic classroom are similar in almost all areas. Thus, the research question on authentic learning is appropriate in light of the PI as a student-centred pedagogy.

4.14 Summary of Results for Research Question 3

Given the details analysis of the EPA, the dialogical argumentation transcript and the responses of the students to the interviews conducted for the experimental group; six authentic learning elements were identified. The elements identified are authentic context, authentic activities, collaboration, articulation, scaffolding and coaching, and reflection. It was established that the authentic learning and the constructivist learning are correlated: constructivism (PCC and VSC) being the theory on which the peer instruction is anchored. Therefore, it could be inferred that the authentic learning classroom and constructivism classroom are correlated.

4.15 Chapter Summary

This chapter presents the summary of findings based on the three research questions, as mentioned in Chapter One of the study. The cohorts of participants were a group of pre-service Physics teachers who were in their first-year programme of Physics education in a College of Education in Nigeria. Electromagnetism I was the course under investigation as being one of the compulsory courses for all the pre-service Physics teachers in Nigerian Colleges of Education. The triangulation of data derived from the Electromagnetism Physics Assessment (EPA), Peer Instruction Dialogical Argumentation Questionnaire (PIDAQ), the Dialogical Argumentation Transcript and Semi-structured interviews were utilized. To answer the research questions as stated in Chapter One, discussion of the analysis of the results was done and supported by the underpinning theories discussed in Chapter Two. Chapter Five was a summary of critical findings which informs implications for identified role players in addition to recommendations for further research imperatives by way of suggestions to address challenges highlighted by Physics educators in the extant literature.

CHAPTER FIVE: CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a synopsis of the main findings obtained from the data analysed in Chapter Four. The data analysis focused on the effectiveness of Peer Instruction (PI) in enhancing pre-service teachers' understanding of Electromagnetism I in a Nigerian College of Education. The effectiveness of the PI was based on the findings arising from the three research questions reiterated below.

1 Does the incorporating DAIM into PI intervention have an impact on the pre-service physics teachers' understanding of electromagnetism I?

2 Is there any gender impact of PIDAIM on the pre-service science teacher in the learning of electromagnetism I?

3 Is there any correlation between authentic learning classroom and the constructivist classroom based on the students' academic performance of Electromagnetism I?

The analysis of triangulated data from the EPA, PIDAQ, the dialogical argumentation transcripts and the semi-structured interviews showed that the PI intervention impacted the pre-service Physics teachers' understanding of Electromagnetism I positively.

Peer Instruction also helped to support the Authentic Learning experiences of the Physics students in understanding Electromagnetism I concepts. Six out of the nine fundamental elements of Authentic Learning identified in the study are authentic context, authentic activities, collaboration, articulation, scaffolding and coaching, and reflection. However, indicators suggest that some areas such as authentic context, authentic activities and reflection need further investigation.

This chapter also highlights some implications and recommendations for further study. However, it is appropriate to reiterate that the kernel of the study was to determine the effectiveness of Peer Instruction (PI) in enhancing pre-service teachers' understanding of electromagnetism. Based on the data collected and analysed in Chapter 4, the following conclusions have been reached:

5.2 Pre-service Students' Understanding of Electromagnetism I before the Intervention

Analysis indicated that the pre-service Physics teachers' understanding of Electromagnetism I before the intervention was inadequate. Detailed analysis shows that the students' knowledge in charge and charges distribution was excellent and appropriate in contrast with students' knowledge in other areas of the Electromagnetism I like Ohm's law and capacitor and capacitance. The analysis also revealed that students' knowledge in both conceptual and problem-solving skills was weak and inadequate thus implying that students' knowledge in these aspects before the Electromagnetism I course appeared inadequate. The Electromagnetism Physics Assessment (EPA) showed that students lacked a conceptual understanding of Electromagnetism I. The PIDAQ also revealed that students displayed some misconceptions about Electromagnetism I before the intervention concepts such as capacitor/capacitance and resistor/resistance.

A unique area emerging from this study is the integration of a Dialogical Argumentation Instructional Model (DAIM) into the PI. The issue of whether the students learned or not in PI was triangulated with the results emerging from PI and DAIM. The results showed that students learned through collaborative dialogue. This outcome allayed the concern that students copied from those students who knew the right answer during the voting process on PI, as explained in Chapter 3. Further research is required in this area.

The analysis of the results collated from all the research instruments shows that there are conceptual conflicts in Electromagnetism I before the intervention. This conflict informed the level of misconceptions held by students. For example, there are two types of charges, negative and positive. Most physics students learned by definitions that current is the rate of flow of electrons. Thus, they think since the electron is negatively charged misconceived it that current flow from negative to the positive charge. However, in the real sense, the conventional current is flowing from positive to negative. The study also discovered that pre-service Physics students displayed poor knowledge of problem-solving skills. The study shows that the students find it challenging to solve calculations that have no direct application of formulas. For instance, questions 11, 12 and 13 of the EPA have no specific formula for solving the problems. The students had to go through different formulas to address each of the problems. Many students could not get the questions correctly as they were unable to apply these formulas, but thinking they will use only one formula. It implies that the level of critical thinking of the students was low; however, studies revealed the importance of critical thinking in scientific inquiry. Rodrigues and Oliveira (2008) concurred that critical thinking is crucial to Physics learning. The inadequate knowledge of the students in this study can be attributed to the students' critical thinking ability and other factors beyond the scope of this study. Rodrigues and Oliveira opined that critical thinking is a factor that predicts the Physics students' academic performance because the evolvement of critical thinking contributes to improving students' performance in Physics. One factor contributing to poor performance in critical thinking maybe that the students learned mainly through memorization and correctly repeated what they have crammed for examination purposes.

5.3 Pre-service Students' Understanding of Electromagnetism I after the Intervention

Physics understanding can be classified into two critical cognition categories, namely conceptual understanding and problem-solving skills.

The findings reveal that students' knowledge in both conceptual Physics and problem-solving skills was poor even with the intervention. Peer instruction had more impact on the problem-solving skills than the conceptual knowledge in the Electromagnetism I. This is evidenced by the 35.9% of student's score in problem-solving skill as against 29.3% of the conceptual in the post-test in table 4.5.

The Electromagnetism I in this study was divided into two branches of Physics which are electricity and electrostatics. Findings show that there was no improvement in the students' knowledge of electricity even with peer intervention. The analysis shows only 27.8% of the students had the correct answer to the electricity questions before the PI and 26.3% after the PI. For the electrostatics, there was an improvement in the students' knowledge as a result of the peer instruction intervention. This is evidenced by the analysis that shows that 29.8% of the students had the correct answer to the electrostatics questions before the PI and increased to 34.6% after the PI. However, it was revealed that despite the improvement in the electrostatics, the students' understanding was still not encouraging in both electricity and electrostatics. The achievement gain of 4.8% in electrostatics is too small to rely upon as an improvement. The gain is the difference between the pre-test scores and the post-test scores of the EPA.

The findings also showed that students' misconceptions in Electromagnetism I were corrected by the peer instruction intervention. For instance, the misconception the students had about resistor, resistance, capacitor, and capacitance was resolved, as seen in table 4.11. The findings reveal some right ideas about concepts in Electromagnetism I which were wrongly applied by the students. For example, students had the right idea about charges but misapplied the flow of electrons as a basis for the current electricity. Some of these misunderstood and misapplied concepts include a resistor, resistance, capacitor, capacitance, insulator and an electrical circuit.

There had been concerns about how students learned during peer discussions. Some believed not much is known about the dynamics of the peer discussion before students registered their answers (James, 2006). Some worried about whether a student indeed learned or just copied the correct answer in their groups (Porter, Lee, Simon & Zingaro, 2011). The findings show that the students did not copy correct answers from their groups but learned by personal thinking, active involvement in the argument and careful analysis of their peer's contributions.

This finding emerges as a result of the incorporation of dialogical argumentation into peer instruction. The earlier studies on peer instruction have not gone beyond what is called "convince your neighbour." Therefore, this finding is a real innovation in peer instruction.

5.4 The Difference between Male and Female Students' Academic Performance in Electromagnetism I after the PI Intervention

There were fifteen male student participants in the experimental group and eleven female students. Findings reveal that there was a statistically significant difference between boys and girls in this group. The independent t-test analysis of male and female scores indicated a significant value of 0.030 less than the probability value of 0.05. This result is concerning the students' academic performance only in the Electromagnetism I.

However, some findings are germane to the extant literature on the gender effect in Physics learning. Male students show a superior knowledge of Electromagnetism I than their female counterparts. However, the level of superiority was minuscule. It was discovered that female students were better than male students in the application of Ohm's law, capacitor related areas and electromagnetism words problem. Also, female students in the control group improved in the understanding of Electromagnetism than the male students after the intervention. Thus, the study shows that the academic performance of students in the Electromagnetism I has no gender bias.

This finding also indicates that male students had a better academic understanding of both the conceptual electromagnetism and problem-solving skills than the female students after the peer instruction intervention. The case is similar to current electricity and electrostatics.

5.5 Peer Instruction related to Authentic Learning (AL). Experiences of Electromagnetism I

The findings of this study about how Peer Instruction assists pre-service Physics teachers' authentic learning experiences in Electromagnetism I are encouraging. The findings reveal that PI can help students have an authentic learning experience in Physics class.

The findings illuminated the following Authentic Learning elements emerging from a PI class: authentic context, authentic activity, collaboration, articulation, reflection, coaching, and scaffolding. This finding shows the advantage of peer instruction over other cooperative learning strategies that are in vogue in Nigerian schools today.

The finding shows the students had real-life experience in learning of Electromagnetism I and learned by themselves. The learning activities were ill-defined and not laden curriculum activities. The students cooperated and collaborated in learning not only cooperation as done by other student-centred activities. Additionally, the findings reveal that students articulate their understanding and the students have time to reflect on their learning by revisiting the learning activities. Finally, the study shows there is a perfect correlation between the authentic classroom and constructivist classroom.

5.6 Summary of the Major Findings

The following significant findings of the study on the effectiveness of Peer Instruction (PI) in enhancing pre-service Physics teachers' understanding of Electromagnetism I is now presented.

- Students who attended peer instruction classes have a better understanding of Electromagnetism I than those who attended traditional lecture method classes
- Peer instruction helps to identify and correct some of the students' misconceptions of Electromagnetism I
- There was a statistically significant difference between male and female students in peer instruction classes. However, gender did not affect the students' academic performance in Electromagnetism I.
- Peer instruction as a research-based pedagogy helps the student to have an authentic learning experience in electromagnetism I.
- There is a perfect correlation between the authentic classroom and the constructivist classroom PIDAIM
- The emergence of Peer Instruction Dialogical Argumentation Model (PIDAM) for teaching electromagnetism
- The evolvement of peer instruction authentic learning framework for teaching electromagnetism

5.7 Implications of Major Findings

Given the findings of this study, the following implications have been identified and a proposal imperative for further actions. The findings imply government policy on education, teacher training programme, pre-service teachers, and learners.

5.7.1 Implications for government policy on education. The results of this study confirmed many research studies earlier conducted that peer instruction improves both the conceptual and problem-solving skills of students in Physics (Smith et al. 2009; Lasry, Mazur & Watkins, 2008; Crouch, Watkins, Fagen & Mazur, 2007). Thus, government educational research bodies, curriculum planners, education counsellors, in-service teachers would benefit from these findings if the government could sponsor workshops, seminar, conferences, and resources for its implementation in schools.

Government policy on education needs to be changed towards making teaching and learning of Physics practicable outside the classroom. To achieve this, the present policy where teaching strategies are stipulated without adequate monitoring for effectiveness should be stopped. NCCE prescribed some teaching methods for Physics education programme in Nigerian colleges of education. These are mere prescription in the government book called National Minimum Standard, but many teachers do not care to implement the policy. Therefore, even if peer instruction is to be added to the existing teaching methods without proper monitoring, it may also fail.

There are policy statements about Physics education in Nigeria as prescribed by the National Policy on Education. One of these statements is: to provide a basic literacy in Physics for functional living in the society (Omosewo, 2009). Therefore, to make Physics students functional in society, teaching and learning must go beyond the present talk-and-talk method of instruction. To achieving this demand a change of paradigm in instruction and embrace a research-based pedagogy for the teaching of Physics at all level.

Adopting peer instruction as a method of teaching will require training and retraining through workshops, seminars, and conferences for Physics teachers in the country. It implies that the government needs to make the fund available for the necessary resources. For more than six weeks of the interventions, a considerable amount of money was spent to implement the teaching of Electromagnetism I using peer instruction in a college of education. Resources were made available for the success of the programme: human and other resources.

The implications of the findings for the Physics curriculum planners are that there is a need for the revision of the existing Physics curriculum. The present curriculum pays too much attention to the teacher as the provider of Physics learning information. In other to produce Physics students who will be functional in society, the curriculum should be centered on the students' activities, not the teachers. The learning task should be ill-defined and learn to be contextualized.

The dialogical argumentation, as a method of science instruction, should be included in the Physics curriculum. The promotion of proficiency in science among Physics students where they could stand boldly to defend and articulate Physics knowledge requires scientific argumentative skill. Argumentation is an essential means of generating cognitive conflict forcing the student to identify their current conception and engage in the cognitive act of comparison, contrast, and evaluation of evidence (Osborne et al. p.317). According to Aina (2017), proficiency demand that every student can articulate his or her scientific knowledge anywhere and at any time.

Workshops, seminars, and conferences could continuously be organized for Guidance and Counsellors on the importance of the need to make Physics functional through a research-based pedagogy. Besides, Physics students need to be adequately guided that Physics is not an abstract discipline that cannot be applied outside the classroom. The Physics students need to be counselled and guided that Physics can be applied to everyday life if teachers aimed at an authentic learning experience. The implications of these findings for the formulation and implementation of government education policy could be a significant consideration by curriculum planners, teacher educators, teachers and other stakeholders in education.

Given the above observations, government policymakers could consider the following:

- Ensure that Physics curriculum is revised to make it more of students' activities and less of the teachers' instructions to give way to the authentic learning experience by the students.
- Appreciate the abilities of the Nigerian Physics students by providing the enabling rich environment where they have the opportunity to investigate many ideas, roles, and perspectives (Herrington & Kelvin, 2007).
- Develop the Physics students' knowledge towards enriching collaborative learning that goes beyond just cooperative learning in Physics classes.
- Developing Physics classrooms where students could articulate their understanding to provide them with opportunities to speak and write about their growing Physics understanding (Herrington, Reeves & Oliver, 2010).

- Developing teaching and learning environment where Physics student can adequately reflect on their learning by returning to the experience, attends to feelings and re-evaluate the experience (Boud, Keogh & Walker, 1985). Learning is enhanced by learners through the integration of the new knowledge into their day-to-day life by being directed to discuss, reflect on, or defend their new skill (Merrill & Gilbert, 2008).
- Developing Physics teacher's awareness of his or her role in the class as a guide, not a provider of information in schools. Many Physics teachers in Nigerian schools assumed the position of information provided while students are assimilators of the information. The teacher in the peer instruction class plays the role of coaching and scaffolding, not information provider. Scaffolding is the support gives to the students during the learning process which is directed to the needs of the students to help such students to achieve their learning objectives (Sawyer, 2006).
- Provision of learning resources to meet the needs of present-day Physics learning.

This study made use of flashcard during the intervention, which is not the most appropriate for present-day learning. It is a simple, easy-to-implement, and cost-effective response system (Mazur, 1997). Provision of electronic response system (ERS) would be the best and most appropriate. Presently, in Nigeria, it is not sure if any public school has an electronic response system for Physics teaching and learning. Besides, resources like Reading Quiz, Mechanics Baseline Test, Force Concept Inventory, the Astronomy Diagnostic, Conceptual Survey on Electricity and Magnetism, Maryland Physics Expectations Survey and Lawson's Test of Scientific Reasoning (Crouch et al., 2007; Rosenberg et al., 2006) are paramount to PI. Many of these resources are freely accessible at http://hea-www.harvard.edu/~pgreen/PI.html. However, some of these resource materials adopted from the Peer Instruction User's Manual by Eric Mazur are provided in the Appendix. (Appendix J).

- The adequate power supply is crucial to the implementation of peer instruction. Throughout the eight weeks of the intervention, the researcher made use of a private electrical generator in classes. The electrical power supply is indigent in Nigeria. This implies that schools in Nigeria need a steady power supply if the Nigeria government would benefit from the findings of this study.
- Constructing ConcepTest regarded as the cornerstone of peer instruction (Mazur, 1997) require that the teacher possesses strong content knowledge of Physics. The in-

service Physics teachers need on-the-job training to upgrade their knowledge of Physics regularly. It is vital to avoid increasing the student's problem with misconceptions. Beside misconception, Aina and Langenhoven (2015a) argued that a teacher with poor PCK could quickly lose class control during the implementation of peer instruction.

The need for Physics teachers with high self-efficacy is crucial to the implementation of peer instruction in Physics class. This is a new strategy of teaching, and usually, students resist change (Mazur, 1997). The first lecture of this intervention was not easy for the researcher and the research assistants: the class seems rowdy and noisy. With a teacher who has a low self-efficacy, he or she may not be able to cope with such a class. Therefore, it is crucial to develop the Physics teacher self-efficacy through regular workshops, seminars, and conferences. Self-efficacy, a belief the teacher is having about his or her ability in accomplishing a particular teaching task (Lunenburg, 2011). According to Bandura (1993), when teachers have high self-efficacy, there is a possibility to work more to learn new activities as they are more confident in their abilities than a teacher with low self-efficacy. The success of a teacher in any class depends on some factors such as self-efficacy (Aina & Olanipekun, 2015).

- Developing students and teachers proficiency in Physics is crucial to the application of Physics to everyday living. Proficiency in science demand students to ably articulate their scientific understanding as appropriately related to relevant experiential situations. Therefore, the need to include argumentation as pedagogy in the Physics curriculum creates the relevant teaching and learning environment for active discourse. This space is quickly established through the integrated Peer Instruction (PI) and Dialogical Argumentation Instructional (DAIM) models.

5.7.2 Implications for pre-service teacher and teacher training programme. It is normal that students resist change (Rosenberg et al.), therefore explaining what you are doing is essential. The reason you are making these changes, and what the students benefit will be made known: it is crucial to making any change in your course successfully. This is a new programme for the Physics students, and the need for both the government and the teachers to motivate them is crucial otherwise; it may fail.

The teachers in Nigeria have been criticized for lacking teaching qualifications (Akindutire & Ekundayo, 2012) and competence in teaching due to faulty teacher education programme (Akinbote, 2007). Okemakinde et al., (2013) said quality teachers should be available in sufficient quantity at all levels of the educational system to meet the needs of the nation through quality teacher education. It implies that implementing the new educational programme in Nigeria there is the need first to overhaul the entire teacher education programme. Okeke-Otie and Adaka (2012) succinctly argued that no educational programme could succeed with pedagogically ineffective teachers.

The Nigerian teacher education programme is weak in pedagogical studies because of the short period used for practical teaching. The importance of pedagogical knowledge was underscored by Gore, Griffiths, and Ladwig (2004) suggesting that productive pedagogy knowledge should come in the early stage of teacher education to be fully integrated into students' knowledge base for learning.

Therefore, benefitting from the findings of this study require teachers who are sound in pedagogical knowledge. The quality teacher education programme is imperative to the success of peer instruction in Nigeria. The quality teacher education programme will produce quality teachers because James (2003) and Ipaye (2002) concurred that quality teacher is central to all educational programmes. Teachers who anchor all educational programmes are to have adequate teacher preparation programme (Darling-Hammond, Berry & Thoreson, 2001). Research shows a definite connection between teachers' preparation in their subject matter and their performance and impact in the classroom (Wilson, Floden & Ferrini-Mundy, 2001). The implication, therefore, is that to implement this finding, there is a need for sound and effective teacher education programme in Nigeria.

5.7.3. The implications for Physics textbook writers. The writing of Physics textbooks to communicate Physics knowledge to students is not the best, and textbook writers could benefit from the finding of this study. To benefit from the outcome of this study requires that authors shift completely from mere factual knowledge but to provide authentic learning scenarios that could benefit the construction of Physics knowledge through activities. This implies that Physics textbooks should be written to guide students in the path of knowledge construction. Thus, books must be made up of students' activities. The authors should use different topics in Physics to design activities for students that will inevitably lead them to the collaborative dialogue. Given the implications of the findings of the study, the study moves to recommendations.

5.8 Recommendations

Based on the conclusion of this study, the following recommendations are proposed:

- Peer instruction should be adopted alongside the lecture method in other colleges of education in Nigeria in science classes for two years. After two years of assessment, the method could be extended to the universities and in other subjects. The failure and success of the two years implementation can then determine the government position on the fitness of the programme for the entire education system.
- There should be proper training of Physics teachers who will implement PI in schools in the forms of workshops, seminars and conferences and, in-service training. The training of Physics teacher is along the same line as Porter et al., (2011) emphasized the importance of instructors in the PI for computing science.
- Experts in Physics should come together to develop ConcepTests databases and library base on the Nigerian student needs. Although ConcepTests exist, these can be validated and made relevant to the Nigerian experience. The need for the experts to develop and validate the ConcepTests is underscored by Crouch et al., (2007) that a poorly prepared ConcepTest can lead students to more confusion.
- The government should review the Physics teacher education programme in Nigeria with the view to strengthening the pedagogical study of the pre-service teachers for effective implementation of PI in schools. This is important to allay the fear of many scholars and stakeholders in education who believed the Nigerian teacher education is poor (Ogunyinka, Okeke & Adedoyin, 2015; Jibril, 2007).
- The Physics curriculum in Nigeria colleges of education should be revised to permit the use of peer instruction in all level of Physics teaching. Many of the Nigerian Physics educators had suggested the review of the Physics curriculum in school for many reasons such as aligning with the innovation in teaching (Augustine & Adeoye, 2011; Adejuyigbe & Adejuyigbe, 2016).
- The dialogical argumentative instruction is crucial to conceptual Physics learning. Therefore, Physics teachers should be trained on its use for Physics instruction. Different authors and scholars have argued that argumentative instruction will not succeed except the teachers have sound argumentative

knowledge (Osborne, Simon, Christodoulou, Howell-Richardson, & Richardso, 2013; Erduran, Ardac & Yakmaci-Guzel, 2006).

- The government should make the fund available to colleges of education to make Physics lecture rooms suitable for the implementation of peer instruction. Electronic Response System, multimedia, and constant power supply are essential for the implementation of PI in schools. Inadequate funding for education is a problem of sustainable development in Nigeria as observed by Nwanchukwu (2014).

5.7.1 Recommendations for further studies. Peer instruction is a new method of teaching that many Nigerian teachers are ignorant of because there are other similar methods people are confused about it. Since this study had been carried out successfully among the Physics students in a college of education, a stage has been set for a similar study in other subjects and at other levels. The literature in different studies also indicates the effectiveness of the PI in enhancing students' learning. However, many of the writing on the PI cited were the studies carried outside of African countries. Therefore, the study recommends that this study should be replicated in another college of education, polytechnics, and universities and any other subject. Nonetheless, one must remember that African countries have an educational background different from all the nations where PI has been adopted. For instance, the illiteracy level of many countries in Africa is very high compared with other Western countries. Another example is that the infrastructure in African countries is weak. These are factors and much more that may seriously influence both the teachers and the students participating in the PI research study. It is equally important to understand that the PI depends much on the right ConcepTest (Crouch et al., (2007). Therefore, the success in replicating this study in any part of Nigeria will depend on the ConcepTests. It is also essential to know that many of PI studies used Electronic Response System (ERS) which may not be available in most schools in Nigeria. Thus, it is essential to make it as part of the further study the impact of the alternative students' response method adopted. For instance, this study used flashcards, and other researchers used clickers.

The student's attitude towards the PI is crucial, and it is suitable for any teachers to know that this may bring discouragement. Therefore, for the success of the further study in PI, the teacher should be aware that the result may be or not the same as those studies from countries outside Africa due to the different educational background, infrastructures and the PI resources.

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APPENDICES

APPENDIX A: Instruction Programme

WEEK 1

Topic: ConcepTest 1, 2 and 3 **(**Charges and Coulomb's Law**)**

Duration: two lecture periods **(**1 hour for each period)

Material Resources: multimedia projector, laptop, flashcard, camera, video and audio recorder, white board markers, chalk, Physics textbooks and Peer Instruction: A User's Manual.

Performance Objectives: At the end of the lesson, the students should be able to:

a. Identify different types of charges
b. Correctly state Coulomb's law

Previous Knowledge: the students have been taught atomic structure

Introduction: The teacher briefly introduces types of charge and Coulomb's law.

Teacher's Activities: The students are made to form different groups. The teacher poses ConcepTests 1, 2 and 3 one after the other. The teacher briefly explains the answer after a group leader has discussed the final answer to the class.

Students' Activities: the students provide an answer to the ConcepTest individually, then go into their various groups to discuss the answers. After the group discussions, a group leader discusses the final answer with the whole class while other members agree or query the answer.

Conclusion: selected students' interview

WEEK 2

Topic: ConcepTests 4, 5, 6, and 3 **(**Charge distribution over conductors, electric field and electric potential**)**

Duration: two lecture periods **(**1 hour for each period)

Material Resources: multimedia projector, laptop, flashcard, camera, video and audio recorder, white board markers, chalk, Physics textbooks and Peer Instruction: A User's Manual.

Performance Objectives: At the end of the lesson, the students should be able to:

a. Differentiate between conductor and insulator.

b. Define charge density

c. Identify good conductor and bad conductor

d. Differentiate between the electric field and electric potential

Previous Knowledge: the students have been taught types of charges

Introduction: The teacher introduces the meaning of conductor and electric field potential.

Teacher's Activities: The students are made to form groups different from the groups they had in the previous week. The teacher poses ***ConcepTes***ts 4, 5, 6, and 7 one after the other. The teacher briefly explains the answer after a group leader has discussed the final answer to the class.

Students' activities: the students provide an answer to the ConcepTests individually, then go into their various groups to discuss the answers. After the group discussions, a group leader discusses the final answer with the whole class while other members agree or query the answer.

Conclusion: selected students' interview

WEEK 3

Topic: ConcepTests 8, 9, and 10 **(**Storage of charges and the arrangement of capacitors in a circuit)

Duration: two lecture periods **(**1 hour for each period)

Material Resources: multimedia projector, laptop, flashcard, camera, video and audio recorder, white board markers, chalk, Physics textbooks and Peer Instruction: A User's Manual.

Performance Objectives: At the end of the lesson the student should be able to:

a. Define capacitance of a capacitor
b. Clearly identify capacitor and cell in a circuit
c. Identify different types of capacitor
d. Describe at least one application of a capacitor
e. Identify two types of capacitors arrangement in a circuit
f. Solve simple mathematical problems involving capacitors in a circuit

Previous Knowledge: the students have been taught types of charges and charges distribution

Introduction: The teacher introduces storage of charges and different arrangement of capacitors in a circuit.

Teacher's Activities: The students are made to form groups different from the groups they had in the previous week. The teacher poses ConcepTests 8, 9, and 10 one after the other. The teacher briefly explains the answer after a group leader has discussed the final answer to the class.

Students' Activities: the students provide an answer to the ConcepTests individually, then go into their various groups to discuss the answers. After the group discussions, a group leader discusses the final answer with the whole class while other members agree or query the answer.

Conclusion: selected students' interview

WEEK 4

Topic: ConcepTests 11, 12, and 13 **(**Current electricity)

Duration: two lecture periods **(**1 hour for each period)

Material Resources: multimedia projector, laptop, flashcard, camera, video and audio recorder, white board markers, chalk, Physics textbooks and Peer Instruction: A User's Manual.

Performance Objectives: At the end of the lesson the student should be able to:

a. Define electric current correctly
b. Differentiate between current, potential difference and electromotive force
c. Explain causes of hindrance to the flow of current

d. Explain the relationship between the current, potential difference and resistance
e. State Ohm's law correctly
f. Differentiate between Ohmic and none Ohmic materials
g. Identify instruments used to measure current, potential difference and resistance
h. Manipulates these instruments to form a simple electrical circuit

Previous Knowledge: the students have been taught types of charges and charges distribution

Introduction: The teacher introduces current from the knowledge of charges.

Teacher's Activities: The students are made to form groups different from the groups they had in the previous week. The teacher poses ConcepTests 11, 12, and 13 one after the other. The teacher briefly explains the answer after a group leader has discussed the final answer to the class.

Students' Activities: the students provide an answer to the ConcepTests individually, then go into their various groups to discuss the answers. After the group discussions, a group leader discusses the final answer with the whole class while other members agree or query the answer.

Conclusion: selected students' interview

WEEK 5

Topic: ConcepTest 14, and 15 **(**Arrangement of resistors in a circuit and thermal electricity)

Duration: two lecture periods **(**1 hour for each period)

Material Resources: multimedia projector, laptop, flashcard, camera, video and audio recorder, white board markers, chalk, Physics textbooks and Peer Instruction: A User's Manual.

Performance Objectives: At the end of the lesson the student should be to:

a. Identify two types of resistors arrangement
b. Differentiate between the two arrangements
c. Solve simple mathematical problems involving electric current, potential difference and resistance.
d. Define heat energy correctly

e. Identify source of heat in an electrical circuit

Previous Knowledge: the students have been taught current electricity

Introduction: The teacher introduces ageneration of heat energy by resistance to the flow of electric current.

Teacher's Activities: The students are made to form groups different from the groups they had in the previous week. The teacher poses ***ConcepTes***ts 14, and 15 one after the other. The teacher briefly explains the answer after a group leader has discussed the final answer to the class.

Students' Activities: the students provide an answer to the ConcepTests individually, then go into their various groups to discuss the answers. After the group discussions, a group leader discusses the final answer with the whole class while other members agree or query the answer.

Conclusion: selected students' interview

WEEK 6

Topic: ConcepTests 16, and 17 **(**Electrolysis)

Duration: two lecture periods **(**1 hour for each period)

Material Resources: multimedia projector, laptop, flashcard, camera, video and audio recorder, white board markers, chalk, Physics textbooks and Peer Instruction: A User's Manual.

Performance Objectives: At the end of the lesson the students should be able to:

a. Define electrode correctly
b. Mention types of electrodes
c. Differentiate between cell and battery
d. Differentiate between primary

Previous Knowledge: the students have been taught current electricity

Introduction: The teacher introduces chemical energy.

Teacher's Activities: the students are made to form groups different from the groups they had in the previous week. The teacher poses ConcepTests 16 and 17 one after the other. The teacher briefly explains the answer after a group leader has discussed the final answer to the class.

Students' Activities: the students provide an answer to the ConcepTests individually, then go into their various groups to discuss the answers. After the group discussions, a group leader discusses the final answer with the whole class while other members agree or query the answer.

Conclusion: selected students' interview

WEEK 7

Topic: ConcepTests 18, 19, and 20 **(**Magnetostatics)

Duration: two lecture periods **(**1 hour for each period)

Material Resources: multimedia projector, laptop, flashcard, camera, video and audio recorder, white board markers, chalk, Physics textbooks and Peer Instruction: A User's Manual.

Performance Objectives: At the end of the lesson the student should be able to:

a. Define and identify magnetic field
b. Differentiate between electromagnet and solenoid

Previous Knowledge: the students have been taught current electricity

Introduction: The teacher introduces the generation of current by magnetism.

Teacher's Activities: The students are made to form groups different from the groups they had in the previous week. The teacher poses ConcepTests 18, 19, and 20 one after the other. The teacher briefly explains the answer after a group leader has discussed the final answer to the class.

Students' Activities: the students provide an answer to the ConcepTests individually, then go into their various groups to discuss the answers. After the group discussions, a group leader discusses the final answer with the whole class while other members agree or query the answer.

Conclusion: selected students' interview

WEEK 8

The teacher administers tests and interview to the students.

APPENDIX B: Electromagnetism Physics Assessment (EPA)

CIRCLE ONLY THE CORRECT ANSWER.

1. An electric charge could be transmitted through

   A. Wood, rubber and stone, **B**. Paper, clay and plastic

   C. Glass, acid and cloth, **D**. The human body, water and metals

2. Every house supplied with electricity is provided with a box of fuses so that

   A. Consumption of electricity can be recorded

   B. People residing in the house will not have an electric shock if they touch a live wire

   C. The total current drawn from the mains can be limited

   D. The voltage supply can be established

3. According to Ohm's law, the ratio V/I is constant for

   A. An electrolyte, **B.** A diode, **C**. Silver, **D**. A transistor

4. Which of the following is stored by a dry Leclanche cell?

   A. Electric power, **B**. Kinetic current, **C.** Electric current, **D.** Chemical energy

5. The function of a 5A fuse included in a circuit supplying a household refrigerator with power is to keep the

   A. Temperature of the refrigerator low and constant

   B. Current supplied to the refrigerator below 5A

   C. Voltage supply constant

   D. Current supplies to the refrigerator constant and above 5A

6. A short chain is sometimes attached to the back of a petrol tanker to

   A. Generate more friction

   B. Ensure the balancing of the tanker

   C. Caution the driver when over speeding

   D. Conduct excess charges to the earth

7. Power supply is transmitted at a high voltage and low current in order to

   A. Make it travel fast

   B. Prevent overheating of the coil

   C. Make it pass through the transformers

   D. Increase the power supply

8. In homes, electrical appliances and lamps are connected in parallel because

   A. Less current will be used, **B**. Less voltage will be used

C. Parallel connection does not heat up the wires

D. Series connection uses high voltage

9. Which of the following materials has an increase in resistance with temperature

A. Wood, **B**. Electrolyte, **C**. Water, **D**. Metals

10. Capacitors are used in the induction coil to

A. Dissipate energy, **B**. Prevent distortion of electric fields

C. Prevent electric sparks, **D**. Control circuits

11. Two lamps rated 40W and 220V each are connected in series. The total power dissipated in both lamp is **A.** 10W, **B**. 20W, **C**. 40W, **D.** none of the above

12. A house has ten 40W and five 100W bulbs. How much will it cost the owner of the house to keep them lit for 10 hours if the cost of a unit is ₦5?

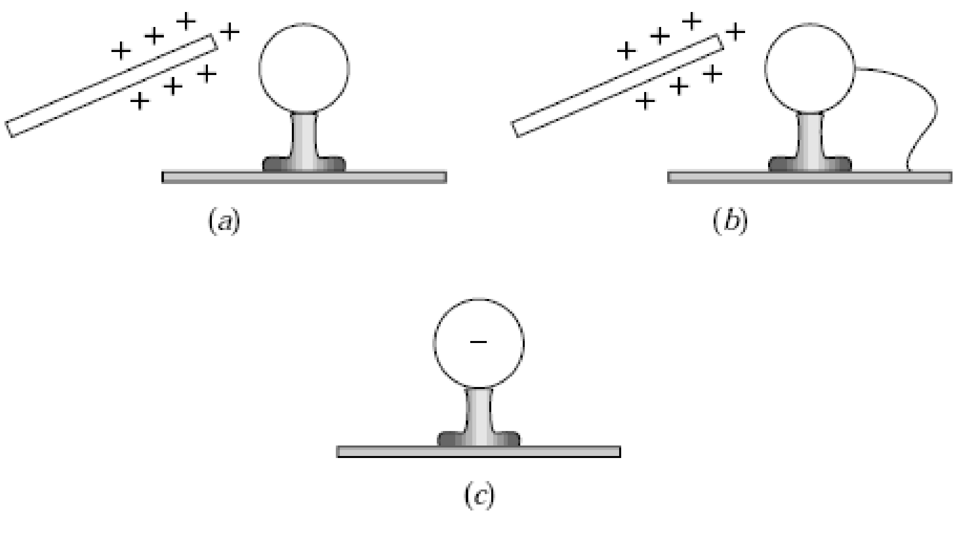
A. ₦50, **B**. ₦45, **C**. ₦20, **D**. ₦90

13. Two 50 µF parallel plate capacitors are connected in series. The combined capacitor is then connected across a 100-V battery. The charge on each plate capacitor is

A. 500 $\times 10^{-5}$C, **B**. 2.50 $\times 10^{-3}$C, **C**. 1.25$\times 10^{-3}$C, **D**. 1.00$\times 10^{-2}$C

APPENDIX C: ConcepTests

1. A positively charged object is placed close to a conducting object attached to an insulating glass pedestal (*a*). After the opposite side of the conductor is grounded for a short time interval (*b*), the conductor becomes negatively charged (*c*). Based on this information, we can conclude that within the conductor



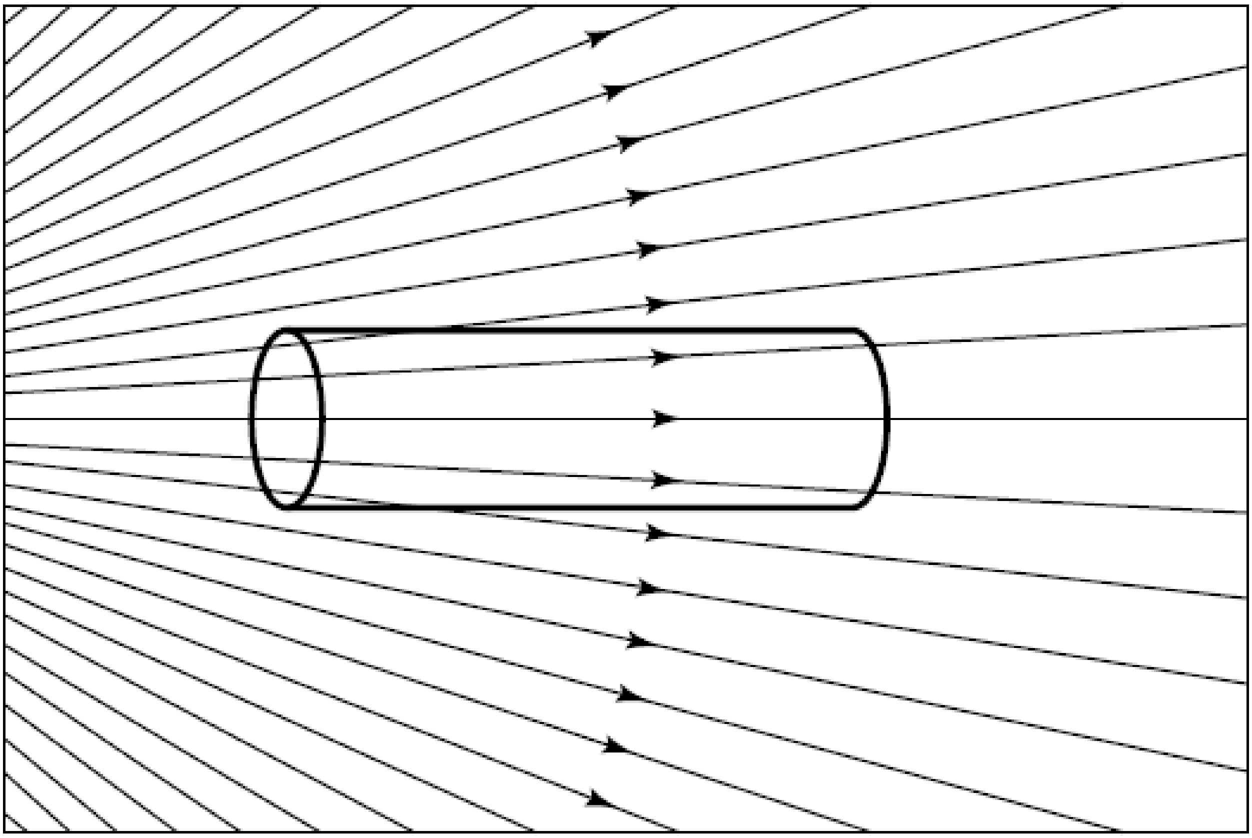
1. both positive and negative charges move freely.
2. only negative charges move freely.
3. only positive charges move freely.
4. We can’treally conclude anything.

2.Three pithballsare suspended from thin threads. Various objects are then rubbed against other objects (nylon against silk, glass against polyester, etc.),and each of the pithballs is charged by touching them with one of these objects. It is found that pithballs 1 and 2 repel each other and that pithballs 2 and 3 repel each other. From this, we can conclude that

1. 1 and 3 carry charges of opposite sign.
2. 1 and 3 carry charges ofthe equal sign.
3. all three carry the charges of the same sign.
4. one of the objects carries no charge.
5. we need to do more experiments to determine
the sign of the charges.

3.A cylindrical piece of insulating material is placed in an external electric field, as shown. The net electric flux passing through the surface of the cylinder is

1. positive.
2. negative.
3. zero.

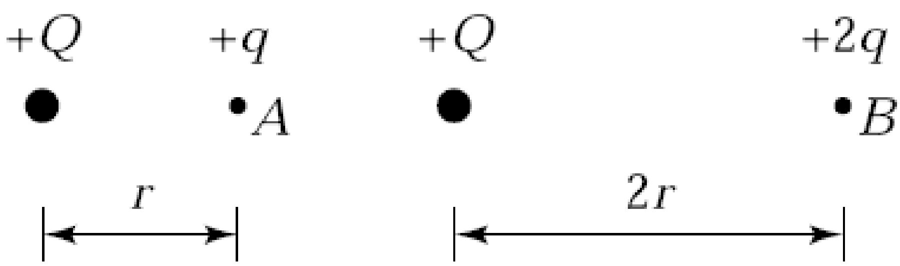


1. positive.

2. negative.

3. zero.

4.Two test charges are brought separately into the vicinity of a charge +*Q*. First, test charge +*q* is brought to point *A* a distance *r* from +*Q*. Next, +*q* is removed, and a test charge +2*q* is brought to point *B* a distance 2*r* from +*Q*. Compared with the electrostatic potential of the charge at *A*, that of the charge at *B* is



1. greater.

2. smaller.

3. the same.

5. A solid spherical conductor is given a net nonzero charge. The electrostatic potential of the conductor is

1. largest at the center.
2. largest on the surface.
3. largest somewhere between center and surface.
4. constant throughout the volume.

6. Consider two isolated spherical conductors each having net charge *Q*. The spheres have radii *a* and *b*, where $b > a$. Which sphere has the higher potential?

1. the sphere of radius *a*
2. the sphere of radius *b*
3. They have the same potential.

7. What happens when two different materials like woolen cloth and a plastic ruler are rubbed together?

1 the cloth cleans the ruler

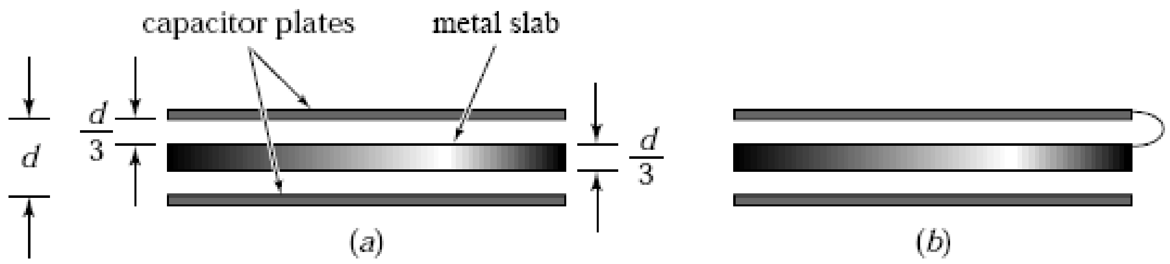
2 electrons are transferred from one material to the other

3 nothing happen

8. Consider a capacitor made of two parallel metallic plates separated by a distance *d*. The top plate has a surface charge density +*s*, the bottom plate –*s*. A slab of metal of thickness $l < d$ is inserted between the plates, not connected to either one. Upon insertion of the metal slab, the potential difference between the plates

1. increases.
2. decreases.
3. remains the same.

9.Consider two capacitors, each having plate separation *d*. In each case, a slab of metal of thickness *d*/3 is inserted between the plates. In case (*a*), the slab is not connected to either plate. In case (*b*), it is connected to the upper plate. The capacitance is higher for



1. case (*a*).

2. case (*b*).

3. The two capacitances are equal.

10. Consider a simple parallel-plate capacitor whose plates are given equal and opposite charges and are separated by a distance *d*. Suppose the plates are pulled apart until they are separated by a distance $D > d$. The electrostatic energy stored in the capacitor is

1. greater than
2. the same as
3. smaller than

before the plates were pulled apart.

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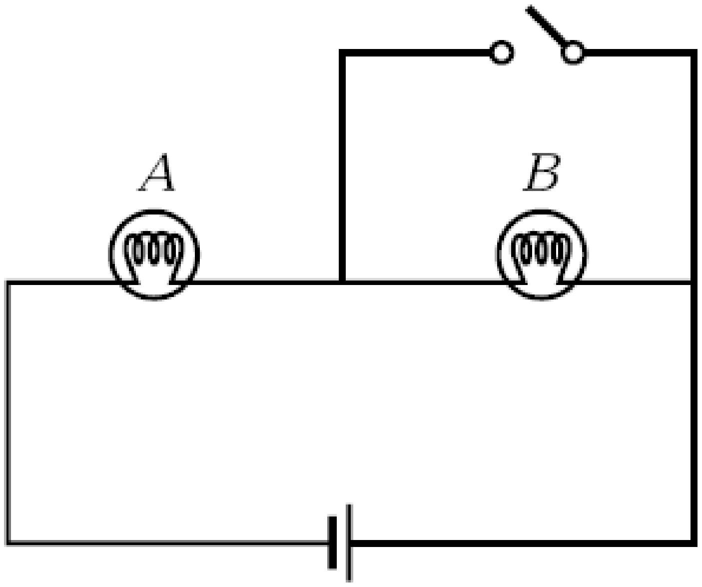
11. Consider two identical resistors wired in series (one behind the other). If there is an electric current through the combination, the current in the second resistor is

1. equal to
2. half
3. smaller than, but not necessarily half the current through

the first resistor.

12. The circuit below consists of two identical light bulbs burning with equal brightness and a single 12 V battery. When the switch is closed, the brightness of bulb *A*



1. increases.

2. remains unchanged.

3. decreases

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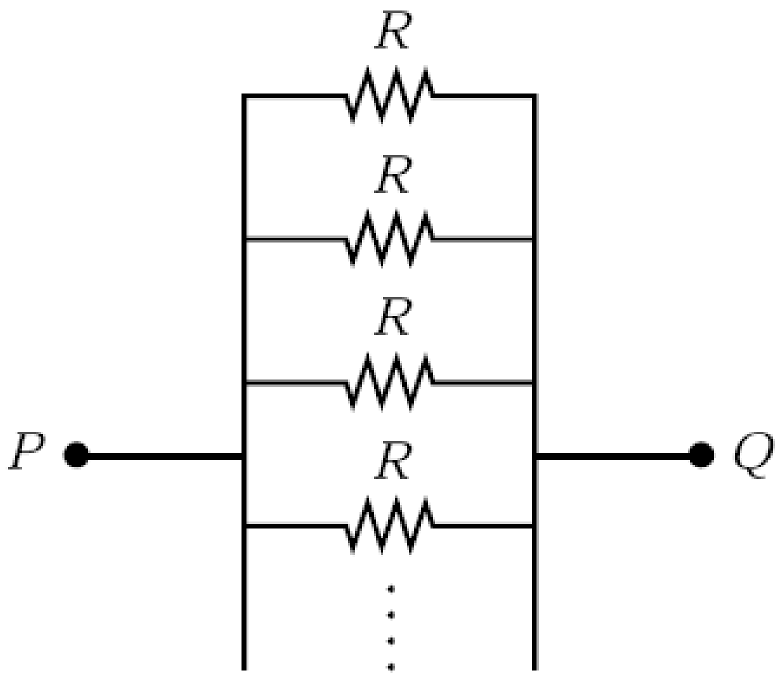
13. As more identical resistors,*R* are added to the parallel circuit shown here, the total resistance between points *P* and *Q*

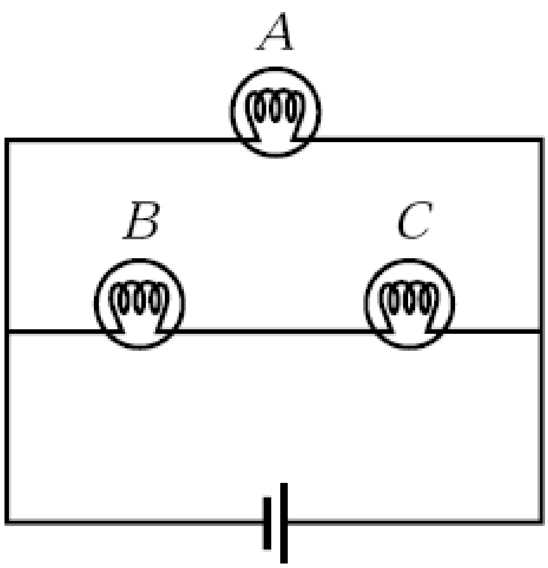
1. increases.

2. remains the same.

3. decreases.



14. The three light bulbs in the circuit all have the same resistance. Given that brightness is proportional to power dissipated, the brightness of bulbs *B* and *C* together, compared with the brightness of bulb *A*, is



1. twice as much.
2. the same.
3. half as much.

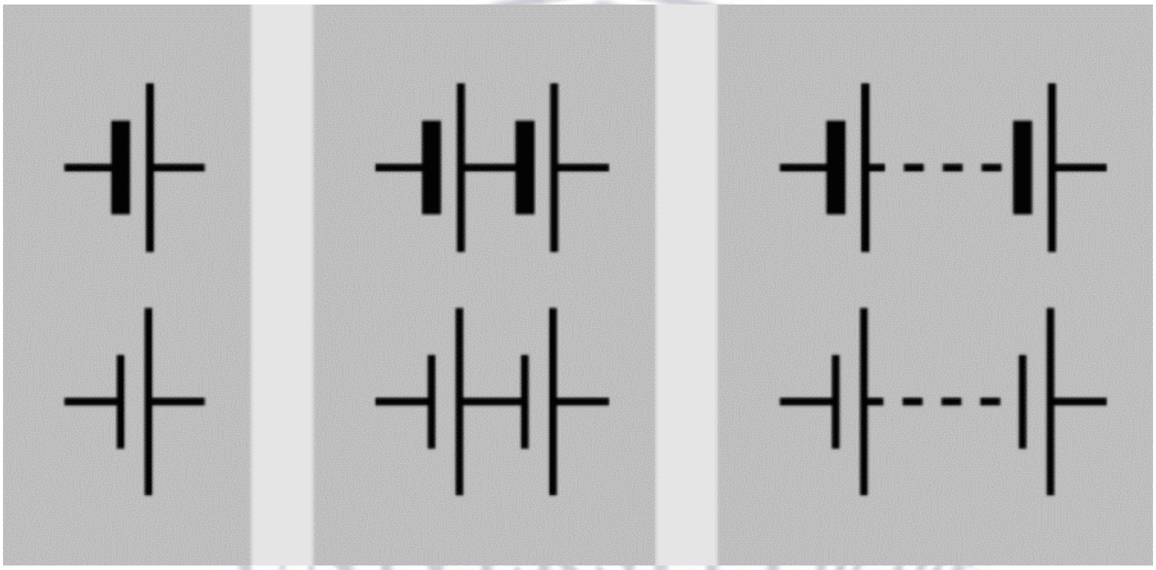
15.A fuse should be placed close to the power source or power input point in a circuit so that it

1 protects as much of the circuit as possible.

2. acts as an additional power input

3 helps to reduce the loads on electrical appliances.

16. The schematic diagram below represents that of a

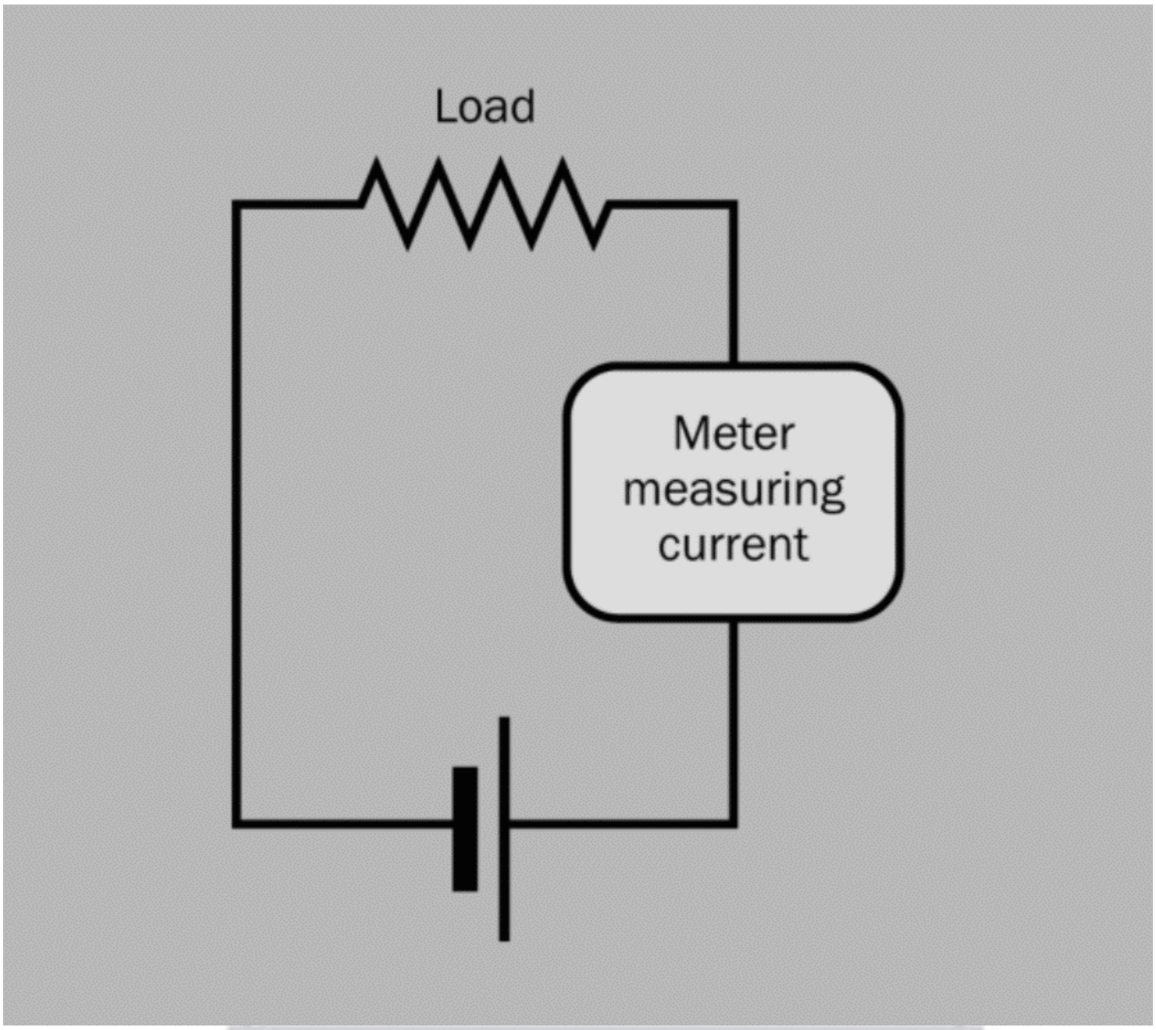


1 capacitor

2 transistor

3 diode

17. The battery, load, and ammeter are connected as shown in the diagram below



1 to protect the battery

2 to protect the meter

3 to reduce the load effect on the battery

---

18. When a lead-acid battery is partially or completely discharged and is allowed to remain in that state, sulfur tends to build up on its metal plates. The effect of this sulfur is

1 forming a barrier against the electrochemical reactions

2 protecting the battery terminal from rusting

3 there no effect on the battery

19.A sphere of radius *R* is placed near a long, straight wire that carries a steady current *I*. The magnetic field generated by the current is *B*. The total magnetic flux passing through

the sphere is

1. $m_o I$.

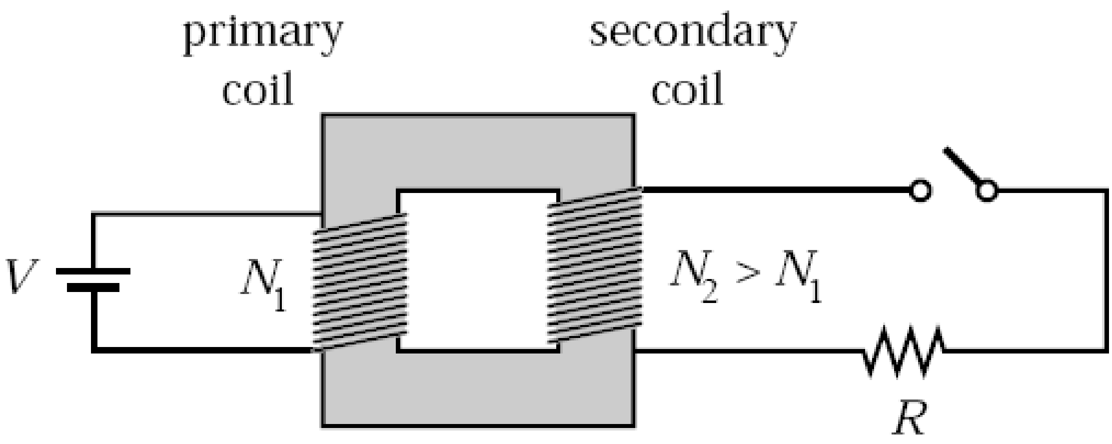
2. $m_o I/(4pR^2)$.

3. $4pR^2 m_o I$.

4. zero.

5. need more information

20. When the switch is closed, the potential difference across *R* is



1. VN^2 / N_1.
2. VN^1 / N_2.
3. *V*.
4. zero.
5. insufficient information

Appendix D: Peer Instruction Dialogical Argumentation Questionnaire (PIDAQ)

Department (Not Physics) …………………………………..

Group number ………………………………………………

Gender ……………………………………………………….

Read the statements below and tick (√) where appropriate to show whether you Agree (A) or Disagree (D) or Don't Know (DK) about the statements. Do not tick more than one response per item.

S/N	Statements	A	D	DK
1	I am hearing and taking part in peer instruction where I can argue with my fellow students for science learning purpose.			
2	If this is not your first time: in what subject did you take part in peer			

	instruction with an argument for learning purpose?			
3	My experience in this peer instruction with argument is interesting			

4. Briefly, explain why it is interesting or not interesting

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

5	I always get the correct answer in peer instruction before group argument			
6	From the peer instruction through argument,I understood better many concepts in electromagnetism			

7. List three concepts in electromagnetism you understood more through the peer instruction argument?

…………………………………………………………

…………………………………………………………

…………………………………………………………

8	I got rid of some misconceptions in electromagnetism when I took part in the peer instruction argument.			

9. Mention one misconception in electromagnetism that peer instruction helps you to overcome

…………………………………………………………………………………………

10	In my opinion, peer instruction is not necessary for science because it is a waste of time			

11	The peer instruction through argument helps me to learn better in electromagnetism			

12. Briefly, in not more than five steps, explain how you got a correct answer to any conceptest in your group discussions

………………………………………………………………………………………
………………………………………………………………………………………
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APPENDIX E: The School Clearance Letter

Flat 6 Rosehope,
Rose bank
Main road Mowbray
Cape Town
9 June, 2015.

The Registrar,
Aseyori College of Education,
Oke-Odo.
Dear Sir/Madam,

<u>Re: Permission to conduct the research (case study)</u>

I, the researcher, a postgraduate student at the University of the Western Cape, hereby request permission to conduct a research study to a sample of 52 Physics education100 level students in your college. These students will attend lectures for 8weeks after which they will be evaluated through assessment test and interview. Both the lectures and the interviews will be recorded (audio and video).

The identities of the participants will remain private and the findings will be handed to the school management in a soft copy and hard copy for backup. The research study will be conducted without any pride or prejudice.

I hope my application will receive your endorsement.

Yours in education

APPENDIX F- LEARNER CONSENT LETTER

UNIVERSITY OF THE WESTERN CAPE

FACULTY OF EDUCATION

The consent form for learner

Note well: **This consent form should be kept in a secure place by the participant and the school principal**

I…………………………….. , a learner at Aseyori College of Education in 100 level hereby, give permission for the researcher who is a postgraduate student at the University of the Western Cape, South Africa to conduct a research study where I will be a participant. My participation is personal, voluntary and will not influence my results at school.

Signature …………………… date…………………………

APPENDIX G: Work Plan

S/N	Activity	Timeframe
1	PhD Registration	April 2015
2	Introduction of research proposal	May 2015
3	Final submission of research proposal	June 2015
4	Development of instruments, clearance letters, and ethical considerations	July 2015
5	Distribution and collection of survey questionnaire	Sept 2015

6	Intervention and data collection	Oct 2015-March 2016
7	Data analysis	April-June 2016
8	Report writing	July-Dec 2016
9	Submission of final draft	Jan 2017

APPENDIX G: Classroom Activity

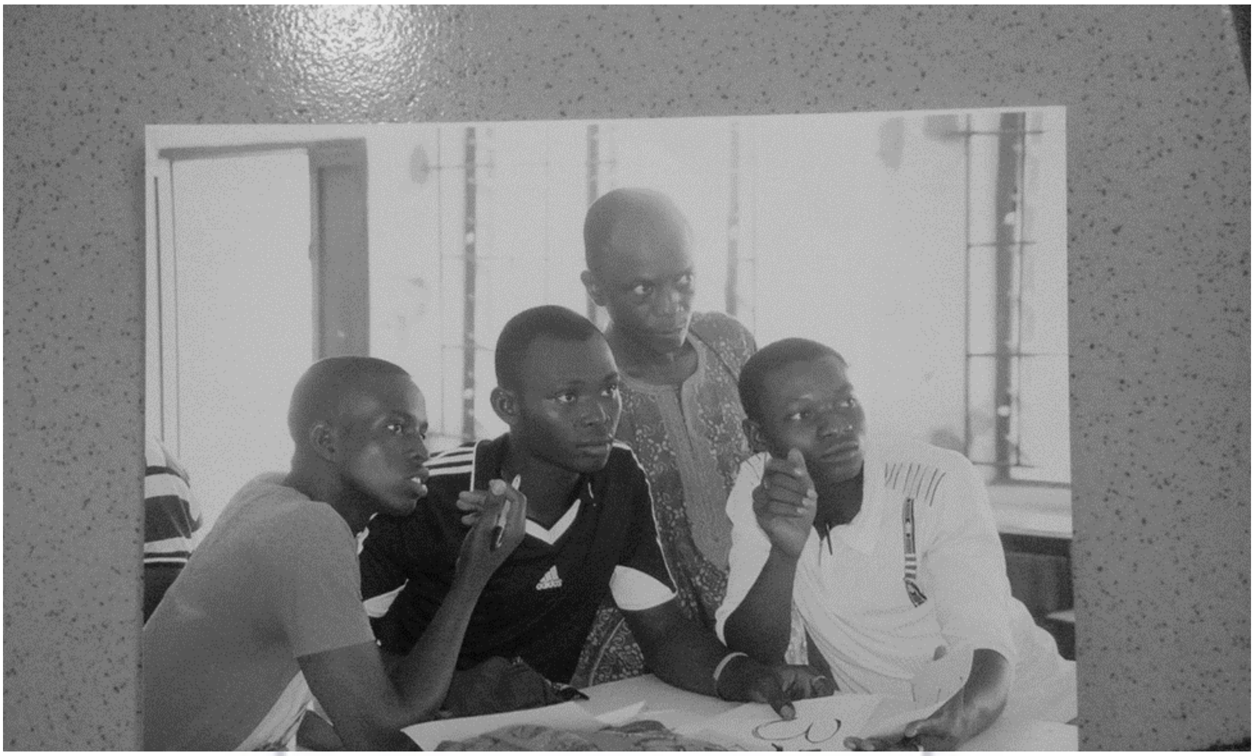
Here the teacher is starting the lecture with a brief introduction. At the beginning of every lesson in peer instruction the teacher should make a short introduction of the topic to be discussed before posting any ConcepTest.

A ConcepTest is posted while the teacher waits for a two minutes of critical thinking before students raise their individual answer. The procedure of the PI is that the teacher posts a ConcepTest and wait for about two minutes for the students to critically think about the possible answer before raising flashcards for the correct answer.

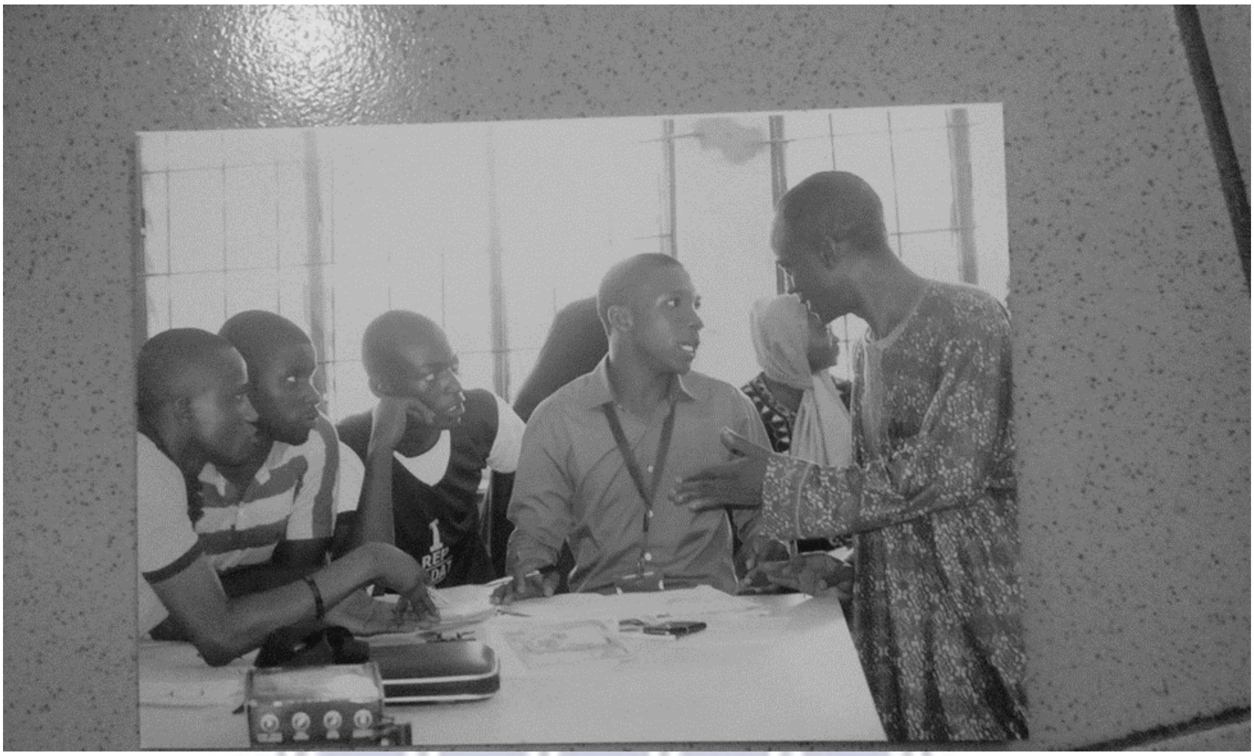
The students are seen here raising up the flashcards in response to the ConceptesT posted by the teacher. The uniqueness of peer instruction is what the students are doing here. The flashcards represent the answer choose by the students.

Students are responding to another ConcepTest during the peer instruction intervention in electromagnetism class. A ConceptesT is not allowed to test too many concepts. In a period of lesson 3-5 ConcepTests may be used.

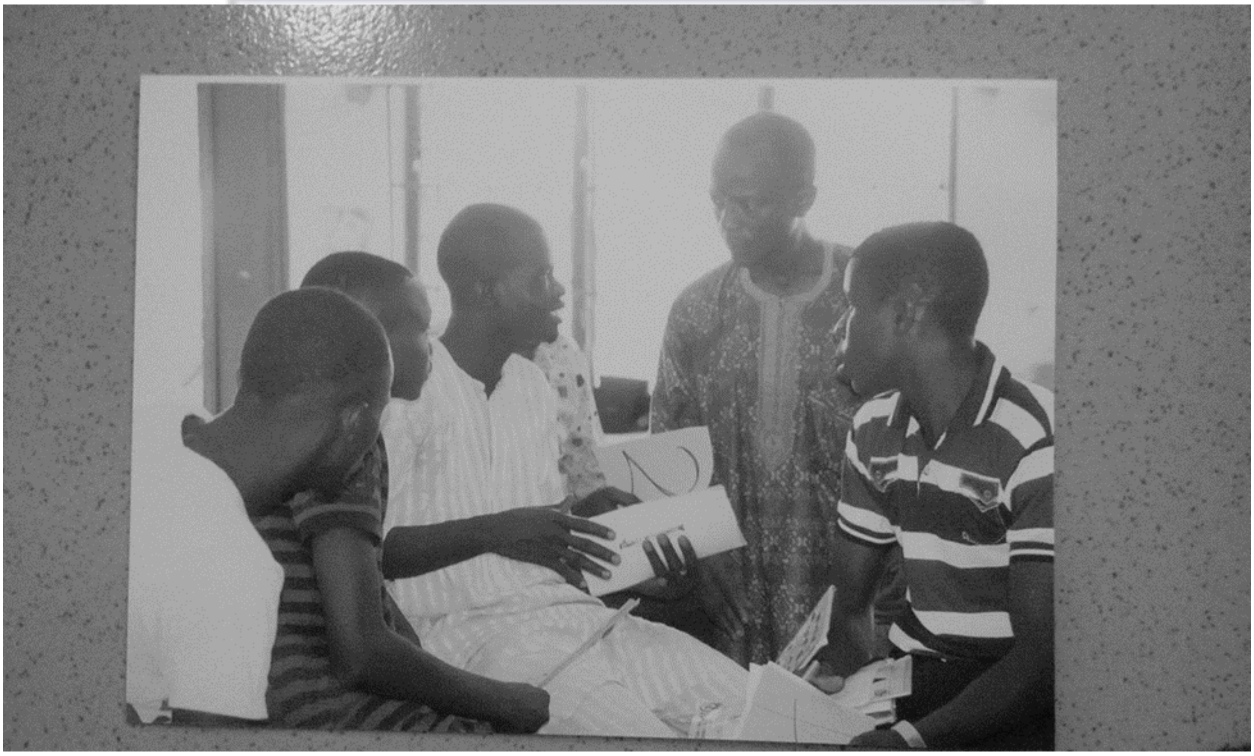
The students are seen here discussing in groups. The kernel of peer instruction is the students forming a collaborative group. The students had time to collaborate on a learning task. What is seen here is not a division of labour because the students are discussing the same issue trying to solve the same problem. What is seen here is authentic learning because the students learned by themselves and are not restricted to a particular resource but have multiple perspectiveson the learning.



Students in a group discussion are discussing as the teacher listens. In the peer instruction, students are not completely left alone without monitoring. The teacher always moves around the class to hear what the group discussed. This process serves as a feedback to the teacher. By the end of the group discussion, the teacher would have had enough feedback to address the students' conceptions.



The teacher listens to students as they discussed and offered assistance where required. What the teacher is doing are coaching and scaffolding. For learning to be authentic, the teacher must not be a provider of information but coach and scaffolds.



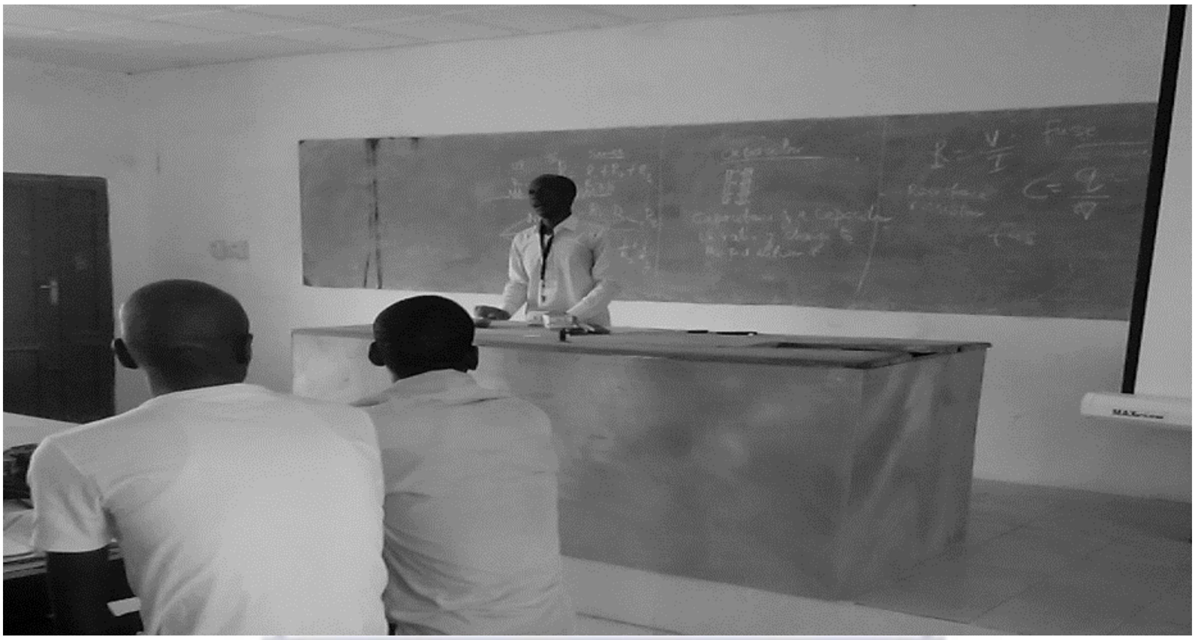
The teacher here listens to a group member articulating his knowledge while another member listens. Articulation is an essential element of authentic learning. The seen here indicates that peer instruction supports authentic learning.

The students discuss among themselves during the peer instruction intervention. Scaffolding is not limited to the teacher alone during learning: more knowledgeable student can help his or her peer out of a problem. Here there is scaffolding among the students while the teacher listens.

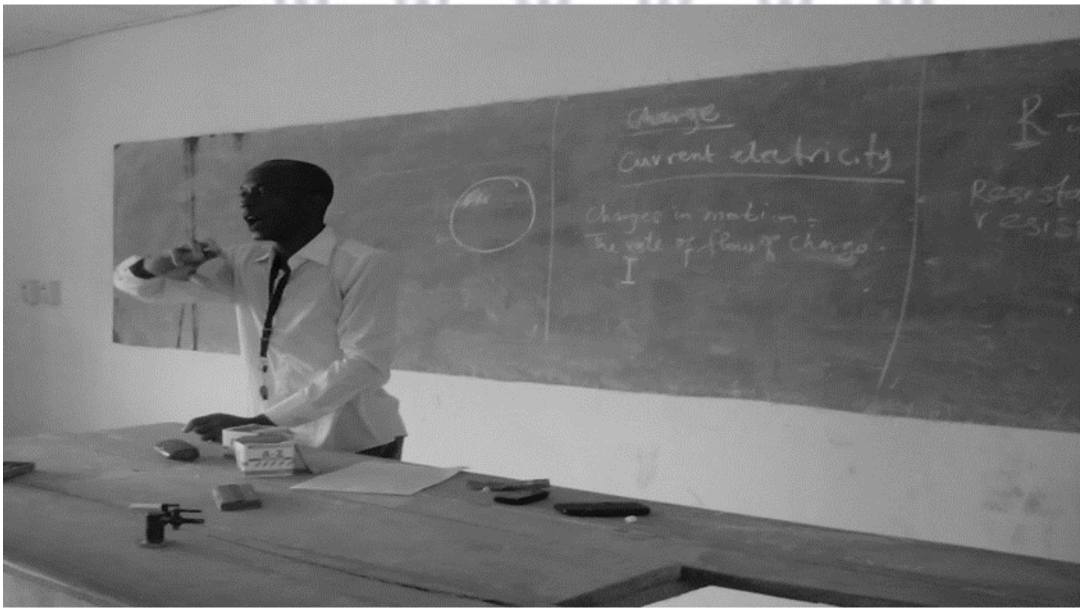
Here a female student is defending an argument in a group. One of the new knowledge added to the peer instruction is the dialogical argumentation. The constructive controversy theory has it that students learn when they are giving a chance to dialogically argue on conflicting views and opinions to reach a compromise among the group.

Another female student is defending her opinion in a group. What is evident here is that no student is passive they are all actively participating in the group discussion. One of the beauties of the peer instruction is that it is an active learning instruction.

A group leader here is defending his group opinion about their conclusion after all the group's discussions. The entire class listens and any member of the class are free to support or against the opinion with reason(s). It is another aspect of articulation that is paramount in authentic learning.



What is seen here is a lecture with the control group where the teacher used the conventional lecture method only to teach the students. The same topics taught in the peer instruction class is also taught in the control group.



The teacher treats current electricity with the control group by explaining to the students some concepts like charge, resistance, and resistor. The teacher is the provider of information here while the students listen passively.

The last day of the intervention the researcher appreciated the research assistants by taken photo with them.

An exclusive photo of the participants and the researcher at the end of the peer instruction intervention.

APPENDIX I

Interview Protocol

Name ____________________________Title ______________ Date_______

Group/ Department ____________________Level ______ Phone_______

Interviewed by____

As you know, there are challenges in the teaching and learning in our colleges of education especially in Physics. Students GPA is gradually dropping as the student moves to a higher level of learning. Many have been pointing to the teacher's method of teaching as one of the leading causes. To seek for a better way of teaching Physics where students will be able to participate in learning process actively, we must do something. It is the reason you are selected as students who had attended the PI classes for the past six weeks for this interview. I am interviewing many of you to find out about your experiences as you interacted with your classmates and the teacher. The goal is to know your opinion about Physics learning through the PI. In other words, I am interested in understanding more about how you learn in the PI class.

The information you provide in this interview will be used to make a plan for a better teaching and learning in Physics class in the future. Our interest is in learning from your experience. The collected comments, experience and suggestions from all of the students interviewed will be summarized and reviewed by Physics education experts.

The interview will take about 60 minutes. The interview will tend to focus on the PI when it is used to teach Physics in different topics of electromagnetism I.

EXPERIENCE OF PHYSICS

To begin, I would like to learn about your beginnings with the Physics.

- What attracted you to the Physics as a course?
- What were your initial excitements and impressions when you first enrolled as a Physics student?

- What has been your challenges in learning as a Physics student?
- What has been your encouragement despite these challenges
- Have you been satisfied with your academic performance in Physics?

EXPERIENCE OF PEER INSTRUCTION

Let me know you experience about the peer instruction in electromagnetism I class.

- Have you heard about peer instruction since you starts schooling?
- If you have heard about it: have you been involved in it?
- Is there any difference between the one you involved before and the just concluded one?
- Tell me your personal experience about the dialogical argument in your group discussion
- How can you compare your learning using textbook and teacher's lecture with your learning during the dialogical argumentation in the PI?
- Tell me what you do when you divides into group during the PI
    - Do you select a teacher among yourselves or you all participate in the discussion?
- How did you personally get the correct answers to the ConcepTests in the PI classes?
- Do you think group leader's presentation is necessary since you have agreed in your group on the right answer?

  IN CONCLUSION
- What are problems you encountered in the PI and your advice?

Thank you for sparing your precious time for this interview.

APPENDIX J: **Peer Instruction Resource Materials for Electromagnetism**

An electron is pushed into an electric field where it acquires a 1-V electrical potential. Suppose instead that two electrons are pushed the same distance into the same electric field. The electrical potential of the two electrons is

1. 0.25 V.
2. 0.5 V.
3. 1 V.
4. 2 V.

5. 4 V.

A solid spherical conductor is given a net nonzero charge. The electrostatic potential of the conductor is

1. largest at the center.
2. largest on the surface.
3. largest somewhere between center and surface.
4. constant throughout the volume.

Consider two isolated spherical conductors each having net charge *Q*.The spheres have radii *a* and *b*,where *b*>*a*.Which sphere has the higher potential?

1. the sphere of radius *a*
2. the sphere of radius *b*
3. They have the same potential.

Consider a simple parallel-plate capacitor whose plates are given equal and opposite charges and are separated by a distance d. Suppose the plates are pulled apart until they are separated by a distance D >d. The electrostatic energy stored in the capacitor is

1. greater than
2. the same as
3. smaller than

A parallel-plate capacitor is attached to a battery that maintains a constant potential difference V between the plates. While the battery is still connected, a glass slab is inserted so as to just fill the space between the plates. The stored energy

1. increases.
2. decreases.
3. remains the same.

Consider two identical resistors wired in series (one behind the other). If there is an electric current through the combination, the current in the second resistor is

1. equal to
2. half
3. smaller than, but not necessarily half the current through the first resistor.

A beam of ultraviolet light is incident on the metal ball of an electroscope. Which statement (s) is/are true?

1. If the electroscope was initially positively charged, it discharges.
2. If the electroscope was initially negatively charged, it discharges.
3. Both of the above.

4. Neither of the above.

A beam of ultraviolet light is incident on the metal ball of an electroscope that is initially uncharged. Does the electroscope acquire a charge?

1. Yes, it acquires a positive charge.
2. Yes, it acquires a negative charge.
3. No, it does not acquire a charge.

Reading Quiz

Which of the following is not true? The electric force

1. decreases with the inverse of the square of the distance between two charged particles.
2. between an electron and a proton is much stronger than the gravitational force between them.
3. between two protons separated by a distance *d* is larger than that between two electrons separated by the same distance *d*.
4. may be either attractive or repulsive.

A material that permits electric charge to move through it is called an

1. insulator.
2. conductor.
3. capacitor.
4. inductor.

When the electric charge on each of two charged particles is doubled, the electric force between them is

1. doubled.
2. quadrupled.
3. the same.
4. none of the above

Which statement is not true?

1. The electric field obeys the principle of superposition.
2. The tangent to an electric field line at a point gives the direction of the field at that point.
3. The density of electric field lines is directly proportional to the strength of the field.
4. Negative charges are sources of electric field lines and positive charge

sinks.

A spherical metal shell carries a uniform positive surface charge. The potential is the same over the surface of the shell. Which statement is correct?

1. The potential is highest at the geometrical center of the shell volume.
2. The potential is lowest at the geometrical center of the shell volume.
3. The potential at the center of the shell volume is the same as on the shell surface.

The amount of energy required to assemble a point charge is called the charge's

1. capacitance.
2. self-energy.
3. field strength.
4. not covered in the reading assignment.

Two identical capacitors are connected first in parallel and then in series. Which combination has the greater capacitance?

1. the pair in parallel
2. the pair in series
3. the two combinations have the same capacitance

Two identical resistors are connected first in series and then in parallel. Which combination has the larger net resistance?

1. the pair in series
2. the pair in parallel
3. The two combinations have the same resistance.

Which is(are) true? The emf of a source of electric potential energy is

1. the amount of electric energy delivered by the source per coulomb of positive charge as this charge passes through the source from the low to the high-potential terminal.
2. equal in magnitude to the potential drop in the external circuit connected between the terminals of the source of emf.
3. both of the above
4. neither of the above
4. joule-heating losses.

A resistor and an initially uncharged capacitor arranged in series are charged by a battery, which is connected at t = 0.The current in the circuit

1. is constant because the emf supplied by the battery is constant.
2. decreases exponentially in time.

3. increases exponentially in time.

4. There is no current because the electrons cannot flow through the gap in the capacitor.

Two current-carrying coils of wire are in close proximity. We can change the mutual inductance of the pair by

1. changing the relative positions of the coils.
2. changing the currents.
3. increasing the number of turns in one of the coils.
4. all of the above.
5. two of the above.

A resistor R and an inductor L are connected in series to a battery, which is switched on at t = 0.The current in the circuit is time-dependent. If we repeat the experiment with a resistor of resistance 5R, the time constant

1. decreases by a factor of 5.
2. increases by a factor of 5.
3. does not change.

In a circuit consisting of a resistor connected to an oscillating source of emf, the current

1. leads the emf.
2. lags behind the emf.
3. is in phase with the emf.
4. the answer depends on the source of emf

A capacitor is connected to an oscillating source of emf. As the frequency of the emf increases, the capacitive reactance

1. increases.
2. decreases.
3. remains the same.
4. depends on the direction of the current.

In a dc circuit (which means the frequency of the source of emf is zero), which circuit element presents the greatest "resistance" to charge flow?

1. capacitor
2. inductor
3. resistor
4. Answer depends on the relative values of *C*, *L*, and *R.*

A capacitor having an initial charge Q and an inductor are connected in series. The energy in the inductor is a maximum when the charge on the capacitor is

1. *Q*.

2. 1⁄2 *Q*.

3. zero.

4. the energy does not depend on the charge

A capacitor having an initial charge *Q* is connected in series with an inductor and a resistor. As a function of time, the charge on the capacitor

1. oscillates sinusoidally.

2. oscillates sinusoidally with exponentially decreasing amplitude.

3. does not vary in time as there is no driving emf.

4. not covered in the reading assignment

In transmitting electricity from a power plant to the consumer, transformers are utilized for which of the following tasks?

1. stepping up the output voltage at the power plant

2. stepping down the voltage just before it reaches the consumer

3. both of the above

4. neither of the above

A capacitor has been charged to a constant potential V. The displacement current between its plates

1. is equal to the current that was required to charge up the capacitor.

2. depends on the Ampèrian surface chosen.

3. is zero.

4. induces a magnetic field.