

**EFFECTS OF PROBLEM-BASED LEARNING ON LEARNERS'  
ACQUISITION OF CORE CRITICAL THINKING SKILLS IN HEATING EFFECT  
OF ELECTRIC CURRENT IN NAKURU COUNTY SECONDARY SCHOOLS,  
KENYA**

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**A thesis submitted to the Graduate School in partial fulfillment for the requirements of  
the Master of Education degree in Science Education of Egerton University**

**EGERTON UNIVERSITY  
NOVEMBER, 2019**

## DECLARATION AND RECOMMENDATIONS

### Declaration

This research thesis is my original work, and has not been presented for award of a degree in any other university.

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## **DEDICATION**

I dedicate this work to my wife Getrine Basweti and, our children Emmanuel Elijah and Gabriel Gideon.

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## ABSTRACT

Physics is recognized today as a fundamental part of both science and society. Knowledge of physics provides solutions to many of the problems that occur in today's world. Deficiency in linking physics knowledge to real-life context of problem-solving by learners is however a major problem in the Kenyan education as evidenced by results in KCSE Physics national examinations. Progressive research recognizes the importance of teaching thinking skills through appropriate methodology as key to developing learners' problem solving ability. The study investigated the effects of PBL instruction on learners' acquisition of core critical thinking skills in physics in Nakuru East and Nakuru west Sub-county secondary schools using Solomon Four non-equivalent Control Group design. A sample of 154 students from four schools obtained through stratified random sampling was used in the study. The students were selected from the population of 1,108 form three physics students in the Sub-counties. Independent variables for the study were PBL mode of instruction and the conventional teaching, while dependent variable were learners' core critical thinking skills in physics. The instrument for data collection was the Core Critical Thinking Skills Physics Achievement Test (CCTSPAT) prepared by the researcher, reviewed by three specialists in physics education from Egerton University and four qualified and experienced physics teachers. Reliability of the CCTSPAT instrument was determined through internal consistency reliability estimation using Cronbach's Coefficient alpha. Two independent samples of thirty form three physics students from two schools of similar characteristics as sample schools were used in a pilot test in which an acceptable Cronbach's  $\alpha$  value of 0.74 was obtained. Data collected was analyzed using both descriptive and inferential statistics. Differences between means of the four groups were analyzed using ANOVA while ANCOVA was used to reduce experimental errors. All hypotheses were tested at  $\alpha$  equal to 0.05 level of significance. The study established that the achievement of analyzing skills by students taught by PBL was higher than that of students taught using conventional methods but not significantly different (ANCOVA results for F was equal to 1.205 at  $df(3,134)$  and  $p < 0.05$ ). The study however found that the achievement of applying skills by students taught by PBL was significantly higher than that of students taught using conventional methods (ANCOVA results for F was equal to 9.287 at  $df(3,135)$  and  $p < 0.05$ ). The study established that PBL may be used as a suitable intervention for developing applying skills in learners in physics in the topic of 'heating effect of electric current' but was inconclusive about developing learners analyzing skills in a similar way. Use of PBL is likely to improve the physics curriculum in Kenya by enhancing its capacity to develop applying skills and perhaps analyzing skills in learners. Students taught using PBL are likely to acquire more analyzing and applying skills in Physics, and better subsequent preparation for problem-solving in real life than those taught using conventional instruction. The study revealed some fundamental skills to be acquired by teachers, critical considerations for effective implementation of PBL instruction in the classroom and guidelines for curriculum developers on PBL integration into the Kenyan physics curriculum. The study recommends that classroom practices in Kenyan schools should be reviewed so as to incorporate instructional approaches such as PBL that promote inquiry and increased learner engagement.

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## LIST OF ABBREVIATIONS AND ACRONYMS

AERA	: American Educational Research Association
ANCOVA	: Analysis of Covariance
ANOVA	: Analysis of Variance
APA	: American psychological association
ASEI	: Activity-Based Student-Centered Experimental work Improvisation
CCTSPAT	: Core Critical Thinking Skills Physics Achievement Test
CEMASTEAM	: Centre for Mathematics Science and Technology Education in Africa
CPDQ	: Cambridge Professional Development Qualifications
CPU	: Central Processing Unit
CT	: Critical Thinking
IC	: Integrated circuit
ICSU	: International Council for Science
ICT	: Information and Communication Technology
KCSE	: Kenya Certificate of Secondary Education
KCPE	: Kenya Certificate of Primary Education
KIE	: Kenya Institute of Education
KICD	: Kenya Institute of Curriculum Development
KNEC	: Kenya National Examinations Council
MOEST	: Ministry of Education Science and Technology
NACOSTI	: National Commission for Science, Technology and Innovation
NCME	: National Council on Measurement in Education
NRC	: National Research Council
NSTA	: National Science Teachers Association
OECD	: Organization for Economic Co-operation and Development
OOSREA	: Organization of Social Sciences Research in East and South Africa
PBL	: Problem-Based Learning
PBLLOC	: Problem-Based Learning Lesson Observation Checklist
PDSI	: Plan Do See Improve
PSSC	: Physical Science Study Committee
SMASE	: Strengthening of Mathematics and Science Education
SMASSE	: Strengthening of Mathematics and Science in Secondary Education

SPSS : Statistical Package for Social Sciences  
SSP : School Science Project  
UNESCO : United Nations Educational Scientific and Cultural Organization



# CHAPTER ONE

## INTRODUCTION

### 1.1 Background Information

Physics is recognized today as a fundamental part of both science and society (Oliveira, 2012; UNESCO, 2005). The universe, human existence, livelihood, economy, security and communication are all understood fundamentally in terms of physics (Sovacool, 2010; Nyakan, 2008). Innovations and discoveries of physicists have had and continue to have profound effect on everyday life and society (Jacobson & Reimann, 2010; Effandi & Zanaton, 2006).

Concepts of physics learned and applied in life are all around us every day. Knowledge of physics provides solutions to many of the problems that occur in today's world (Radido, 2017; Zahoyao, 2002). To solve the problems, adequate and well developed critical thinking skills have also been recognized as essential (Veloo, 2015; Moore, 2009). That is why contemporary thought regarding effectiveness in physics instruction favours instructional methods that are likely to enable learners to acquire critical thinking skills and inquiry so as to enhance their problem-solving ability in everyday life (Okere, 2006; Hmelo-Silver, 2004).

The importance of physics in everyday life is also recognized in communication systems. Information flowing through the internet, radio, TV and the mobile phone involves application of many ideas of physics. Devices such as diodes, transistors and integrated Circuits, commonly found in communication equipments are all manufactured and organized into circuits, using the knowledge of physics (Hall, 2008; Tooley, 1994). Through knowledge of physics, innovations such as the optical fibre, satellite links, radar systems and the internet have been developed and utilized in the realization of great advancements and refinements in modern communication (Hall, 2008). For knowledge of physics to provide a strong foundation for development of communication systems, adequate critical thinking skills are necessary (Jacobson & Riemann, 2010).

Knowledge of physics has been of great benefit to the farming enterprise. Majority of tools and equipments that are often employed in agriculture to enhance production have been developed and polished in performance through physics (Radido, 2017; Wambugu & Changeiywo, 2008). As a result, much food has been made available for humanity leading to

a more healthy population. In the area of human shelter, important practices such as building of homes, fencing of compounds and erecting of enclosure around homesteads employ ideas of physics in a number of ways. Considerations such as tensile strength, stress bearing capacity and thermal properties that enable man to achieve more secure, durable and comfortable shelter are all obtained from knowledge of physics that is anchored on well developed critical thinking skills (Kenya Institute of Education [KIE], 2006).

Physics knowledge has many other applications especially in medicine where it has been exploited in making devices for diagnosing and treating a variety of illness (Wambugu & Changeiywo, 2008; Ministry of Education Science and Technology [MOeST], 2004). X-rays for example are used in detection of defects in the skeletal system and also in diagnosis and treatment of various disorders including cancer, peripheral vascular disease and hepatic interventions. Through the guidance of X-ray Images, interventional radiologists with minimal invasion are able to guide instruments through the body of a patient to areas containing a disease, and this effectively minimizes physical trauma to the sick and recovery time (Oliveira, 2012; Sovacool, 2010).

Knowledge of Physics has made it possible to produce heating devices for both domestic and industrial applications (KIE, 2006, 2009). For Manufacturers to make heating appliances of varied heating intensities and fine temperature regulation, knowledge of heating effect of electric current is essential. Application of heating effect of electric current in production and use of heating appliances has become important today because of environmental friendliness (Lund, 2006). Electricity has been classified by environmentalists as a form of green energy indicating that its use for heating effect among other applications is encouraged and has high likelihood of increasing with time (Hohmeyer & Bohm, 2015). This shows that solid knowledge of the concept of heating effect of electricity is of great relevance to society today.

Benefits of knowledge of physics are sometimes overshadowed by the detriments it causes. One example is the Chernobyl disaster of 26 April 1986 – the nuclear accident that occurred at the Chernobyl Nuclear Power Plant in Ukraine (Walker, 2016; Sovacool, 2010). Following the accident, large quantities of radioactive fuel and core materials were dispersed into the atmosphere leading to many fatalities and severe contamination especially at Belarus (Nechepurenko & Fountain, 2016; Petryna, 2002).



Growing demand for quality and competitiveness especially in industry, medicine, agriculture and communication requires effective use of knowledge of physics in solving problems of society (Sovacool, 2010). The expertise is possible when learners' critical thinking skills are well developed. That is why the teaching of critical thinking skills should be a fundamental part of curriculum that involve methodology that ensure the skills are transferable (Okere, 2006).

Lack of adequate knowledge of physics in students and school leavers has been attributed to many problems facing the world today (Sovacool, 2010; Gorbachev, 1996). The problems include release of radiation into the environment, air and water pollution and reckless waste disposal. Unless knowledge of physics is engaged in solving threats such as global warming, climate change, pollution and nuclear weapons, adequate solutions for these problems may never be found (Nechepurenko & Fountain, 2016). This means that study of physics is of much relevance in today's schools and universities; it should be a fundamental part of the educational system of modern society (Sovacool, 2010; Wambugu & Changeiywo, 2008).

The UNESCO/ICSU World Conference on Science has documented the perennial problems that affect the teaching of physics in schools (UNESCO, 1999). Most important are its abstract nature, lack of visualizable elements and mathematical presentation. These problems are also the reasons why learners often find physics subject matter to be complex and somewhat distant from their everyday life concerns (KIE, 2009; Kiboss, 2002). Unless physics instruction is made congruent and responsive to learners' social, physical and emotional needs, there is a high likelihood that many learners may fail to grasp the relevance of the subject in life and to society.

Clarity of relevance of physics in life to learners is necessary for sustained learner interest and motivation in the subject (Ali & Awan, 2013). Absence of clarity of relevance of the subject may cause learners to shy away from the subject when they encounter difficulties in their studies and pressure in their pursuit of good grades (Nyakan, 2008; Changeiywo, 2001). The persistent poor performance in physics in Kenyan schools may be attributed to this lack of clarity of significance of physics in lives of learners (Kenya National Examinations Council [KNEC], 2010; KIE, 2009). Table 1 shows the national mean scores for physics in Kenya Certificate of Secondary Education (KCSE) between 2009 and 2017.

**Table 1****Mean in KCSE Physics from Year 2009 To 2017**

Year	2009	2010	2011	2012	2013	2014-	2015	2016	2017
Mean score (%)	35.31	38.52	39.74	38.64	40.10	38.84	43.68	39.77	35.05
Grade	D+	D+	D+	D+	C-	D+	C-	D+	D+

Source: KNEC Examination report, (KNEC, 2010, 2013, 2015, 2018)

As shown in Table 1, over the last nine years, all the mean scores for physics in KCSE exams were between 35.0 and 40.0% (equivalent to a grade of D+) except in the year 2015 and 2013. Compared to the maximum aggregate of 100% (equivalent to a grade of A), the means show that progressive performance in secondary physics in Kenyan schools is below average (KNEC, 2010, 2013, 2015, 2018). The performance has been poor and the subject less popular among students as compared to other science subjects (KNEC, 2017). Table 2 shows performance of physics in Nakuru East and Nakuru West Sub-counties over the same period.

**Table 2****Mean Scores for Physics in KCSE from Year 2008 To 2017 in Nakuru Sub-Counties**

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Nakuru Municipality	4.26	4.26	4.21	4.10	4.21	4.42	4.61	4.17	4.21
Molo	4.21	4.20	4.18	4.25	4.17	4.34	4.51	4.06	4.19
Njoro	3.86	4.06	4.11	4.10	4.31	4.22	4.31	4.02	4.31
Nakuru North	3.96	4.16	4.13	4.15	4.31	4.22	4.31	4.07	4.11
Mean Grade	D+	D+	D+	D+	D+	D+	C-	D+	D+

SOURCE: Ministry of Education (Nakuru Education Day), 2018

As shown in Table 2, almost all the mean scores aggregates were below 4.5 (equivalent to a grade of D+) out of the maximum aggregate of 12 (equivalent to a grade of A). The grades show that progressive performance in physics in Naivasha, Molo, Njoro and Nakuru Municipality (Nakuru East and Nakuru West) Sub-counties, is similar to the national means for physics over the same period.

Although there are many causes that have been advanced to explain the poor performance in physics, the quality of instruction remains the central theme in most of them (CEMASTE, 2004, 2017; KIE; 2009). The Kenya Institute of Education has described clearly the situation in Kenyan education; it vividly indicates that the 8-4-4 curriculum is visibly deficient on aspects related to innovation and technology due to lack of expertise in physics, a problem that has often been attributed to inadequate development of learners' critical thinking (CT) skills (Okere 2006; Hmelo-Silver, 2004). It is therefore important that physics instruction is improved so as to provide adequate development of thinking skills especially the core critical thinking skills in learners.

Core critical thinking skills refer to the range of critical thinking skills that contribute most towards problem solving. A number of critical thinking skills have been recognized in the study as core in the learning of physics. These include analyzing, synthesizing, evaluating, applying, generating idea and solving problems (Okere, 2006; Valentino, 2000). For secondary school learners, analyzing and applying skills are the most applied critical thinking skills in the learning of physics and their reinforcement is easy to attain in a physics lesson (CEMASTE, 2017; KIE, 2006).

Analyzing Skills refers to the ability of a learner to separate a complex idea into its constituent parts. The skills are manifested through communication of understanding of the organization and relationship between parts of a complex idea or design (Moore, 2009; Okere, 2006). Analyzing skills may be recognized in situations where learners express awareness of logical fallacies in reasoning, relationships between elements and, through comparison and contrast of alternatives in procedures (Srivastava & Kumari, 2005; Rani, 2004).

Applying Skills on the other hand as used in the study shall refer to the range of skills that demonstrate ability of the learner to use information and ideas in novel situations. The skills are manifested when learners apply concepts and principles to new situations (Rae & Reddy; 2003). They include ability to solve problems, construct charts and graphs, and demonstrate correct usage of a method or procedure (Hmelo-Silver, 2004).

Sufficient attention on development of core CT skills is a requirement in the teaching and learning of science especially physics. Without this, physics education may not be able to

achieve its avowed aim of developing learner's problem solving ability (Moore, 2009; KIE, 2009). Many learners in Kenya secondary schools often find the problems they encounter in physics lessons and in their everyday life too difficult to solve even when they fall within the scope of what they have learned. That is why, it is important to focus instruction on development of core CT skills. Nevertheless, in many of the physics instructional programmes, only casual attention on development of critical thinking skills is present.

Much attention has been drawn to Problem-Based learning (PBL) pedagogy, indicating how it is likely to achieve development of critical thinking skills and problem solving ability in learners at any levels of learning (CEMASTEА, 2017; Gerace & Beatty, 2005). In many contexts where PBL has been applied, it has affected learners positively; it has enhanced students' problem-solving skills, increased their motivation to reflect on learning and also enhanced their self-directed learning skills (Barrett & Moore, 2010). Other key benefits of PBL cited in research literature include fostering critical thinking, conceptual understanding and intrinsic motivation towards becoming self-directed learners (Sungur & Tekkaya, 2006; Hmelo-Silver, 2004).

PBL has been instrumental in enabling medical students at McMaster University and other medical schools to attain robust development of critical thinking skills (Chin & Chia, 2005; Barrows & Tamblyn, 1980). Consideration of its theoretical bases reveals that PBL pedagogy may be helpful to learners at secondary school level as well; it has potential to realize measurable and predictable achievement in development of their core CT skills (CEMASTEА, 2017; Sungur & Tekkaya, 2006). Since PBL has been helpful in enhancing learners' thinking skills in other fields of study, there is a high likelihood that it can be used to enhance learners' Core CT skills in Physics in Kenya especially in Nakuru East and Nakuru West Sub-County so as to improve their performance.

## **1.2 Statement of the Problem**

Learner's deficiency in linking instruction in Physics to real life context of problem solving is a persistent challenge to teachers in Kenyan schools. For many learners, concepts of physics learned in class and applied in real life situations such as heating effect of electric current are difficult to understand and effectively apply in problem solving. Majority of secondary school physics students in the 8-4-4 curriculum often lack adequate problem-solving ability

due to inadequate development of their critical thinking skills. Progressive Research findings have shown that development of critical thinking skills and problem solving ability in medical students and those in other professional fields of study is achievable through Problem-Based Learning (PBL) mode of instruction. Deficiency of research finding that shows the effect of PBL on acquisition of core CT skills among learners of physics at secondary school perhaps indicates the rarity of relevant studies on the subject. A study on the effects of PBL on learners' core CT skills in secondary physics was therefore considered important especially in Nakuru East and Nakuru West Sub-county schools where performance of physics has been poor, a problem that has often been linked to inadequate development of learners CT.

### **1.3 Purpose of the Study**

The purpose of the study was to investigate the effects of PBL instruction on learners' acquisition of analyzing and applying CT skills in physics in Nakuru County Secondary Schools, Kenya. The skills are recognized in the study as core CT in the teaching and learning of physics. Comparison between achievement of analyzing and applying skills in learners taught using PBL and those taught using Conventional instruction was done so as to establish the comparative effect of PBL.

### **1.4 Research Objectives**

The study was guided by the following objectives:

- i. To compare the acquisition of analyzing skills in the topic of heating effect of electric current by learners taught using PBL and those taught using conventional instruction
- ii. To compare the acquisition of applying skills in the topic of heating effect of electric current by learners taught using PBL and those taught using conventional instruction

### **1.5 Research Hypotheses**

Ho<sub>1</sub> There is no statistically significant difference in learners' achievement of analyzing skills in the topic of heating effect of electric current between those

that were taught using PBL and those that were taught using conventional instruction only.

H<sub>02</sub> There is no statistically significant difference in learners' achievement of applying skills in the topic of heating effect of electric current between those that were taught using PBL and those that are taught using conventional instruction only

## **1.6 Significance of the Study**

Findings of the study are expected to provide information on effects of PBL instruction on secondary school learners' core critical thinking skills in physics. The findings are likely to show how integrating PBL pedagogy with traditional instruction at high school could enhance learners' acquisition of core critical thinking skills and problem-solving ability. For physics teachers, this is likely to become suitable reference when planning to use PBL instructional method in teaching the subject. The findings are also likely to reveal to those involved in curriculum improvement how integrating PBL into the local curriculum would benefit development of learners' core CT skills in physics and their subsequent preparation for problem-solving in real life.

## **1.7 Scope of the Study**

The study was focused on Critical Thinking Skills, a group of science skills that correspond to the cognitive processes that involve skillful conceptualization of information as a means of regulating beliefs and actions through reflective judgment. A number of critical thinking skills have been recognized in the study as core in the learning of physics. These include analyzing, synthesizing, evaluating, applying, generating idea and solving problems (CEMASTE, 2015; Valentino, 2000). The study however focused on analyzing and applying skills only because they were the most applied critical thinking skills in the learning of physics at secondary school and their reinforcement was easy to attain in a physics lesson (Moore, 2009; KIE, 2006).

Only the topic of "Heating Effect of Electric Current" was covered, the 27th topic in the revised KIE syllabus for secondary school physics (KIE, 2006). The topic is taught in form three and has been rated as difficult to 76% of the students in the SMASSE baseline survey

(CEMASTEVA, 1998, 2004). The topic is widely applied in everyday life and has many opportunities for enhancing developing of CT skills in learners. The study was confined to form three students in mixed day secondary schools in Nakuru County, Kenya and involved an intervention that lasted for only three weeks.

### **1.8 Assumptions of the Study**

This study was carried out on the basis of the following assumptions:

- i. Teachers in the sample schools had similar competence with regard to subject matter and pedagogy so as to allow the intervention to be the only agent for change during instruction.
- ii. Most of physics instruction in secondary schools involved instructional methods such as lecture, class discussion, teacher demonstrations and class experiments. Conventional instruction in the control groups was therefore more or less the same.

### **1.9 Limitations of the Study**

The study experienced a number of limitations among which we have the following:

- i. In terms of scope, the study is only focused on form three students in secondary schools in Nakuru East and Nakuru West Sub-counties. This means that its findings may only be generalized to form three students but not to other forms.
- ii. It is possible to find that other instructional methods such as regular students' personal self-study have influenced students' acquisition of skills of interest alongside the treatments. As a result, learners' achievement of intended critical thinking skills may not be entirely attributed to the underlying treatments. Conclusions that shall arise may therefore be subject to bias which shall be difficult to detect and correct.
- iii. The duration of intervention was limited to three weeks. This was determined by the length of the topic and time allocated according to the KICD syllabus. The long term effect of the intervention may not be established over such a short period.

## 1.10 Definition of Operational Terms

**Achievement:** An achievement is something that has been accomplished, especially by hard work, ability or heroism (Macmillan English dictionary, 2002). The term may also be used to refer to the measure of attainment of an attribute as expressed by numerical value. Achievement is therefore an indicator of acquisition of an attribute. In this study achievement refers to the score of a learner in the CCTSPAT instrument.

**Acquisition:** Acquisition is the learning or developing of a skill, habit or quality (Simpson & Weiner, 2010). The term may also be used to refer to the state of having attained an attribute as indicated by a measurable characteristic such as achievement. In this study acquisition refers to the level of achievement of a given skills as indicated by the CCTSPAT score.

**Analyzing skills:** These are thinking skills that are characterized by keen attention that seeks to clarify information by examining its parts and relationships (Srivastava & Kumari, 2005). In his study analyzing skills refers to learners' ability to categorize pieces of information or state relationships between them as indicated by a score on items testing the skills on the CCTSPAT instrument.

**Applying skills:** These are thinking skills that are characterized by the ability to use knowledge, ideas and physical laws to obtain adequate solutions to Physical problems (Rani, 2004). In his study applying skills shall be indicated by learners' score on items testing the ability to solve numerical and statement problems correctly on the CCTSPAT test.

**Conventional Instruction:** The commonly applied instructional methods in teaching (MoEST, 2014). In the study it shall refer to instruction delivered through lecture, class discussion, teacher demonstrations and class experiments.

**Core critical thinking skills:** These are Critical thinking skills that contribute most towards problem solving. The skills are the most applied in the learning of physics at secondary school and their reinforcement is easy to attain in a physics lesson (Srivastava & Kumari, 2005). In this study, core thinking skills refer to analyzing and applying skills.

**Critical thinking skills:** Critical thinking (CT) has been described as the "reasonable reflective thinking focused on deciding what to believe or do (Ennis, 2003). In this study, the term shall be used to refer to skillful conceptualization of information as the means of regulating beliefs, decisions and actions through reflective judgment



**Effects:** A change that is a result or consequence of an action (Macmillan English dictionary, 2002). In the study the term is used to refer to measurable changes that occur in a learner as a result of instruction.

**Established secondary school:** This refers to any school that offers a regular academic curriculum to learners at all levels of secondary school, support a complete secondary curriculum and is regulated by the national education policies (MoEST, 2014). In the study the term refers to a school that supports a complete curriculum for secondary school learners, offers examinations for certification and is has been operational for at least four years.

**Problem solving:** Mayer (Mayer, 1990) has defined the term as the summary of the cognitive processes focused at the change of a given state to the final state or result using the available instruments. The term also refers to the process of examining a perplexing or difficult situation for the purpose of generating a solution. In this study problem solving shall be indicated by a learners' visual or verbal communication in pursuit of a solution to a problem

**Problem-Based Learning:** An inquiry based instructional approach in which students learn through facilitated problem solving, working together in small groups to solve ill-structured problems that encompass authentic discipline-based content (Barrows & Tamblyn, 1980). In this study, PBL refers to instruction that is facilitated by a teacher and is characterized by students working together in small groups of about five members to solve a real life problem that forms the basis for learning new knowledge as part of problem solving.

**Problem-solving ability:** Ability to obtain solutions to broad range of problems types including novel ones (Barrows, 1996). In this study problem solving ability shall be indicated by learners' score in a test involving a wide range of CT skills.

**Public School:** A school that provides education to the public and is managed by a governmental agency (MoEST, 2014). In the study the term is used to refer to all schools that are managed by the government of Kenya.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

This section deals with literature review. Starting with a global perspective of science education, the section also covers historic development of science education and curriculum in Kenya, physics instructional methods, and performance of physics in Kenya. Attention has been given to the way physics is taught in Kenya with special reference to the importance of science process skills and critical thinking skills in physics instruction. Also covered here is Problem-Based Learning (PBL) pedagogy, its effects in other fields of study and theories influencing practice of PBL instruction. The theoretical and conceptual frameworks that shall guide the study are also discussed here.

#### **2.2 Evolution of Science Education a Worldwide Perspective**

School science instruction has been a continuous process of change in almost all societies. In England as an example, science education evolved to emphasize science facts before the 1960s (David, 2007). This led to classroom instruction that encouraged rote learning with little attention given to acquisition and development of higher order thinking skills in learners'. Introduction of the Nuffield Science in the 1960s brought into the fore the teaching of balanced science based on science process other than facts (Doris & Dillon, 2012). The process of change in science education in England however has been characterized by shifting pedagogic perspectives to the extent that older views of science such as an empiricism and inductivist have been replaced by newer ones such as constructivism.

In the Soviet Union, science education lagged behind that of their more developed European counterparts due to lack of adequate commitment to enhance science in schools (Chamberlin, 2014). This pushed the society into relative economic backwardness until they came to recognize that development of science was the remedy for the mess. To liberate their society from the prevailing human economic and social inadequacy, a resolve within the Russia government to popularize science was made. Consequently, Science was placed at extraordinary high value, popularized through magazines, popular newspapers and mass periodicals (Romanenchuk, 2006,) The Soviets made science available to the broad masses

and as a result was able to develop scientists that earned the reputation of being among the best experts in the world during the soviet period.

The First World however brought a challenge to the Russian perspective about science. The disaster and its absurdity made the post war public to doubt their optimistic worldview of science (Keane, 2008). The war came to be perceived as a crisis that was aggravated by advancement of science and technology. Mobilization of science for war time use was therefore considered irrational and unprofitable to the Soviets (Bailes, 2015). Nevertheless, the prestige of science continued to rise in the post war years with the orientation of science inclined towards producing useful knowledge.

Development of Russian science and the underlying Soviet science educational model exerted strong international influence on countries of Eastern Europe as well as China. Specifically, the Chinese chose to establish their pursuit of science exclusively in the Soviet model of science. This influence was aggravated further by the Russian successful launch of the Sputnik I satellite in 1957 (Rudolph, 2005c). Through the Sputnik incident, European nations and the US were brought to awareness of the inadequacy of their science education systems and compelled to change their pedagogy and content in both primary and secondary schools to avoid lagging behind.

In America, schools Science was born in the early 19<sup>th</sup> century and has since then been characterized by continuous reform. The reforms have been compelled by demands in the scientific profession and intensified by shifting social, cultural, and political forces in schools and in the public(Rudolph, 2005a). As subject of great utilitarian value and available as factual content in text books, educators came to treat science disciplines as information giving subjects and consequently used transmission instruction pedagogy thus encouraging rote learning (Rudolph 2005b ; Slotten, 1991).

Laboratory teaching came as part of professionalization of science in the United States inspired by young scientists returning home from German after studies abroad ((Hoffman, 2011; Higham, 1979). The change came as part of a wide range of reforms in the American school science brought about by interested stakeholders including college admission boards, educational committees and conference reports. Further reforms came as influence from the success in Soviet Union's Sputnik I satellite launching (Glaze & Goldston, 2015; Renner,

1972). The event generated public concern over the adequacy of US curriculum and galvanized support for curriculum revision by raising pertinent security concerns.

A crisis atmosphere was generated by the Sputnik incident that led to formation of many curriculum development projects directed by scientists from top research universities across the country (Clowse, 1981). A common theme among the projects was promotion of scientific inquiry as the process through which scientists acquired knowledge about the world (Urban, 2010; Rudolph, 2005c). Through a Physical science syllabus assembled to reform high school science curriculum, the Physical Science Study Committee (PSSC) project promoted practical oriented teaching in science and use of inquiry method in teaching so as to promote development of higher order thinking skill in the learning process (Rigden, 2006).

In developing countries especially those in Africa, Science education in a formal context largely shadowed practices in their ex-colonial powers - the industrialized European countries. Most of their curricula were borrowed (Little, 1990), with minimal attention to local conditions. It is observed that many British ex-colonies across the world only modified General Certificate of Education examinations (G.C.E.) slightly for their secondary schools in the 1960s. Exams were assessed by overseas examining bodies in an arrangement that unfortunately made science a relatively more difficult subject to pass.

In the 1970s, science education development projects shifted from borrowing curricula to adoption. The curricula were generally adopted from the Nuffield, PSSC, CHEM Study and BSCS among others projects in the developed world. It was however realized that adopted curricula were inadequate for instruction most of the time. As a result, curriculum project shifted to adaptation approach (Lewin, 1992). This involved accepting only what was thought to be good practice in industrialized countries in local curricula. One example is the Scottish Integrated Science developed in Scotland in the 1960s that formed the basis for many junior science programmes in countries in West and Southern Africa (Chisman & Wilson, 1989; Wilson, 1975).

From the foregoing discussion, it may be recognized that curricula reforms efforts across the world have progressively shifted from teacher centered pedagogy to more learner centered instruction. Attention has become increasingly focused on promotion of learner centered instructional methods such as inquiry for them to acquire scientific knowledge about the

world and also develop ability to apply the knowledge. Besides use of acquired knowledge, effective problem solving also requires application of adequate and well developed CT in learners. A casual attention to learners' acquisition of critical thinking skills may does not develop CT skills adequately; deliberate effort should be made to facilitate the acquisition of the skills by learners during instruction.

### **2.3 Science Education Curriculum in Kenya**

In Kenya, formal education began way before independence with a science curriculum comprising of a general science syllabus. Instruction was mainly teacher-centered (Koech, 1999) and consisted of scientific facts that learners would reproduce when taking examinations (Kamunge, 1988). Though intended to prepare learners for employment and also for further education in academic fields, the curriculum generally lacked keen attention on the subject of acquisition and development of learners' higher order thinking skill. Due to racial segregation and failure to respond to local needs, the form of education offered was resisted by Africans (Gachathi, 1976) and finally progressively reviewed so as to accommodate some of the needs that were previously ignored.

Through Gachathi review two independent curricula in Kenyan Science education were introduced; a Physical science syllabus adopted from the Physical Science Study Committee (PSSC) project previously followed in the USA in the 1950s and the School Science Project (SSP) adopted from the Nuffield Science Project of the UK (Ministry of Education, 1988; Bessey, 1972). The two curricula were practical oriented and appropriate for promotion of scientific inquiry and development of higher order thinking skill in the life of learners. Many schools were however unable to adopt these curricula effectively due to some inherent internal weakness.

For learners to understand the significance of ideas and appreciate their subtle distinctions, the PSSC curriculum engaged both teacher and learner in intensive thought processes during learning (Rigden, 2006). Teachers were pushed by the curriculum with intense preparation and students engaged in experiments that were not well structured in series of well described steps. As a result, both teachers and students perceived the curriculum as difficult which led many schools to decline its adoption.

On the other hand, the SSP syllabus by virtue of being project-oriented became too expensive for schools in terms of materials requirements (OECH, 1982). Even in schools that were adequately equipped for SSP science, the input required from learners and their teachers was scarcely met due to lack of proper interpretation of the curriculum (Kay, 1975). Due to these limitations, a pure science syllabus was introduced for well equipped schools in the 1970s (Okere, 1996).

The three science syllabi were offered concurrently for some time but with fairly minimal success in science education due to their internal weaknesses and rapid changes in the society (Eshiwani, 1993; Gachathi, 1976). SSP required students to be guided by their teachers in investigations and this was unfulfilled for many schools (Lillis, 1981). Many science teachers failed to interpret the curriculum correctly and as a result were not able to guide the students as required (Oech, 1982; Page-Jones, 1978). Due to the overwhelming challenge the SSP curriculum presented to learners and the high cost incurred in its running (Republic of Kenya, 1981), it was phased out in 1984 as the 8-4-4 system of education came into existence (Kamunge, 1988; Okere, 1996).

With the introduction of the 8-4-4 system, a new science curriculum consisting of physical sciences and pure sciences was introduced, a curriculum that was broad-based and practical oriented with much emphasis on technical skills (Kamunge, 1988; Ministry of Education, 1988). Following a mid-term survey by KIE in 1999, it was recognized that the curriculum was short of addressing some emerging issues such as industrialization and environmental education that were of much relevance to contemporary Kenyan society (KIE, 2006).

The curriculum was overloaded with subject matter with some content well beyond the learners' scope of experiences (Koech, 1999). Also noted was the problem where some objectives were found unrealistic and not easily achievable within the given time. Due to these shortcomings, a system-wide review was done in 2001 and subsequently, the physical science curriculum was phased out leaving only the pure science curriculum to date (MOeST, 2004).

#### **2.4 Physics Education and the Teaching of Physics in Kenya**

Physics instruction in Kenya has continually been guided by the general objectives of teaching the subject - objectives that are derived from the national goals of education. The

content of physics lessons is usually devised and geared towards enabling a learner acquire knowledge, skills, and attitudes that should lead to development of the individual and the nation (KIE, 2006). This ideal is expected to be fulfilled when physics lessons enable learners to acquire certain desirable behavioral changes that would lead to achievement of the specific objectives of teaching physics. Since specific objectives of physics are derived from the general objectives of teaching physics in Kenya, achievement of the former promotes the attainment of the latter and consequently enhances the realization of the national aims of education in Kenya (KIE, 2009; Wambugu & Changeiywo, 2008).

The teaching of physics in Kenya is first of all intended to promote scientific knowledge about the physical world among the Kenyan citizenry. This means that the number of people studying Physics should be relatively large and there should be an adequate qualified number of teachers of physics (Okere, 2006). Unfortunately, there are only a few people studying physics beyond high school. For this reason, the level of physics literacy in the Kenyan public is below expectation. As a result, cultural influence and religious beliefs form a significant part of Kenyans understanding of the physical world (KIE, 2006).

Another reason for teaching physics in Kenyan schools has been to sharpen logical thinking skills among the youth and promotion of scientific attitude in the Kenyan Public (KIE, 2009). Unfortunately, scientific investigations and practical work have been very little in schools (Okere, 2006). This is partly due to the large number of teachers who are never prepared adequately to implement the curriculum (Wambugu & Changeiywo, 2008;). At the same time, majority of schools are inadequately equipped for practical work (KIE, 2006). Unless learners are adequately exposed to scientific knowledge and practical work, cultural practices are likely to continue to prevail against the scientific method.

Technological development has also been among the aims of teaching physics in Kenyan schools (KIE, 2009). Unfortunately, little progress has been made in this direction due to lack of exposure. As a result, many problems such as crime, insecurity, climate change and waste management have lacked lasting solution due to inadequate knowledge of physics and the allied sciences (Kiboss, 2002). For the Kenyan curriculum to address vital issues affecting the country today, it is necessary to find better ways of teaching physics and other sciences. Instruction should be able to prepare learners for further education, address vital issues like technological development and lead to mastery of basic skills that are relevant in the

everyday life of a learner and in the world of work (Kamunge, 1988). These concerns are the reasons for this study; findings from the study are likely to provide a better way of instruction that may lead to more effective development of thinking skills in learners.

## **2.5 Significance of Science Skills**

Science has evolved in three basic dimensions. The first of these is the Knowledge dimension and comprises the content of science. The other two dimension covers science skills and the science attitudes respectively (Anderson & Krathwohl, 2001). A Science skill refers to any ability that is acquired or developed through training or experience and is fundamental to thinking and operating like a scientist (Friedl, 1995). Science skills have been broadly categorized into three separate groups: Process Skills, Reasoning Skills, and Critical Thinking Skills (Valentino, 2000). The groups correspond to the three distinct types of cognitive processes involved in learning science. Process skills are used to gather information about the world (Anderson & Krathwohl, 2001). Reasoning skills on the other hand enable learners to make sense of the information they gather by fostering an open mind, curiosity, logic, and a data-based approach to understanding of the world. Through critical thinking skills, learners apply the information in new situations and also participate in solving problems (Ennis, 2003; Wade, 1995).

## **2.6 Science Process Skills**

Science process skills are any abilities acquired by an individual by which one is able to collect information about the physical world (CEMASTE, 2014; Srivastava & Kumari, 2005). The skills are the foundation of the scientific methods and these occur in isolation, and also in integrated form in the everyday life of a learner. The skills have different levels of sophistication and complexity, depending on the level of a learner (Anderson & Krathwohl, 2001; Angelo, 1995). At the lower levels of learning, learners spend most of their time in observing and communicating. As they advance in learning, much of the learners' time is spent in using the skills of inference and prediction. Classification and measurement tend to be more evenly practiced across the levels though in different ways and with different levels of sophistication (Valentino, 2000).



## 2.7 Critical Thinking Skills in School Science

Critical thinking (CT) has been described as the “reasonable reflective thinking focused on deciding what to believe or do (Ennis, 2003). It has also been described as “the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (Center for Critical Thinking, 1996; Paul & Scriven, 1987). The term was coined in the 20<sup>th</sup> century and in its exemplary form, is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness (Paul & Elder, 2007).

In this study, Critical thinking shall be viewed as the skillful conceptualization of information as the means of regulating beliefs, decisions and actions through reflective judgment. This position is opposed to the popular perception in many school science instructional contexts in Kenya where students are often viewed as passive receptors of information (KIE; 2009). To facilitate availability of the information to them, extensive use of ICT has become a norm in modern learning institutions leading to information explosion. Due to the massive amount of information available today, students need to "develop and effectively apply critical thinking skills to their academic studies and to the critical choices they may encounter as a result of the information explosion and rapid technological changes" (Oliver & Utermohlen, 1995).

The significance of CT in academics can be recognized from its role in the learning process. Usually, learners begin by constructing in their minds the ideas they find in lesson content and then proceed to apply these in relevant situations in their lives. If teachers are aware of the importance of CT in learning, inclusion of provisions that foster development of CT skills may be more readily adopted as a necessary part of instruction (Scriven & Paul, 1996). Instruction that is embedded with aspects of CT intended to be developed in learners is likely to be more effective in developing the skills than learning that has no clear attention on development of CT.

A number of critical thinking skills have been recognized as core in the teaching of physics at secondary school. These include analyzing, synthesizing, evaluating, applying, generating ideas and solving problems (Valentino, 2000). The meaning and significance of each of skills has been discussed in the sections that follow.

### **2.7.1 Analyzing Skills in School Science**

This refers to the ability of a learner to separate a complex idea into its constituent parts and understanding of the organization and relationship between the parts. In illustrative behavioural terms, a learner should be able to do the following: recognize logical fallacies in reasoning, analyze elements and relationships between elements, compare and contrast alternatives and justify the adoption of certain procedures (Srivastava & Kumari, 2005;). To assess analyzing ability, one can use a test that is structured using action verbs such as the following: point out, differentiate, relate, distinguish, identify, illustrate, infer, outline, select, separate, and sub-divide.

Although much thought and research have been devoted to both Content-based instruction and the teaching of critical thinking skills, little has been done as regards to investigation of the development of analyzing thinking skills of learners in physics. A search of related literature revealed that such investigations have been quite recent and only limited. In Hong Kong, Chapple and Curtis used film as a source of content in language courses. In their study, 31 Cantonese students taking a general education course taught in English were asked to rate their own progress. Although the researchers did not plan to focus their investigation on the development of critical thinking skills, the responses of the students indicated they had made the greatest gains in analytical and critical thinking (Chapple & Curtis, 2000).

Huang's studies on content-based Chinese as a foreign language program focused on classroom language activities that were designed and implemented to serve the dual goals of language development and cultural learning. The study revealed that children expressed obvious evidence on use of certain thinking processes; by thinking and talking about reasons, the children engaged in higher-level cognitive activity. The researcher concluded that the children had gained more opportunities for cognitive development through engaging in various thinking processes in the content-based language program (Huang, 2003a, 2003b). According to Moore (2009), students can learn both content and thinking skills through the experience of solving problems which in view of Hmelo-Silver favours knowledge application (Barrett & Moore, 2011; Hmelo-Silver, 2004)

### **2.7.2 Learners' Synthesizing Skills**

This is the ability of the learner to create mental construction of ideas and concepts from knowledge obtained from multiple sources to form complex ideas into a new integrated and meaningful pattern, subject to given constraints (Srivastava & Kumari, 2005; Sharma, 2003). The skills are expressed for instance when a learner assembles parts of a machine together to form the complete structure. The learner integrates knowledge from several sources to solve a problem and can reverse processes to emphasize meanings or structures. Synthesizing skill is expressed through learners' responses to problems structured using such verbs as categorize, combine, compile, compose, create, organize, devise, design, explain, generate, modify, organize, plan, re-arrange, reconstruct, relate recognize, revise, rewrite, summarize, tell and write (Rani, 2004)

### **2.7.3 Evaluating Skills among Learners**

This is the ability of a learner to make judgments of ideas or methods using external evidences or self selected criteria substantiated by observations or informed rationalization (Rao & Reddy; 2003). It is the making of judgments about the value of ideas or materials; an example is when one attempts to justify a new budget. Evaluating skills can be assessed using test items structured around key verbs such as compare, critique, evaluate and judge, complete, demonstrate, differentiate, appraise, defend, describe, discriminate, explain, interpret, justify, relate, summarize, support (Srivastava & Kumari, 2005).

### **2.7.4 Learners Applying Skills**

Application has been defined as the ability of the learner to use information and ideas in novel situations. In illustrative general terms, it refers to learners' ability to apply concepts and principles to new situations, and also to apply laws and theories to practical situations. The skills also encompass the ability to solve problems, construct charts and graphs, and demonstrate correct usage of a method or procedure (Rao & Reddy; 2003). Application can be assessed using test items with key verbs such as compute, discover, demonstrate, manipulate, modify, operate, predict, prepare, relate, show, solve and use. An exemplary illustration is when a learner is able to apply Newton's third law of motion to calculate the take off speed of a rocket (KIE, 2006).

The CT skills discussed in the foregoing context are only examples to illustrate that the range is broad. Occurrence of the skills depends on the level of learners and the subject matter involved (Anderson & Krathwohl, 2001; Angelo, 1995). This has led to a section of the skills to be recognized as core in the learning of physics (Valentino, 2000). Analyzing and applying skills are recognized as the most applied critical thinking skills in the learning of physics at secondary school and whose reinforcement is easy to attain in a physics lesson (KIE, 2006). For that reason, the study was focused on the two skills.

## **2.8 The 21st Century Skills**

Rapid changes of today's world are redefining the sets of skills that students need to be adequately prepared in, so as to contribute more effectively to today's society (Wilmarth, 2010; Levy & Murnane, 2005). A complex set of skills has been identified and defined, and this encompasses the following: learning and innovation skills; information, media, and technology skills; life and career skills; adaptability; complex communication; social skills; non-routine problem solving; self-management and self-development, and systems thinking (NRC, 2010b ; Windschitl, 2009).

Although it has been argued that the skills have always been recognized as important, the need for them to be possessed by the majority of the population at present demands that the skills should be given priority in today's education system (NRC, 2010a; Bybee 2010a). Science education should therefore aim at practices that are likely to develop these various skills of 21<sup>st</sup> century especially critical thinking, problem solving, and information literacy (NRC, 2010b; Bybee, 2010b). A study on how PBL may contribute towards development of critical thinking skills may therefore be of great significance to science education in this era. Through the study, findings on how PBL may be used to enhance development of critical thinking skills in learners are likely to be obtained; this may mean that science education shall be more equipped to address part of the challenge of developing the 21<sup>st</sup> century skills

## **2.9 Proficiency in Critical Thinking Skills**

Critical thinking skills are a very necessary requirement in modern society whose everyday life is characterized by rapid changes and many alternatives (Awang & Ramly, 2008; Cotton, 1991). Acquisition of the skills enables learners to make complex choices as well as participate more fully in the economic and technological development of the society. As a

fundamental part of education, teachers of physics and other subjects continually seek to teach the skills though often indirectly or implicitly while teaching subject matter (Willingham, 2007; Noddings, 2006; Siegel, 1986).

Whether this approach succeeds is really doubtful as majority of the students never pick the skills (CEMASTE, 2015; KIE, 2009). This has been attributed to a number of causes: lack of clarity as to what constitutes the skills (Noddings, 2004), instruction that is achievable through memorization of facts (KIE, 2006) and programmes that generally undermines effective learning of thinking skills (Paul & Elder, 2008; Gallagher, 1998). The approach does help some students learn the skills to some degree, but in general serves students poorly and is not well matched to the avowed goals of teaching. That is why many educators are becoming increasingly interested in teaching the skills directly and explicitly (Dolhenty, 2008; Gerace & Betty, 2005).

Studies have shown that there is a greater chance of developing students' critical thinking skills when deliberate effort to teach the skills is made (Chapple & Curtis, 2000; Huang's, 2003a). The Way one has learned to think eventually determines in large part the individuals thinking patterns. Considerable research that has been done on the subject of developing thinking skill is now explicit that the teaching of thinking skills should be made explicit in curriculum (McGuinness, 1999; Noddings, 2004). The studies clearly indicate through progressive research finding that proficiency in thinking skills may be better developed through appropriate pedagogic practices.

In PBL pedagogical approach, acquisition of knowledge and skills, thinking process and associated learner behaviour are all driven by the challenge of solving a problem (Tortop & Ozek, 2013). The method requires learners to identify learning gaps (Hmelo-Silver, 2004) and formulate learning issues that facilitate collection of relevant information to solve the problem (Pijl-Zieber, 2006). The context is characterized by cognitive demands that compel a learner to exercise and develop appropriate thinking skills as required in the solution seeking process. By designing problems around specific thinking skills that learners are required to develop, it is possible to enhance proficiency in the specified critical thinking skills. In this study, learners were able to sharpen their analyzing and applying thinking skills through solving authentic or ill structured problems that required them to use the skills.

## **2.10 Physics Instructional Methods and their Effectiveness**

In science instruction, particularly in the teaching of physics, teachers have often adopted a wide range of instructional methods subject to one's discretion. The methods are generally recognized as falling in a continuum that tends to be highly teacher-centered on one extreme and highly student-centered on the other (CEMASTE, 2015; Bennaars, Otiende & Boisvert, 1994).

In a teacher-centered lesson, knowledge is assumed to be owned by the teacher and should be transmitted to the learners. Without the teacher (the source of knowledge), there is little prospect that learners shall acquire the knowledge (CEMASTE, 2004). This however is untrue given that learners may acquire a significant amount of knowledge from their everyday life experience, learners' previous experience being recognized as a major contributor towards the acquisition of new knowledge (Okere, 2006). Studies have established that science students who graduate from education system that are highly centered on didactic pedagogical approaches tend to have strong factual knowledge about science but weak in scientific problem-solving skills (Venthan, 2006). Extreme teacher-centered instruction is therefore generally regarded as a less effective way of teaching science because it fails to equip learner with adequate problem solving skills (CEMASTE, 2016) in the face of ever-growing sophistication of societal needs and problems.

In the learner-centered approach, the role of the teacher is mainly to initiate the learning and guide students through small steps of instructional materials as they step through a learning task (CEMASTE, 2004). The approach is characterized by provisions for Learners to predict, explore and investigate scientific phenomenon as they construct the required knowledge and skills (Willingham, 2007). Modern thinking as regards to effectiveness in physics instruction strongly favour learner-centered approach because it provides greater engagement of learners in the learning process (Okere, 2006). The approach enhances the development of self-directedness in learning, a skill that is recognized as likely to promote life-long learning (Barrett & Moore, 2011; Hmelo-Silver, 2004).

Extreme learner-centered teaching and learning however, has been criticized as less effective. Left on their own, learners fall into many errors that sometimes completely derail them from learning purposes or that may lead to unacceptably too-long-time to achieve learning objectives (Willingham, 2007; Fisher, 2001). Due to the limitations of either extremes of the

teaching approach continuum, it is the consensus of majority of educators that a teacher should adopt a blend of instructional methods that reasonably integrate both approaches to maximize effectiveness in instructional delivery (Noddings, 2008; CEMASTEА, 2004).

### **2.10.1 Class Experiments**

As one of the methods of teaching science that teachers often use, class experiments have been rated as the most effective approach to teaching physics (NSTA, 2007). The method gives learners the opportunity for hands-on activities; students use apparatus to collect data and in the process are able to acquire manipulative skills. For the method to be effective, the teacher is required to perform experiments in advance, ensure that apparatus are in their working order and also avail clear and precise instructions to students (KIE, 2006).

During experiments, teachers are required to maintain order and discipline in the laboratory as well as to ensure that learners are able to follow required procedures in their working. Though effective, the efficacy of this approach may be seriously limited when class sizes are too large. The method may be less effective especially when apparatus are inadequate for all learners and when the time that is available is not enough for length experiments (Willingham, 2007). Nevertheless, the method is in common use and improvisation using locally available materials and use of micro-experiments has been used to enhance its effectiveness alongside equipping teachers with appropriate skills (CEMASTEА, 2005).

### **2.10.2 Class Demonstrations**

A demonstration is an experiment that is performed by the teacher during physics instruction so as to enable learners to observe the phenomenon under study. This is usually occasioned by such factors as inadequate apparatus or when an experiment involves risks that cannot warrant students handling apparatus (CEMASTEА, 2015; Okere, 1996). Through a demonstration, the teacher is able to show learners the procedure involved and with their help collect data and draw conclusions. To achieve greater benefit to learners, it is recommended that the teacher should involve the learners as much as possible in performing the experiment. Where classes are too large, a teacher should divide learners into more manageable group sizes so as to ensure that all learners are able to participate actively (KIE, 2006).

### **2.10.3 Discussion**

A discussion is a conversation intended to achieve some specified goal (CEMASTEА, 2004). In a classroom context, this often takes place in a small group of about five members. For a discussion to be meaningful, teachers are encouraged to specify its objectives, and also to guide and supervise the students. Learners on the other hand are encouraged to exchange ideas freely, ask questions and respond to all proceeding of the discussion responsibly (CEMASTEА, 2015; Okere, 1996).

The supervisory role of the teacher involves maintaining order and ensuring that all participants are given due attention and fair chance to make contributions. The teacher may occasionally interject the discussion process to direct attention towards specific aspects that may need special awareness of learners. As learners exchange ideas, a discussion enhances development of problem solving skills, social skills, and divergent thinking (Venthan, 2006; Okere, 1996). With good supervision, a discussion may enable the teacher to diagnose learners' difficulties and problems, and therefore be in position to provide necessary help. A discussion that is poorly supervised however may give learners a chance to become rowdy and irresponsible, in which case objectives of the lesson may not be achieved (KIE, 2006).

### **2.10.4 Informal Lecture**

Lecture-based instruction refers to the type of teaching where the teacher provides information both orally and visually to students (CEMASTEА, 2004). Graphics organizers enable students to follow through discussions and to build their own understanding of concepts that are learned. The method is particularly helpful when teaching fact-based information. A major criticism against lecture method has mainly been the way it creates passiveness in students; learners are reduced into passive recipients of information with little provision for development of science process skills (Carin & Bass, 2001; Okere, 1996). The method seems to be the most preferent mode of instruction when teaching large classes and when delivering a huge volume of content. Teachers are however encouraged to combine it with other method such as class demonstration and discussions, so as to cushion the limitations it present that inhibits its effectiveness (Willingham, 2007).



### **2.10.5 Project Work**

A project is an instructional method that is characterized by a problem to be solved through an investigation. It entails identification of the problem, design of an investigation, data collection, results analysis and generalization. A project enables learners to achieve objectives in all the domain of learning (CEMASTEА, 2017). In the Current KIE curriculum in Kenya, 18 projects have been suggested for learners in physics (KIE, 2006). To enhance the utility of the projects to learners, it may be helpful if teachers would allocate them enough time in their schemes of work as well as follow up each of the project with intensive discussions on concept, skills and attitudes that may be deemed necessary (CEMASTEА, 2004).

### **2.10.6 Excursion**

An excursion or field trip is a lesson conducted outside the classroom at a place that contains features that are relevant to the concepts to be learned. A physics lesson may take place at a power plant, a factory or at a garage. Though expensive and time consuming, excursion can be very enriching to concepts taught in class, adding to them realism and also enhancing learners' first-hand experience in them (KIE, 2006).

When preparing students for an excursion, it is important for the teacher to ensure that learners have covered relevant topics. The teacher should also make a reconnaissance to sites of interest to ensure that they conform to expectations that are necessary to meet the instructional objects of the trip (CEMASTEА, 2015). If a field trip is not well co-ordinated, it may result to loss of time, wastage of funds and unwarranted interruption of the school programme.

### **2.10.7 E-Learning**

E-learning is the general term used to refer to all forms of electronically supported teaching and learning. In e-learning, instruction may be delivered through the internet, CD-ROM, and the satellite TV among other means. To a large extent, the term describes computer and network enabled transfer of knowledge and skills (Pijl-Zieber, 2006; Kiboss, 2002).

Within the context of physics instruction, computers may be used in three areas: in general administration, in testing and in instruction (Bhatt & Sharma, 2003). A computer can enable a learner to perform self-instruction. The computer presents information in a programmed

format and the students responds by keying in responses. This may take the linear programmed learning format in which subject matter is broken down into a sequence of small steps that logically follow each other or in the form of branching programmed instruction segments (Rao & Reddy, 2003)

Another way a computer may be used for instruction in Physics is through computer simulation. This is particularly helpful when it is not possible to perform educational activities in the classroom for a number of reasons: when learning resources are too expensive, very dangerous, time consuming, unethical or impractical. A computer simulation may be used to demonstrate all functions of interest in a way that gives learners a chance to observe processes, predict events, manipulate variables and observe results through the simulated processes (Bates, 2005).

From the foregoing discussions on instructional methods in physics, it has been revealed that each of the instructional methods presented has unique set of characteristics - some that are desirable and others not. This has lead to a continuing search for better ways of teaching the subject. The advent of PBL was as a result of students' inability to apply knowledge learned to solve problems in real-world situations (Albanese, 2004; Barrows, 1996). Previous studies have shown that PBL developed learners' inquisitiveness (Schmidt, Rotgans & Yew, 2011) and improved their critical thinking skills in chemistry (Awan, Hussain & Anwar, 2017). The current study established that PBL was able to enhance learners' analyzing and applying skills in physics.

### **2.11 Learner Performance in KCSE Physics**

The quality of performance in school physics in Kenyan education is usually indicated by learners' grades in the subject in the national examinations. Reports from the Kenya National Examinations Council however, have progressively shown that the number of students who are unable to do well in Physics exams has continually remained high. Added to this is the element of the large number of school leavers who are unable to apply physics in solving problem they encounter in their everyday life (CEMASTE, 2015; KIE, 2009).

According to the KNEC KCSE examination report (2017), physics has been the least enrolled science and the worst performed of all sciences most of the time since year 2006. The national mean for the subject between year 2006 and year 2017 was well below 50 % (Table

1). As a step towards eliminating the deficiency, much professional development of teachers has been done through SMASSE programmes since year 2004. Nevertheless, the national mean for physics has remained below average (KNEC, 2017) and the achievement of technical skills below curriculum expectation (KIE, 2009).

As the foundation of science and technology, the teaching of physics should be effective; school leavers should be equipped with knowledge and skills as may be considered necessary for them to contribute more effectively towards national development and technological advancement (NSTA, 2006). Instructional methods that are likely to help learners achieve innovativeness, skills development and problem solving ability should be embraced so as to ensure that school leavers are well equipped for the challenges of everyday life and their world of work (KIE, 2006).

Investigation on the effects of PBL on learners' core critical thinking skills in the current study found that learners taught using PBL when compared to those taught using conventional instruction acquired more critical thinking skills. Specifically, in both analyzing and applying skills, PBL learners scored more than those taught using conventional methods. The study therefore established that when learners are taught physics using PBL, they acquire more critical thinking skills and therefore likely to perform better in physics exams.

## **2.12 PBL Pedagogy and its Effects in other Fields**

PBL as is generally known today is an inquiry based instructional approach in which students learn through facilitated problem solving (Barrett & Moore, 2011; King, 1995). Basically, Students work together in small groups (typically of about five members) to solve ill-structured problems that encompass authentic discipline-based content. It was initially formalized for instruction in medical education at McMaster University in 1968 but now is applied to other educational settings around the world (Chin & Chia 2005; Barrows & Tamblyn, 1980).

PBL has continued to expand to lower levels including secondary school contexts because of its well-established promise of increasing problem solving ability of learners at all levels (Belland, French & Ertmer, 2009; Hmelo-Silver, 2004). In many contexts where PBL has been applied, it has affected learners positively; it has enhanced students' problem-solving skills, increased their motivation to reflect on learning and also enhanced their self-directed

learning skills. Other key benefits of PBL sighted in research literature include fostering critical thinking, conceptual understanding and intrinsic motivation towards becoming self-directed learners (Barrett & Moore, 2011; Sungur & Tekkaya, 2006).

In Kenya, poor performance in physics has been most attributed to the quality of physics instruction which does not achieve adequate development of learners' critical thinking skills (CEMASTEPA, 2017; KIE; 2009). As a result, the 8-4-4 curriculum has continually produced school leavers that are visibly deficient on aspects related to innovation and technology due to lack of expertise in physics (Okere 2006; Hmelo-Silver, 2004). The study established that when learners were taught using PBL, they acquired more analyzing and applying skills than those taught using conventional methods effectively reducing their inadequacy in development of critical thinking skills. The learners were therefore likely to improve their performance in physics exams, and thereafter become more innovative in problem solving and active contributors in nation building especially in aspects related to technology.

### **2.13 Theoretical Framework**

The study was based on the constructivist learning theory. Constructivism is the worldview of knowledge that positions learning as a process through which people construct their own knowledge and understanding of reality from experiences (Bimbola & Daniel, 2010). The paradigm holds that learners construct meaning through experiences and interaction between prior knowledge and new events (Akinibola & Afolabi, 2009). In Piaget's view, information from the environment and ideas from the individual interact and result to internalized structures developed by the learner.

Vygotsky (1978) describes learning as a social process of building knowledge and skills. In his theory also known as social constructivism, he argues that knowledge is first constructed in a social context and then appropriated by individuals (Vygotsky, 1978). According to social constructivists, the process of sharing individual perspectives results in learners constructing understanding together that wouldn't be possible alone (Vianna & Stetsenko, 2006). He recognizes a learner's background culture as an important agent that shapes the knowledge and truth that the learner creates in the course of learning.

Bruner's idea of scaffolding learning through social and informational environment (Brunner, 1960) has also helped to shape constructivism. He views learners as individuals

who construct their own knowledge and understanding of the world through experiences they encounter. He emphasizes the importance of making learning active, reflective, collaborative and evolving through activities that enable students to experiment, manipulate objects, ask questions and try things (Akinibola & Afolabi, 1960).

In constructivism, the responsibility of learning rests with the learner (Tobias & Duffy, 2009). The learner is actively engaged in the learning process in order to construct own understanding of the world. The theory positions the teacher as a facilitator of the learning process; facilitation simply meaning providing guidance and creating the conducive environment for the learner to create knowledge. The intention of constructivism is to create a learning environment that supports and challenge learners' thinking so that the learners become effective thinkers (Akinibola & Afolabi, 2009).

Comparisons between learner achievement in constructivist classrooms and conventional classrooms have shown that results in constructivist learning are usually better. A study by Bimbola and Daniel done in Homa-Bay County indicated an improvement in academic performance of students in the constructivist group on pre-test and delayed post-test. The same groups of students retained about 80% of the concepts taught in a delayed post-test compared to their colleagues in conventional lecture group who only retain about 10%.

In Turkey, a meta-analysis was conducted in 10 different provinces and 3 different countries (Turkey, USA, and Korea) involving 28 studies on academic achievement, retention and attitude at secondary school level (Semerci1 & Batdi, 2015). The study established that a constructivist learning approach in a learning environment led to greater academic success than traditional teaching methods in terms of improving learners' academic success, retention and attitude scores. The findings in the above studies therefore indicate that constructivist instructional methods consistently produced better learner achievement.

In the current study, learners were engaged through PBL in solving ill-structured problems that tends to have many possible solutions. This made learning active as required in constructivist and made learners active creators of knowledge. As a result, learners were able to use active learning techniques such as experimentation and real world problem-solving to build new ideas on what they already knew. The learners were therefore able to develop deep

understanding of content learned and capacity to apply the knowledge (Ertmer & Simons, 2006) and hence formulate systematic and well integrated universe of knowledge.

### 2.14 Conceptual Framework

Figure 1 illustrates various variables involved in the study. On the top left hand side are the independent variables namely PBL instruction and Conventional instruction. PBL was offered to learners in experimental groups while conventional instruction was given to learners in control groups. On the right hand side are the dependent variables; the Learners’ core critical thinking skills in terms of analyzing skills and applying skills. Other variables that are of concern in the study are the intervening variables that include Learners’ gender, Teachers’ qualification, learning environment and school culture.

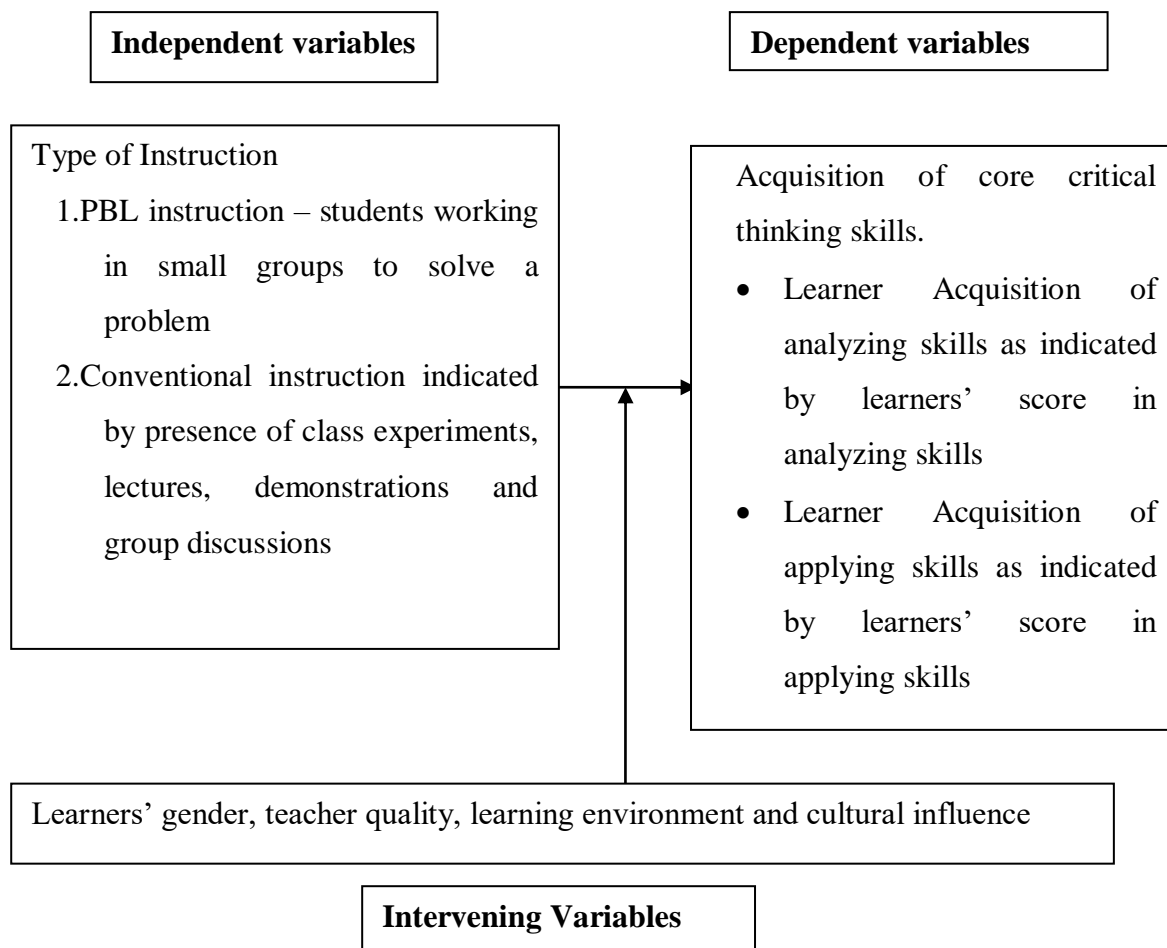


Figure 1: Conceptual framework showing interactions between Independent Variables and Dependent Variables

The interaction between a learner and physics instruction in a learning environment ideally aims at engaging learners’ cognition in construction of knowledge based on new learning

experiences. As shown in Figure 1, in the ideal situation, when a learner is exposed to instruction one is able to pick the knowledge, skills and attitudes that are intended. A learner's score in appropriate test then gives a numerical measure of the level of acquisition of the knowledge, skills and attitudes. The score is a measurable indicator of both the quality of instruction offered to the learner and the learning that has taken place.

If scores obtained from learners of equivalent ability are statistically significantly higher for learners taught using PBL than those from conventional methods, then PBL should be a better mode of instruction than the conventional instruction. Due to the influence of other factors, instructional outcomes may not be entirely attributable to the method of teaching. Factors such as Learners KCPE Marks, learner gender, nature of the learning environment and cultural influences will all contribute to the outcomes of instruction. If the influence of all these other factors is minimized through appropriate controls, then the score obtained should be a significant measure of the quality of the underlying methods of instruction.

To control the effects of learner gender, learners' entry behavior and learning environment, all sample schools were selected from one category namely sub-county mixed day secondary schools. The selection criterion ensured presence of both sexes in each of the samples to minimize any differences that were likely to occur due to gender differences. Sub-county mixed day secondary schools also ensured that learners were more or less equivalent in terms of their entry behavior and academic ability so as to minimize any differences due to learner entry behavior. Generally, schools determine learner entry behavior, staffing, infrastructure and school facilities through the categorization. Schools in same category are meticulously matched in these aspects which effectively minimize differences due to learning environment.

The cultural context of a school bring along cultural influences that affect learning. Learners come to school with prior knowledge acquired variedly from their everyday life experiences. If schools are located in more or less similar cultural contexts, learners have high likelihood of starting learning activities with more or less similar prior knowledge. Variation in acquisition of knowledge due to learner's cultural background would therefore be more or less similar. By arranging to have all sample schools located in the Nakuru municipality (a cosmopolitan social context), the effects of culture on learners' prior knowledge were likely to be same across the sample schools. Learners' acquisition of core CT skills was therefore less likely to vary due to cultural differences.

## **CHAPTER THREE**

### **RESEARCH METHODOLOGY**

#### **3.1 Introduction**

This chapter discusses the methodological aspects of the research. It covers research design, location of the study, population, sampling procedures, and sample size. The chapter includes the instrument used in data collection, its validation, reliability and, the development and implementation of instructional modules. A discussion on data collection and data analysis procedures has also been presented.

#### **3.2 Research Design**

The study was a quasi-experimental pretest-posttest research based on Solomon Four Non-Equivalent Control Group Design. A graphic presentation of the design is shown in Table 3. The method was preferred because of its suitability for investigation of cause effect relationship between variables such as those involved in the study (Mugenda & Mugenda, 2008). The design was particularly appropriate for Kenyan secondary schools given that learners are taught in intact groups and re-arrangement into groups for a study would not be granted by the authorities in host institutions. The unique advantage of the design was its robustness in controlling threats to internal validity; major threats such as maturation and pre-testing were effectively controlled through the selected research design (Fraenkel & Wallen, 2006) as shown in Table 3.



**Table 3****Solomon's Four Non-Equivalent Control Group Design**

Group	Pre-Test	Treatment	Post-Test
E <sub>1</sub>	O <sub>1</sub>	X	O <sub>2</sub>
C <sub>1</sub>	O <sub>3</sub>		O <sub>4</sub>
E <sub>2</sub>		X	O <sub>5</sub>
C <sub>2</sub>			O <sub>6</sub>

Source: Fraenkel & Wallen (2006)

**KEY:** O<sub>i</sub> Observation or score of the learners' core critical thinking skills; the subscript against O identifies the time the score was obtained.

X The PBL treatment on the learners' core critical thinking skills.

As shown in table 3, four groups were involved in the study. The groups were identified as E<sub>1</sub> (an experimental group), C<sub>1</sub> (a control group), E<sub>2</sub> (a second experimental group) and C<sub>2</sub> (a second control group). O represents the score or measurement obtained for the given group during testing. The subscript against O identifies the time the score was obtained. All groups received the post-test; in addition, E<sub>1</sub> and C<sub>1</sub> received the pre-test. O<sub>1</sub> and O<sub>3</sub> are the scores obtained using the pre-test by E<sub>1</sub> and C<sub>1</sub> respectively. O<sub>2</sub>, O<sub>4</sub>, O<sub>5</sub>, and O<sub>6</sub> are the scores obtained with the post-test and corresponding to E<sub>1</sub>, C<sub>1</sub>, E<sub>2</sub>, and C<sub>2</sub> respectively. In addition, each of the experimental groups received the treatment X that comprised PBL instruction. Absence of treatment represented presence of conventional instruction and the broken lines in the table are a representation of the non-equivalence of the groups.

### 3.3 Location of the Study

The study covered secondary schools in two neighbouring sub-counties in Nakuru County, Kenya located at latitude 30°5'E and longitude 0°5'S. The sub-counties namely Nakuru East and Nakuru West are bounded by Nakuru North sub-county to the north and Njoro sub-county to the South, Gilgil sub-county to the east and Rongai sub-county to the west. Two other important features help to define the location of the target sub-counties namely Lake Nakuru Nation Park to the south and Menengai crater to the North.

The sub-counties comprise both an urban and a rural set-up with a cosmopolitan population consisting of almost all ethnic communities in Kenya. The location therefore represents important characteristics of Nakuru County that includes social, cultural, economic and political aspects. With this consideration in place, all other sub-counties of Nakuru County were most likely to replicate to a large extent the findings obtained from the two sub-counties. The study henceforth considered any findings obtained as representative of the situation of form three physics students in Nakuru County secondary school. A map of Nakuru East and Nakuru West sub-counties (Nakuru Municipality) is provided on Appendix “D”.

### **3.4 Target Population**

The target population was 1,108 form three physics students in 24 secondary schools in Nakuru East and Nakuru West sub-counties. Of these students, only those in 16 mixed day public secondary schools were considered suitable for the study. These were students from schools that were mixed gender and established in terms of important characteristic such as availability of learning resources, qualified and experienced teachers, and comparable learner entry marks. The Form three physics students in the schools therefore comprised the accessible population. The rest of the students were from either single sex schools or mixed schools that were not yet established with respect to the requisite characteristics.

The choice of mixed schools was preferred so as to minimize the effect of student gender. By using form three students for the study, it was possible to control factors such as negative attitude and lack of motivation that were likely to interfere with the study. This was possible given that physics is an optional subject that students take out of their own volition as from form three. The sampling frame therefore consisted of the 16 established mixed day public secondary schools in the target sub-counties.

### **3.5 Sampling Procedures and Sample size**

Stratified random sampling technique was used to select four schools for the study. Prior to the sampling, the 16 established mixed day secondary schools in Nakuru East and Nakuru West sub-counties were assigned into four stratum according to their geographical location in the area (refer appendix C). The schools were stratified as follows: five schools that lie within a range of about one kilometre from the Nakuru town central business district (CBD)

were assigned to the Central Block; three schools lying to the northern of the CBD were assigned to the Northern Block; the four Schools to the south of the CBD were assigned to the Southern Block and the remaining four to the Western Block given that they were located to the west of the CBD.

Stratifying was necessitated by the need to ensure that samples were representative of important characteristics of the entire population and minimized experimental contamination through interaction between study groups. Majority of the students normally commute an average range of 2km. By stratifying the sample frame as designated, experimental groups and control groups were effectively mutually separated by a range of about 4km. The students were therefore less likely to interact as they commuted to their schools given that the range of separation of sample school was about twice the average daily commuting distance for majority of the students.

A school was drawn from each stratum through simple random sampling thus giving rise to a sample of four schools. None of the sample schools had more than one stream of form three students taking physics. The sample of four therefore constituted four independent groups as required in Solomon Four Experimental design (Fraenkel & Wallen, 2006). Stratified random sampling ensured that the selected samples were most representative of the target population in terms of the desired randomness (Agresti & Finlay, 2008). The four schools were assigned to the treatment and control groups through simple random assignment. E<sub>1</sub> (an experimental group) and C<sub>1</sub> (a control group) were given both the pre-test and the post-test while E<sub>2</sub> (experimental group) and C<sub>2</sub> (control group) received only the post-test. In addition, each of the experimental groups received the treatment which comprised the PBL instruction.

The accessible population of the study was 16 public secondary schools in Nakuru East and Nakuru West sub-counties (former Nakuru sub-county). From this population, a sample of four schools was drawn. The sample comprised 154 subjects, of whom 147 (respondents) representing 95.5% participated in the study. The respondents constituted four independent samples of at least 35 subjects each leaving out seven subjects constituting 4.5% who did not participate in the study due to absenteeism.

For a study of this kind, the recommended minimum sample size requirement is 30 subjects per a group. The sample sizes included were therefore generally above the threshold and

provided a safe margin for any unexpected change (Wambugu & Changeiywo, 2008; Fraenkel & Wallen, 2006). The samples were considered adequate for generalization of results to be applied beyond the study sample groups (Sawyer, 2013).

### **3.6 Instrumentation**

The study used one instrument in data collection – the Core Critical Thinking Skills Physics Achievement Test (CCTSPAT). The instrument consisted of two sections referred to as CCTSPAT (Section A) and CCTSPAT (Section B) marked out of a total of 50 marks. Section A of the instrument comprised twelve questions marked out of 25 marks for assessment of learners' achievement in analyzing skills. The empirical indicator of a learners' achievement in analyzing skills was the learner's score on responses to items in section A. Section B consisting of thirteen questions for assessment of learners' applying skills was marked out of 25 marks also and provided a score that was an empirical measure of a learners' achievement in applying skills. Each section was marked using a scoring rubric that assigned a maximum of two marks for each of the items in the instrument except two. One of the two items was assigned a maximum of one mark while the other was marked out of three marks.

The Core Critical Thinking Skills Physics Achievement Test (CCTSPAT) was used in measurement of achievement of learners in analyzing and applying skills. Development of the instrument was based on the awareness that learning outcomes are often recognized as the joint responsibility of the teacher and the learner, a learner's score being regarded as the measure of the quality of both the instruction and the learning taking place ((Biggs, Kember & Leung, 2001) . By defining aspects of CT skills to be measured for each of the item on the CCTSPAT test, learners' scores acquired high likelihood of representing their achievement of respective critical thinking skills.

#### **3.6.1 Validation of the CCTSPAT Instrument**

As a way of validating the CCTSPAT instrument, three lecturers in physics education at Egerton University were given the instrument to make suggestions that would be used to enhance its validity. The instrument was also given to four teachers of physics who are qualified and experienced to suggest any appropriate reviews they would find. The experts suggested deletion of items that were deemed duplicated, variations of some items and amendment to syntactical structures of others. Their Contributions were used to review and

fine tune the instrument so as to ascertain that it was well validated in terms of face validity, content validity, and construct validity (Mugenda & Mugenda, 2008; Fraenkel & Wallen, 2006). With these considerations in place, accuracy and meaningfulness of inferences derived from any results that were obtained through the test were ascertained (Cohen, Manion & Morrison, 2007).

### 3.6.2 Reliability of the CCTSPAT Test

Quantities of interest in psychological measurement often fall short of explicit measurement. By asking questions that are related to a given attribute of a phenomenon and combining their answers into a single numerical value, it is possible to formulate a measurement scale for the phenomenon (Cronbach & Richard, 2004). It is on this basis that a measurement scale for core critical thinking was formulated. After piloting, reliability of the CCTSPAT test was determined using the data obtained. Reliability of any instrument often varies depending on the constraints it suffers in the course of its use in the measurement of a phenomenon. Nevertheless, a good instrument is fairly easy to recognize; it should have test items that measure the same thing and that have internal consistence (Gall, et al., 2010).

Reliability of the CCTSPAT test was determined through internal consistency reliability estimation using Cronbach’s Coefficient alpha. The test was pilot tested using two different samples of thirty form three students from two schools in the sub-counties. Schools that were used in piloting were those that had similar characteristics as the sample schools but which were not included in the study. Table 4 shows the results of reliability testing using Cronbach’s Coefficient alpha.

**Table 4**  
**Reliability Statistics for CCTSPAT**

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.744	.735	25

As shown in Table 4, the value of Cronbach’s alpha Coefficient obtained was 0.744. On the first try-out, value of alpha obtained was  $\alpha=0.63$  which was less than the threshold value of  $\alpha=0.7$  (Tavakol & Dennick, 2011; Gall et Al., 2010). This led to rigorous modification of the test and repetition of reliability testing that eventually yielded the value of  $\alpha$  ( $\alpha=0.744$ ) shown in Table 4.

Normally, the Cronbach's Coefficient alpha is maximized when all items measure the same construct; the average inter-correlation among test items being subject to effects such as skewness just like any other average. Nevertheless, a coefficient of 0.7 or more is regarded as of acceptable internal consistence (Nunnally & Bernstein, 1994). Obtaining a coefficient of less than the threshold value of  $\alpha=0.7$  should lead to rigorous modification of the test and repetition of reliability testing until a coefficient of 0.7 or more is obtained for the test to be treated as of acceptable internal consistence reliability and therefore suitable for data collection (Cronbach & Richard, 2004).

Once a coefficient of acceptable level was obtained, the test was treated as of acceptable internal consistence reliability and therefore suitable for data collection (Cronbach & Richard, 2004). The value of Cronbach's alpha of 0.74 indicated that the degree of inter-correlations among test items measuring the designated CT skills was high (Zinbarg, Revelle, Yovel & Li, 2005).

### **3.7 Instructional Modules**

Instructional materials for the experimental and the control groups were prepared by the researcher and these were availed in the form of a PBL instructional module and a conventional instruction module respectively. The modules were developed according to the revised KIE 2006 physics syllabus and used as the guiding manual for the teachers during preparation and execution of the lessons. Though identical to each other in most respects, a subtle difference was included to differentiate the two; problems were incorporated in the PBL module for the purpose of PBL instruction.

Four teachers were taken through a three days training on PBL instructional approach. The training exposed the teachers to fundamentals of PBL pedagogy, preparation of PBL instruction and Classroom arrangement in PBL Instructional environment. The training also provided guidelines to the teachers who were used in the implementation of the PBL module on how to use the PBL manual for instruction.

### **3.8 Data Collection**

After the researcher had been cleared and granted permission by the Board of Postgraduate Studies of Egerton University to continue with the study, as a matter of procedure, the researcher also obtained a research permit from the Ministry of Higher Education through

NACOSTI. Consent was also obtained from the county commissioner and County Director of Education of Nakuru County, the Sub-county director of education Nakuru sub-county and Principals of the various schools involved in the study. With approval from all relevant authorities, the researcher proceeded with data collection as planned.

Collection of data for the study was done using the Core Critical Thinking Skills Physics Achievement Test (CCTSPAT) for students. The first set of data was collected through the pre-test administered to two groups – Group I ( $E_1$ ) and Group II ( $C_1$ ) at the beginning of the treatment period. The other set of data was collected in the third week using a post-test administered to all groups on the last day of the treatment.

### **3.9 Data Analysis**

All data that were obtained were analyzed using the SPSS version 20. Both descriptive and inferential statistics were used in data analysis. Raw data were first of all summarized using means and standard deviations and then ANOVA used to analyze the differences in the four means of the post-test scores to determine whether there were any significant differences among the groups. ANCOVA was used in the analysis to reduce experimental errors by statistical means (Fraenkel & Wallen, 2006). All statistical tests of significance were done at alpha value of 0.5. Hypotheses were only accepted if a p-value of less than the chosen alpha was obtained leading to recognition and acceptance of presence of statistically significant difference between the group means. Table 6 shows the summary of statistical tests performed in the study.

**Table 5****Summary of Statistical Tests**

Hypotheses	Independent Variables	Dependent Variable	Method of Data Analysis
H0 <sub>1</sub> : There is no statistically significant difference in learners' achievement of analyzing skills, between learners exposed to PBL and those that are exposed to conventional instruction only	PBL Instruction and Conventional Instruction	Learners Scores on CCTSPAT (section A)	<b>One way ANOVA ANCOVA</b>
H0 <sub>2</sub> : There is no statistically significant difference in learners achievement of applying skills, between learners exposed to PBL and those that are exposed to conventional instruction only	PBL Instruction and Conventional Instruction	Learners Scores on CCTSPAT (section A)	One way ANOVA ANCOVA



## CHAPTER FOUR

### RESULTS AND DISCUSSIONS

#### 4.1 Introduction

The study sought to compare the acquisition of selected core critical thinking skills by learners taught using PBL and those taught using the conventional instruction. Specific skills examined were analyzing and applying skills among form three physics students in mixed day secondary schools in Nakuru sub-county. The type of instruction given to learners formed the Independent variables while the level of acquisition of the analyzing and applying skills formed the dependent variables. Only form three students were covered in the study to ensure that learners involved were those that take physics on their own volition and therefore likely to have a favourable attitude towards the subject.

A presentation of findings based on the factors investigated is given in this chapter. The results are presented using frequency tables, bar graphs, percentages, means, standard deviations, t-tests, and one-way analysis of variance (ANOVA) and ANCOVA. All statistical data is analyzed using Statistical Package for Social Sciences (SPSS) for windows version 20. Results on the level of acquisition of the core critical thinking skills under study are given for each skill and discussion of implications of the results presented alongside. Important information such as demographic data of respondents and schools is also presented.

#### 4.2 Demographic Information

From each of the four schools, relevant background information about the school and the learners was collected. The first set of information was demographic characteristics of learners. The number of students in each sample and their composition by gender was gathered and their KCPE marks. This was necessary to ascertain that the groups consisted of mixed gender as required for the study. Also collected was the number of form three classes taking physics in each school. Information about teachers' qualifications and teaching experience was also obtained.

### 4.2.1 Learners' Entry Behaviour

Learners KCPE marks were obtained from each of the groups. The scores are summarized as shown in table 6.

**Table 6**

**Learners' KCPE Entry Marks**

Sample	No of students	Minimum KCPE Mark	Highest KCPE Mark	KCPE Mean ( $\bar{X}$ )
E <sub>1</sub>	42	255	317	276.6
E <sub>2</sub>	36	252	310	278.3
C <sub>1</sub>	39	259	330	273.4
C <sub>2</sub>	37	260	305	275.5

According to Table 6, learners selected for the study had marks that were approximately between 250 and 320 marks. The KCPE means for each of the Samples were generally within the range  $\bar{X} = 275 \pm 4$  indicating that learners' entry marks across the sample schools were fairly similar. The result was due to the way schools were generally categorized and regulated by the ministry of education (MOeST, 2014). All sample schools were drawn from the category of county mixed day secondary schools. The status gave the schools equal opportunity in their form one selection through computerized random selection and assignment of students to the schools.

### 4.2.2 Teachers Professional Qualification and Teaching Experience

Data on teachers' qualification and teaching experience was collected from 12 teachers of physics in the four sample schools. Eleven of the teachers were Bachelors of Education degree holders with physics as one of their teaching subjects. Two of the teachers were taking master's degrees in education with one specializing in physics education. Eight of the graduate teachers had taught physics between 7 and 15 years; the rest had less than 5 years teaching experience. The eight teachers were considered qualified and experienced, and therefore were included in the study.

This was done in line with the minimum requirements of at least 5years by the KNEC for one to be recruited as an examiner for physics. It also agrees with CEMASTEAM requirement for

one to be appointed as physics county trainer (CEMASTE, 2014). In both cases, the minimum requirement is a bachelor of education degree with physics as a teaching subject, and also being an examiner with KNEC for those recruited into the SMASE trainers' pool. All teachers involved in the study were therefore assumed to be qualified and experienced for the purpose of the study. In addition to these, teachers used to implement PBL were taken through three days training (see appendix I) to familiarize them with expectations in the methodology.

Teacher quality is one of the important factors in any education system that affects students' achievement (OECD, 2005; Cambridge Professional Development Qualifications [CPDQ], 2015). Bouldersa views teacher training and professional development programmes as the mechanism of improving teachers' content knowledge, and teaching skills and practices so as to assure effective learning (Bouldersa, 2016). Generally, professional development has been recognized as the most important factor in teaching that determines the quality of learning (Vargas, 2007).

Bouldersa has also pointed out the problems associated with lack of effective teacher training on content and pedagogical skills. He clearly shows that teachers involved are forced to make poor decision and deliver ineffective lessons because of poor preparation (Bouldersa, 2016). Pre-service training of teachers equips teachers with adequate subject matters for effective delivery of curriculum and administrative skills for effective running of school programmes such as class instruction (Barber & Mourshed, 2007). The quality of any education system is therefore determined by the quality of its teachers.

By ensuring that instruction was done by teachers that were qualified and experienced, it was assured that quality instruction was delivered to all groups. In addition, the effect of teacher quality on learners' achievement was minimized (CPDQ, 2015). Results obtained from all study groups were therefore assured to be of high validity.

### 4.3 Composition of Learners' by Gender

The number of learners in each of the four sample schools by gender is given in figure 2.

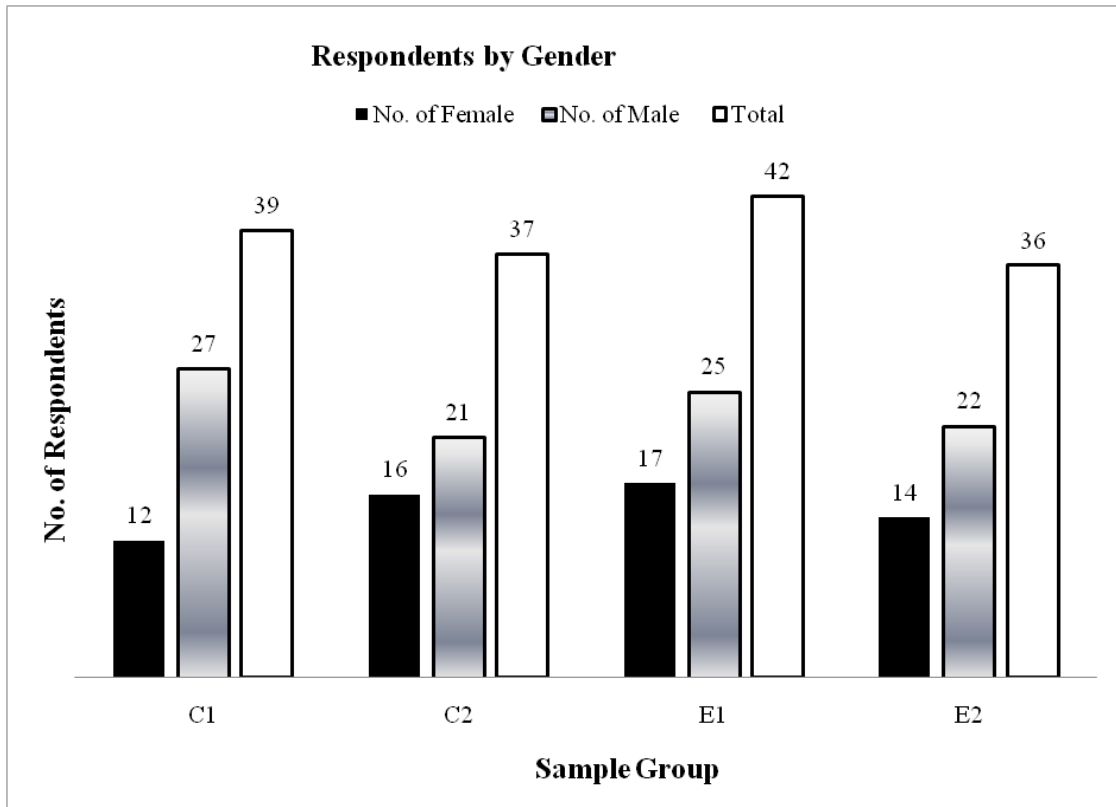


Figure 2: Composition of Learners' by Gender

Figure 2 shows that the number and percentage of female respondents included were 17(40.5%) in E<sub>1</sub>, 12(30.8%) in C<sub>1</sub>, 14(38.9%) in E<sub>2</sub>, and 16(43.2%) in C<sub>2</sub>. Male respondents included were 25(59.5%) in E<sub>1</sub>, 27(69.2%) in C<sub>1</sub>, 22(61.1%) in E<sub>2</sub>, and 21(56.8%) in C<sub>2</sub>. The values indicated that the number of boys taking physics was generally higher than the number of girls in each of the sample schools. This disparity has been recognized as a normal trend in KCSE enrolment for at least the last five years in KNEC annual reports (KNEC, 2017, 2014).

### 4.4 Learners' Acquisition of Analyzing Skills

The first objective of the study was to compare the acquisition of analyzing skills between learners taught using PBL and those taught using conventional instruction. Scores of learners in CCTSPAT (Section A) instrument were compared between the groups. The level of

acquisition of the skills in learners taught using PBL was compared to that of learners taught using conventional instruction in Nakuru East and Nakuru West Sub-counties.

#### 4.4.1 Pre-test Analysis of students score in Analyzing Skills

Two of the groups included in the study namely E<sub>1</sub> an experimental group and C<sub>1</sub> a control group were subjected to a pre-test on analyzing skills. The pretest was administered to estimate the magnitude of incompatibility between the groups before treatments so that learners' growth as a result of the treatments could be tracked (Kelly, 2017). The measure of incompatibility was the value of t-test obtained when comparing pre-test scores of experimental and control groups on analyzing skills. Mean scores of the pre-test are presented in Table 7.

**Table 7**  
**Pretest Students Mean Scores on Analyzing Skills (Levene's test and t-test)**

Sample Group	N	Mean	Std. Dev	F	Sig.	T	Df	Sig. (2-tailed)
E <sub>1</sub>	41	2.488	2.158	.188	.666	.328 Equal var.	70	.744
C <sub>1</sub>	38	2.817	2.680			.329 unequal var.	69.505	.743

$\alpha < 0.05$ ; (df=70,  $t_{\text{calculated}}=0.328$ );  $t_{\text{critical}}=2.42$

Table 7 shows the pre-test analysis of scores obtained on the CCTSPAT (section A) on analyzing skills. Out of a maximum of 25marks, the mean score was ( $\bar{X}=2.488$ ,  $SD=2.158$ ) for E<sub>1</sub> and ( $\bar{X}= 2.817$ ,  $SD=2.062$ ) for C<sub>1</sub>. The mean scores were low with the mean of E<sub>1</sub> less than the mean of C<sub>1</sub>. In terms of standards of measurement of proficiency in skills such as below basic, basic, approaching mastery and mastery as described by Kelly (Kelly, 2017), both groups were ranked below basic.

Table 7 also shows the independent t-test analysis of the pretest scores on analyzing skills between E<sub>1</sub> and C<sub>1</sub>. First, the p-value generated by the Levene statistics was greater than the chosen  $\alpha$  ( $\alpha=0.05$ ) level of significance indicating that the samples were of equal variability (Lee et al., 2015). On t-test, it was observed that a p-value ( $p=0.744$ ) was obtained which was

greater than our chosen  $\alpha$  level. The study concluded that there was no statistically significant difference in pretest means on analyzing skills of learners between those in the experimental group and those in the control group.

The study henceforth established that  $C_1$  and  $E_1$  were at same level in analyzing skills before treatment. The study however recognized that differences were likely to exist between the four groups given that the sampling was done on units that were intact groups of different backgrounds (Rosenbaum, 2015). The effects of differences in Groups that pre-existed treatment were therefore corrected using appropriate statistical tool that included ANCOVA and covariates post-test analysis.

#### 4.4.2 Learners' acquisition of analyzing skills

The effect of PBL learning on learners' analyzing thinking skills was established through a post test on all groups namely  $E_1$ ,  $C_1$ ,  $E_2$  and  $C_2$ . The groups were first exposed to their respective treatments and then a post-test administered to measure their respective performance. Scores of the post-test on learners' level of achievement of analyzing skills are presented in Table 8.

**Table 8**

**Post-test Means of Students Score on Analyzing Skills out of 25marks**

T	N	Mean	Std. Deviation
$E_1$	38	7.079	3.035
$C_1$	34	6.353	2.662
$E_2$	33	6.576	2.807
$C_2$	34	5.794	3.374

Table 8 shows the post-test means attained in the CCTSPAT (Section A) by learners on analyzing skills. Out of a maximum mark of 25, groups means were ( $\bar{X}$ =7.079, SD=3.035) for  $E_1$ , ( $\bar{X}$ =6.353, SD=2.662) for  $C_1$ , ( $\bar{X}$ =6.576, SD=2.807) for  $E_2$  and ( $\bar{X}$ =5.794, SD=3.374) for  $C_2$ . Generally, the Experimental groups attained higher mean scores than the control groups. Group  $E_1$  and  $E_2$  were taught using PBL while group  $C_1$  and  $C_2$  are taught using conventional instruction. From the results obtained, it was noted that learners in the

experimental groups taught through PBL acquired more analyzing skills than those in the control groups who were taught using conventional instruction.

In order to determine the statistical difference in amount of effect of treatment on groups, the groups' post test means were subjected to one way ANOVA. ANOVA test requires data to fulfill six assumptions to minimize biasness or type I and Type II errors (Howell, 2007; Huck, 2004; Morgan, Leech, Gloeckner & Barrett, 2004). Four of the assumption including independence of sample groups and their observations were part of the sampling and study design procedures. Normality and homogeneity were tested and results are given in Table 9 and Table 10.

**Table 9**  
**Test for Normality Post-Test Scores in Analyzing Skills (Shapiro-Wilk Test)**

Sample Group	Statistic	Df	Sig.
E1	.933	38	.025
C <sub>1</sub>	.972	34	.516
E2	.932	33	.040
C <sub>2</sub>	.895	34	.033

As shown in Table 9, only group C1 had data with normal distribution; scores of the other groups deviated from the normal distribution. Normality and variance assumptions can often be violated with impunity (Sawyer, 2013) if sample sizes are sufficiently large (30 or more subjects) and of equal numbers of subjects in each group. On violation of assumption of normality, other studies have recommended that data should be transformed to a variable that is normally distributed to allow ANOVA to be done (Field, 2013). This however creates the challenge of interpretations of results that are based on the transformed variable rather than the actual variable.

Other researchers resort to tests of Statistical significance based on alternative F statistics such as Welch's or Brown-Forsythe that are considered less accurate than Fishers F. Based on the awareness that the sample sizes involved were equal and sufficiently large, ANOVA was considered robust enough against the given violations of normality assumption (Sharpe, 2013, Keselman, Algina, Lix, Wilcox & Deering, 2008). The study considered the normality

assumption not violated too extremely (Howell, 2007; Huck, 2004; Morgan et al., 2004) as to deprive ANOVA test due validity.

**Table 10**

**Test for Homogeneity of Variance for Post Test Score in Analyzing skills**

Analyzing skill			
Levene Statistic	df1	df2	Sig.
.159	3	140	.923

As shown in Table 10 the p value obtained ( $p=0.923$ ) was greater than the chosen level of significance  $\alpha$ . The p-value shows that the samples had equal variance. According to APA, no explicit obligation is placed on researchers to check and report violation of assumptions in their studies (APA, 2009, p. 33). Research should however provide solution to analytic burdens imposed on researchers as well as show robustness in events where violations of the assumptions occur (Sharpe, 2013; Keselman et al., 2008). ANOVA test was therefore done to determine whether there were statistical significant differences between the group means and the results of ANOVA test are given in Table 11.

**Table 11**

**One-Way ANOVA on Post Test Scores on Analyzing Skills (Effect of treatments)**

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	30.457	3	10.152	1.140	.335
Within Groups	1202.147	135	8.905		
Total	1232.604	138			

$\alpha < 0.05$ ;  $F_t(df(3,135) = 2.42)$ ;  $F_c(df(3,135) = 1.140)$

It was observed from Table 11 above that the calculated value of  $F_c(df(3,135) = 1.140)$  was less than table values  $F_t(df(3,135) = 2.42)$  at  $\alpha$  level of significance. This indicated that there was no statistically significant difference between learners taught using PBL and those taught using conventional instruction in achievement of analyzing skills in the topic of ‘heating effect of electric current’.



The results supported the null hypothesis that there exists no significant difference in achievement of analyzing skills in learners between those taught using PBL and those taught using conventional instruction. That finding was contrary to the way PBL has been generally perceived in previous studies; PBL has been recognized to have a well-established promise of increasing problem solving ability of learners at all levels (Belland, French & Ertmer, 2009; Hmelo-Silver, 2004). Other studies have shown that PBL has affected learners positively, enhancing their critical thinking, conceptual understanding and intrinsic motivation towards becoming self-directed learners (Hmelo-Silver, 2004; Barrett & Moore, 2011; Sungur & Tekkaya, 2006).

To achieve greater accuracy in Statistical tests of significance in quasi-experimental designs, ANOVA tests are customarily followed by ANCOVA and other additional statistical tests also called post hoc (Keselman et al., 2008). ANCOVA test is used to eliminate any errors in the post test means that may have resulted from differences between the groups that pre-existed the treatment while post hoc tests are used to identify where differences between groups lie (Sawyer, 2013). ANCOVA test with KCPE marks as covariate was therefore performed on the four sample means. That was necessary given that only two groups in the study were pretested and found to be similar at entry point; differences between the other groups prior to treatments were never determined. Adjusted mean scores of the groups with KCPE mean score as covariate are given in Table 12.

**Table 12**  
**Adjusted Post –Test CCTSPAT Mean Score Using KCPE Marks**

Dependent Variable: Analyzing Skills

Sample Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
E <sub>1</sub>	7.138 <sup>a</sup>	0.495	6.159	8.117
E <sub>2</sub>	6.566 <sup>a</sup>	0.521	5.536	7.597
C <sub>1</sub>	5.822 <sup>a</sup>	0.515	4.803	6.841
C <sub>2</sub>	6.268 <sup>a</sup>	0.532	5.215	7.321

a. Covariates in the model are evaluated at the following values: COVARIATEE = 274.468.

According to Table 12, the adjusted means of experimental group E<sub>1</sub> (7.138<sup>a</sup>), and group E<sub>2</sub> (6.566<sup>a</sup>) were greater than those of the control counter parts group C<sub>1</sub> (5.822<sup>a</sup>) and group C<sub>2</sub> (6.268<sup>a</sup>). The results indicate that learners taught using PBL achieved more analyzing skills than those taught using conventional instruction. Looking at the confidence level set for the study and the standard errors associated with group means above, one may conclude that PBL might be more profitable to learners than conventional instruction. It was therefore concluded that teaching analyzing skills through PBL instruction should yield similar or better results on learners than would be realized under conventional instruction alone.

ANCOVA test was done to correct any errors in the means due to initial differences between the groups. The results for ANCOVA test is shown in Table 13.

**Table 13**  
**ANCOVA Test for Post-Test Means on Analyzing Skills (Univariate Tests)**

	Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	32.344	3	10.781	1.205	.311	.026
Error	1198.94	134	8.947			

$p < 0.05$ ;  $F_t(df(3,134) = 2.42)$ ;  $F_c(df(3,134) = 1.205)$

The F tests result for the effect of Post test mean scores on analyzing skills. This test is based on the linearly independent pair-wise comparisons among the estimated marginal means. Dependent Variable is Analyzing Skills

Table 13 shows the ANCOVA result for the differences in adjusted means on analyzing skills between those of experimental and the control groups. The results show that the calculated value of ANCOVA  $F_c(df(3,134) = 1.1.205)$  was less than tabulated values  $F_t(df(3,134) = 2.42)$  at  $\alpha$  level of significance. The results indicated that the achievement of analyzing skills by students taught by PBL was not significantly different from that of students taught using conventional methods. Based on the results obtained, the null hypothesis ( $H_{01}$ ) that says that there was no statistically significant difference in achievement of analyzing skills in learners between those taught using PBL and those taught using conventional instruction was accepted.

These findings agree with those of Du and Han on medical Students taught with PBL bilingual method and those taught with the bilingual method alone (Du & Han, 2016). They

found that there was no statistical significant difference between the two teaching methods with respect to critical thinking and problem-solving skills. The same study however found that the students taught by PBL bilingual scored significantly higher in basic knowledge, case analysis and treatment selection than students taught with the bilingual method alone. In a number of meta-analyses on the effectiveness of PBL, research findings show that PBL is more effective than traditional approaches when the measurement of learning out-comes are focused on long-term knowledge retention, performance or skill-based assessment, and mixed knowledge and skills (Yew & Goh, 2016).

The reason for lack of statistically significant difference in achievement of analyzing skills by learners exposed to PBL and those taught using conventional instruction in the current study is likely to be due to lack of familiarity to PBL. In the PBL process, a teacher has a critical role; success or failure being largely determined by the commitment and tutoring skills of the teacher (Albanese, 2004). In Gwee's view, the tutor is the one that sets the pulse and tone of discussions in the learning process (Gwee, 2009).

To realize this significant change in mindsets in PBL, effective training programs for both students and teachers must precede its implementation (Albanese, 2004). According to Hamburg and Vladut, efficient and effective implementation of PBL that realizes skills development requires many factors in place; prior knowledge activation, well constructed problems, competent tutors, students self determination, well constructed teams and group dynamics (Hamburg & Vladut, 2016). A number of these factors require significant time to develop. It was therefore concluded that the basic training for teachers and preliminary orientation of learners for PBL may not have been adequate preparation for effective implementation of the PBL process. Familiarity with the methodology was necessary for both students and teachers to internalize the process and that was not possible to realize within the three weeks of exposure to PBL.

Due to the non-statistically significant difference in achievement of analyzing skills between the groups, it is possible to trivialize the impact of PBL on learners. Recognition that learners in PBL groups achieved higher mean scores in analyzing skills than their conventional counterparts may mean that under similar conditions, PBL may enable learners to achieve more analyzing skills than conventional instruction. Besides this, PBL does enhance other competences in learners including problem solving and intellectual skills development. PBL

may therefore be a more profitable instructional method than conventional instruction given that it does equip learners with both cognitive as well as meta-cognitive skills thus preparing them for lifelong learning and life in the twenty-first century.

#### 4.5 Learners' Acquisition of Applying Skills

The second objective of the study was to compare the acquisition of applying skills between learners. Both pretest and Post-test Scores of learners in CCSPAT (Section A) were compared between groups. The level of acquisition of the skills in learners taught using PBL was compared to that of learners taught using conventional instruction.

##### 4.5.1 Pre-test Analysis of Students Score in Applying Skills

Two of the groups included in the study namely E<sub>1</sub> an experimental group and C<sub>1</sub> a control group were subjected to a pre-test on applying skills. Results from the pretest were used to determine what the learners knew or could do before treatment (Howell, 2007; Morgan, et al., 2004) so that the impact of treatments could be established through the post test. Mean scores of the pre-test are presented in Table 14.

**Table 14**

**Learners' Pretest Mean Scores on Applying Skills**

Sample Group	N	Mean	Std. Deviation
E <sub>1</sub>	41	1.415	1.658
C <sub>1</sub>	38	1.921	2.136

Table 14 shows that the pre-test mean scores obtained on the CCTSPAT (Section B) instrument on applying skills were a mean score ( $\bar{X}$ =1.415, SD=1.658) for E<sub>1</sub> and ( $\bar{X}$ = 1.921, SD=2.136) for C<sub>1</sub> out of the maximum score of 25marks. Both mean were low with the mean of E<sub>1</sub> less than that of C<sub>1</sub>. Independent t-test analysis of the scores was therefore necessary to determine whether the differences between C<sub>1</sub> and E<sub>1</sub> were significant or not. Table 15 shows results of the t-test obtained.

**Table 15****Independent Samples t-test for Equality of Group Means**

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	T	Df	Sig.(2-tailed)
PREAPPLYING	2.575	.113	1.182 (equal var.)	77	.241
			1.171 (unequal var.)	69.748	.246

Table 15 shows that a t-value of 1.182 was obtained against a tabulated value of 1.99 at  $\alpha=0.5$  level of significance. The results show that the pretest mean scores on applying skills were not statistically significantly different thus revealing that C<sub>1</sub> and E<sub>1</sub> were similar before treatments.

Differences in groups prior to treatment normally arise when sampling units are intact groups of different backgrounds. These often tend to produce spurious effects that may cloud the post test mean scores so that credibility of inferences is questionable (Sharpe, 2013; Keselman et al., 2008). To minimize these effects, the study adopted sound statistical procedures including ANCOVA and covariates post-test analysis so as to correct errors in the post-test results that would have occurred as a result of initial differences.

#### **4.5.2 Post-test Analysis of Students Score in Applying Skills**

In teaching, success is determined by the degree to which instructional objectives are achieved (Akaraka, 2015; Meziobi & Meziobi, 2014; Biggs & Tang, 2011). The study compared the level of acquisition of applying skills between learners taught using PBL and those taught using conventional instruction in Nakuru East and Nakuru West Sub-counties. Effectiveness of the teaching methods was determined by learners' score in the CCTSPAT (Section B) instrument, an instrument designed to measure the level of acquisition of applying skills.

The effect of PBL learning on learners' applying skills was determined through analysis of performance in the post test. Acquisition of applying skills by learners was indicated by learners score in the CCTSPAT (Section B) instrument. All groups were exposed to their

respective treatments and then a post-test administered to measure performance in applying skills of each group namely E<sub>1</sub>, C<sub>1</sub>, E<sub>2</sub> and C<sub>2</sub>.

Impact evaluation of the treatment was based on the theory of change built around a causal model linking the treatments with learners ‘performance in the posttest (Peersman, 2014). The study considered learners’ post-test scores on the CCTSPAT (Section B) instrument as the outcome obtained as a result of respective treatments on the group. Table 16 presents means on the post-test scores on learners’ level of achievement of applying skills.

**Table 16**  
**Post-test Means of Students’ Score on Applying Skills**

Group	N	Mean	Std. Deviation
E <sub>1</sub>	38	6.211	3.118
E <sub>2</sub>	35	5.614	3.4043
C <sub>1</sub>	34	3.544	2.8321
C <sub>2</sub>	31	3.323	1.9474

Table 16 shows the post-test means attained in the CCTSPAT (Section B) instrument by learners on applying skills. Out of the maximum score of 25 marks, the group means were ( $\bar{X} = 6.211, SD=3.118$ ) for E<sub>1</sub>, ( $\bar{X} = 3.544, SD=2.832$ ) for C<sub>1</sub>, ( $\bar{X} = 5.614, SD=3.404$ ) for E<sub>2</sub> and ( $\bar{X} = 3.323, SD=1.9474$ ) for C<sub>2</sub>. Generally, the Experimental groups attained higher mean scores than the control groups. Group E<sub>1</sub> and E<sub>2</sub> were taught using PBL while group C<sub>1</sub> and C<sub>2</sub> are taught using conventional instruction. From the results, it was noted that learners in the experimental groups taught through PBL acquired more applying skills than those in the control groups who were taught using conventional instruction.

Analysis using ANOVA was necessary to establish whether the difference in means between groups were significant or not. Data was first checked against all the assumptions for ANOVA test; special attention was given to normality test and homogeneity test whose results are given in 17.

**Table 17****Tests of Normality in Post-test Scores in Applying Skills (Shapiro-Wilk Test)**

Sample Group	Statistic	Df	Sig.
E <sub>1</sub>	.944	38	.057
E <sub>2</sub>	.941	34	.068
C <sub>1</sub>	.955	34	.168
C <sub>2</sub>	.943	34	.075

As shown in Table 17, all the p-values obtained for the study groups were above the threshold significance level  $\alpha$  ( $\alpha = 0.05$ ) set for data analysis in the study indicating that all groups had normal distribution. Contravention of normality may impose restriction on subsequent use of the ANOVA test on a given data. In some studies where violation of the assumption of normality has occurred, data transformation may be required to be done before analysis (Field, 2013). The current study however presents a situation where data conform to normality assumptions of ANOVA. Moreover, ANOVA is known to be robust against moderate violation of its underlying assumptions. Table 18 shows results for the homogeneity test for variance for the data above.

**Table 18****Test for Homogeneity of Variances**

Levene Statistic	df1	df2	Sig.
2.011	3	136	.115

Table 18 shows that the p value obtained for homogeneity test for variance ( $p=0.115$ ) was greater than our chosen level of significance  $\alpha = 0.05$ . The value shows that there was no violation of homogeneity assumption indicating that the group means had equal variances.

Once the given data meet all requirements for ANOVA test, it was subjected to ANOVA and the results are presented in Table 19.

**Table 19****Post-test Analysis of Students Score using ANOVA-test**

	Sum of Squares	Df	Mean Square	F	p-value
Between Groups	219.807	3	73.269	8.671	.000
Within Groups	1132.317	134	8.450		
Total	1352.123	137			

\*( $\alpha < 0.05$ ;  $df(3,134)$ ;  $F_t = 2.42$ )

\*( $p < 0.05$  represents a statistically significant difference).

Table 19 shows the one-way ANOVA test on students' CCTSPAT(Section B) post test scores, which compared the effect of PBL instructional approach to conventional instruction on learners' achievement of applying skills. The differences in achievement among the four groups yielded a calculated F-value ( $F [3,134] = 8.671$ ;  $p < 0.05$ ) against a tabulated F-value ( $F [3,134] = 2.42$ ;  $\alpha < 0.05$ ). The results show that the calculated value of F at  $P < 0.05$  was greater than the tabulated F, indicating that there were statistically significant differences in learners' achievement of applying skills among the groups.

Whenever statistical significance is obtained when using ANOVA test, additional statistical tests are necessary to identify the groups whose means differ from each other (Sawyer, 2013). As shown in Table 20, the post hoc analysis (multiple comparison tests) established where the differences were among the groups.

**Table 20****Multiple comparison Tests (Sceffes' Post hoc Analysis) using ANOVA**

(I) Instructional Approach	(J) Instructional Approach	Mean Difference (I-J)	p-value
E <sub>1</sub>	E <sub>2</sub>	0.5962	0.857
E <sub>1</sub>	C <sub>1</sub>	2.6664*	0.002
E <sub>1</sub>	C <sub>2</sub>	2.8879*	0.001
E <sub>2</sub>	C <sub>1</sub>	2.0702*	0.037
E <sub>2</sub>	C <sub>2</sub>	2.2917*	0.02
C <sub>1</sub>	C <sub>2</sub>	0.2215	0.992

\*( $p < 0.05$  represents a statistically significant difference)



As shown in Table 20, the experimental groups namely Groups E<sub>1</sub> and Groups E<sub>2</sub> had means that were greater and significant than the control counter parts namely Groups C<sub>1</sub> and Groups C<sub>2</sub>. Groups E<sub>1</sub> and group C<sub>1</sub> were pretested and found to be similar at entry point. The difference between E<sub>1</sub> and C<sub>1</sub> may therefore be attributed to the instructional methods that were involved in the teaching of the groups. It was therefore concluded that PBL may have enabled learners in group E<sub>1</sub> to gain more analyzing skills than the conventional instruction used to teach group C<sub>1</sub>.

Group E<sub>2</sub> and Group C<sub>2</sub> were never pretested prior to treatments. The difference in mean scores of group E<sub>2</sub> (an experimental group) and that of group C<sub>1</sub> (a control group) may not be entirely attributed to the treatment. Unless correction of any initial differences is done, no valid conclusion can be obtained from the scores alone. ANCOVA test with KCPE marks as covariate was therefore necessary to eliminate the effect of differences due to KCPE marks on the posttest means. Adjusted mean scores of the groups with KCPE score as covariate are given in Table 21.

**Table 21**  
**Adjusted Post –Test CCSCPAT Means Using KCPE Marks as Covariate**

<b>Sample group</b>	<b>Mean</b>	<b>Std. Error</b>
E <sub>1</sub>	6.296a	0.479
E <sub>2</sub>	5.766a	0.497
C <sub>1</sub>	3.349a	0.498
C <sub>2</sub>	3.554a	0.515

a. Covariates appearing in the model are evaluated at the following values: COVARIATE = 274.464

According to Table 21, the adjusted mean of experimental group E<sub>1</sub> (6.296<sup>a</sup>) and group E<sub>2</sub> (5.766<sup>a</sup>) were greater than those of the control counter parts group C<sub>1</sub> (3.349<sup>a</sup>) and group C<sub>2</sub> (3.554<sup>a</sup>). Given that covariate adjustment of posttest mean scores had been performed, it was concluded that the difference between the groups in the posttest was due to the effect of the instructional method that was involved in teaching the groups. Specifically, PBL may have enabled the learners in the experimental group to gain more applying skills than their counterparts in the control groups taught by conventional instruction.

A comparison of the adjusted mean scores was necessary in order to establish whether the differences between the means were statistically significant or not. ANCOVA test was conducted on the group means with KCPE marks as covariate. The effects of any differences due to KCPE marks on the post test means were therefore neutralized leaving only the effect of the treatment. Results of the test are shown in Table 22.

**Table 22**  
**Tests of Between-Subjects Effects**

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	233.349 <sup>a</sup>	4	58.337	6.965	.000	.171
Intercept	0.411	1	0.411	.049	.825	.000
KCPEMARKS	6.638	1	6.638	.792	.375	.006
Contrast	233.348	3	77.783	9.287	.000*	.171
Error	1130.722	135	8.376			
Total	4570.500	140				
Corrected Total	1364.071	139				

a. R Squared = .171 (Adjusted R Squared = .147)

\*(F= (3,135) = 9.287, p<0.05)

Table 22 shows that the differences between the experimental and the control groups were significant (F (3,135) = 9.287, p<0.05). The ANCOVA results indicated that the achievement of applying skills by students taught by PBL was significantly higher than that of students taught using conventional methods. It was therefore concluded that teaching learners using PBL would lead to significantly higher acquisition of applying skills than using conventional instruction in physics in the topic of “Heating Effect of Electric Current”.

The reason why PBL is likely to be more effective in developing learners’ applying skills is due to its learner-centeredness; the method promotes active learner participation in class through problem solving activities (Yew & Goh, 2016; Barrows & Hmelo-Silver, 2006; Barrows, 2000). Barrows and Hmelo-Silver describes PBL as a small group process that

features ill-structured problems, hypothesis generation, revision, and evaluation, inquiry, decision-making, identification of learning issues, self-directed study, and reflection (Barrows & Hmelo-Silver, 2006). Its effectiveness derives significantly from its underpinning philosophy; it considers learning as constructive, self-directed, collaborative and active (Yew & Goh, 2016). It is therefore based on heuristic approach (Olaniyan, 2016), experiential (Torp and Sage, 2002) and organized around resolving meaningful problems (Hmelo-silver, 2004).

Instruction in the PBL process starts with presentation of a problem scenario. Learners are therefore focused on analyzing and understanding the problem better, formulating hypotheses about possible solutions (Barrows & Hmelo-Silver, 2006) and self study as a way of acquiring knowledge that will lead to solving the problem (Oruc & Arslan, 2016; Yew & Goh, 2016). The teacher guides the learning process in a way that learners are able to identify knowledge gaps related to the problem, formulate learning issues and search for relevant knowledge that is required to solve the problem (Gorghiu et al., 2015; Hmelo-Silver, 2004).

By working collaboratively in small groups to solve the problem, learners develop greater competency in problem solving and ability to transfer knowledge more effectively (Yew & Goh, 2016). PBL therefore prepares learners to manage their learning both cognitively and meta-cognitively. The approach equips learners with skills on how to manage their learning by preparing them to work harder, longer and with greater perseverance when experiencing difficulties (Pajares, 2002).

Conventional instruction on the other hand positions a learner as passive recipient of information and the teacher as the source. Instruction is highly teacher centered and often lecture based (Yew & Goh, 2016; Barrows, 2000). This approach has been associated with several limitations: the method encourages development of rote learning (Gorghiu et al., 2015), information overload (Gwee, 2009) and lack of attention to development of higher order thinking skills (Barrows & Hmelo-Silver, 2006).

Conventional instruction largely stands opposed to the contemporary goal of education to develop lifelong learning skills in learners (Zimmerman, 2002). It denies learners the opportunity to participate meta-cognitively in their learning process, and acquisition of knowledge (Martinez, 2006) and self regulate their learning process (Hausand & Reis, 2008;

Pajares, 2002). This effectively inhibits development of learners' ability to solve problem especially those in real life situation where problems are ill-defined and de-contextualized (Barrows, 2002). That explains why Learners in PBL groups performed better in problem solving skills; PBL gave them the opportunity to develop problem solving skills more effectively than learners taught by conventional methods.

Post hoc test (multiple comparison analysis) was necessary so as to locate where the differences lay between the groups. The results are shown in Table 23.

**Table 23**  
**Pair-wise Comparisons of Applying Skills**

Sample Groups	Mean Difference (I-J)	Std. Error	Sig. <sup>b</sup>	(95% Confidence Interval (Difference))	
				Lower Bound	Upper Bound
E <sub>1</sub> E <sub>2</sub>	.529	.692	1.000	-1.324	2.382
E <sub>1</sub> C <sub>1</sub>	2.946*	.685	.000	1.112	4.780
E <sub>1</sub> C <sub>2</sub>	2.742*	.722	.001	.809	4.674
E <sub>2</sub> C <sub>1</sub>	2.417*	.705	.005	.530	4.303
E <sub>2</sub> C <sub>2</sub>	2.212*	.713	.014	.304	4.120
C <sub>2</sub> C <sub>1</sub>	.205	.725	1.000	-1.738	2.147

Based on estimated marginal means

\*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

\*( $p < 0.05$  represents a statistically significant difference)

The results in Table 23 indicate that when PBL was used in instruction, higher learner achievement was attained by experimental groups compared to that attained by control groups under conventional instruction. According to the null hypothesis, it was expected that there could be no statistically significant difference in learners' achievement of applying skills, between those that are taught using PBL and those that are taught using conventional

instruction only. The null hypothesis ( $H_{02}$ ) was therefore rejected. Finding of the study showed that there was a statistically significant difference in learners' achievement in applying skills in physics between those taught by PBL and those taught by conventional instruction only.

Findings of this study provide concrete evidence to show that PBL instruction is more effective in developing applying skills in learners than conventional instruction. Achievement of applying skills by learners taught using PBL was significantly higher than that of learners taught using conventional instruction. PBL can therefore be used as a suitable intervention for developing applying skills in learners in physics.

## CHAPTER FIVE

### SUMMARY, CONCLUSION AND RECOMMENDATION

#### 5.1 Introduction

This chapter presents a summary on the major findings of the study and the conclusions that were drawn. The chapter also presents implications and recommendations that were made based on the findings of the study.

#### 5.2 Summary of the Study and Major Findings

The goal of the study was to investigate the effect of PBL on learners' core critical thinking skills in physics in the topic of 'heating effect of electric current'. Like many of the previous studies in medical and other professional trainings, the current study established that learners' applying skills were developed better through PBL than through conventional instruction. The study however produced inconclusive results as regards to use of PBL to develop learners analyzing skills in the topic. Findings of the study are as follows:

- i. The study established that PBL instruction was more effective than conventional instruction in developing learners' applying skills in physics in the topic of 'heating effect of electric current' than conventional instruction. Achievement of applying skills by learners taught using PBL was significantly higher than that of learners taught using conventional instruction. PBL may therefore be used as a suitable intervention for developing applying skills in learners in physics in the topic of 'heating effect of electric current'.
- ii. The study established that there was no statistically significant difference in learners' acquisition of analyzing skills between those taught using PBL and those taught using conventional instruction. It was however established that under similar conditions, learners taught analyzing skills using PBL attained higher mean scores than those under conventional instruction. PBL may therefore be used to teach learners analyzing skills in physics in the topic of 'heating effect of electric current'. This however may not produce any statistically significant difference.

### **5.3 Conclusions**

Based on the objectives set for the study in the preceding sections, the study led to the following conclusions.

- i. PBL is likely to be a suitable intervention for developing learners applying skills in the topic of ‘heating effect of electric current’. Achievement of applying skills by learners taught using PBL is likely to be statistically significant higher than that of learners taught by conventional methods only in the topic of ‘heating effect of electric current’.
- ii. PBL instruction may not produce any statistically significant difference in learners achievement of analyzing skills in the topic of ‘heating effect of electric current’ when compared to conventional instruction. The study established that no statistically significant difference in achievement of analyzing skills occurs between learners taught analyzing skills using PBL and those taught by conventional methods in the topic of ‘heating effect of electric current’.

### **5.4 Implications of findings of the Study**

According to the study, PBL was found to promote applying skills more than conventional instruction. It was also found that using PBL to teach analyzing skills would enable learners attain better mean score in analyzing skills than their conventional instruction counterparts. In light of this, it may be expected that a physics curriculum in which PBL is integrated would benefit Physics education in Kenyan through enhancing the sharpening of critical thinking skills among the youth. This may lead to a more favourable scientific attitude in the Kenyan public and therefore reduce the cultural influences and religious beliefs that form a significant part of Kenyans understanding of the physical world.

The study recognizes that there has been very little scientific investigation and practical work in many of the Kenyan schools. As a result, many of the problems facing Kenya today such as crime, insecurity, climate change and waste management have lacked lasting resolution. Findings of the study show that if PBL is integrated into the physics curriculum, learners are likely to acquire more adequately physics knowledge through exposure to more practical work and instruction that enhances development of critical thinking skills. This may lead to having more people studying physics beyond high school and consequently increase the level

of physics literacy in the Kenyan public. With increased literacy in physics, the foregoing problems facing modern Kenya are likely to find more adequate solutions.

Through the study, learners in experimental groups were introduced to new study skills that made learning learner-centered and directed through appropriate meta-cognitive skills. PBL made learning constructive, self-directed, collaborative and active. It created a student-centered instructional environment in which learners constructed their own knowledge through inquiry and reflection. All this involved a changing role for the learners as learning became increasingly their responsibility. It was recognized that adequate attention should be taken to induct learners on PBL so as to facilitate the necessary significant change in mind set as learning shifts from conventional instruction to PBL.

## **5.5 Recommendations**

All over the world, Educational systems are increasingly aligning classroom instruction towards learner centeredness and individualized attention. To realize this global shift and other emerging educational trends, the study led to the following recommendations:

- i. Review of classroom practices with the aim of introducing practices like PBL that promote inquiry
- ii. Adoption of classroom practices that allows learners to engage in inquiry activities through appropriate pedagogical approaches such as PBL as a way of entrenching inquiry practices in the classroom.
- iii. Increase learner engagement in the classroom by focusing on activities that make learning learners' responsibility. Given appropriate classroom environment, learners are required to dominate classroom practices.
- iv. Teachers are encouraged to embrace the role of facilitation of learning and not transmission of knowledge.

## **5.6 Suggestions for Further Research**

Following the findings, conclusions and implications obtained in the current study, a number of suggestions for future research have been made.

- i. First, similar studies should be conducted among learners to determine whether there would be similarities with the main findings of the current study. Attention should



be taken to intensifying training of teachers and students to ensure that participants have acquired a favourable and appropriate mind set ahead of the treatments.

- ii. It is also suggested that similar studies can be done using other topics in physics to find out how PBL affect learners critical thinking skills in other topics.
- iii. It is also suggested that similar studies should be conducted on determining the effect of PBL on other learners' critical thinking skills other than analyzing and applying. Such a study would broaden the current thinking about the effects of PBL on learners thinking skills.

## REFERENCES

- Agresti, A., & Finlay, B. (2008). *Statistical options for the Social Sciences, 4th edition*. Saddle River, NJ: Prentice Hall.
- Akaraka, M.B. (2015). Effects of prior knowledge of topics and the instructional objectives on students' achievement in literature-in-english. *Journal of Education and Practice*, 6 (20), 31-34
- Akinibola, A.O., & Afolabi, F. (2009). Constructivist practices through guided discovery approach: the effect on students' cognitive achievement in nigerian senior secondary school physics. *Bulgarian Journal of Science and Education Policy* (3), 2
- Albanese M. A. (2004). Treading tactfully on tutor turf: Does PBL tutor content expertise make a difference? *Med Educ* 38:916–20.
- Ali, M. S., & Awan, A. S. (2013). Attitude towards science and its relationship with students' achievement in science. *Interdisciplinary Journal of Contemporary Research in Business*, 4(10), 707-719.
- American Psychological Association. (2009). *Publication manual of the american psychological association, 6th edn*. Washington, DC: American Psychological Association
- Anderson, L.W., & Krathwohl, D. (2001). *A taxonomy for learning, teaching and assessing: a revision of bloom's educational objectives*. New York, Longman.
- Angelo, T. A. (1995). Beginning the dialogue: Thoughts on promoting critical thinking: classroom assessment for critical thinking. *Teaching of Psychology*, 22(1), 6-7
- Awan, R.N., Hussain, H., & Anwar, N. (2017). Effect of problem based learning on students critical thinking skills, attitude towards learning and achievement. *Journal of Education Research*, 20(2), 2017
- Awang, H., & Ramly, I. (2008). Creative thinking skill approach through problem-based learning: pedagogy and practice in the engineering classroom. *International Journal of Human and Social Sciences*, 3(1), 18-23.
- Bailes, K.E. (2015). *Technology and society under Lenin and Stalin: origins of the Soviet technical intelligentsia, 1917-1941*. Princeton, University Press.
- Barber, M., & Mourshed, M. (2007). *How the world's best performing school systems come out on top*. McKinsey & Company
- Barrett, T., & Moore, S. (2011). New approaches to problem based learning. *British Journal of Education and Technology*, 42(3), 58-64.
- Barrows, S. H., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education (Springer series on medical education)*. New York, Springer Publishing Co. Inc.

- Bates, A., (2005). *Technology, e-learning and distance education*. London, Routledge.
- Belland, B. R., French, B. F., & Ertmer, P. A. (2009). Validity and problem-based learning research: A review of instruments used to assess intended learning outcomes. *Interdisciplinary Journal of Problem-based Learning* 3 (1), 5
- Bennaars. G. A, Otiende J. E., & Boisvert R. (1994) *Theory and Practice of Education*. Nairobi, East African Educational Publisher Ltd.
- Bessey, G. S., (1972). *A Study of Curriculum Development in Kenya*. Nairobi: Government printers.
- Bhatt, B. D., & Sharma, S. R. (2003). *Educational technology concept and technique*. New Delhi-110002: Kanishka Publishing House.
- Biggs, J. B., Kember, D., & Leung, D.Y.P. (2001). The revised two factor study process questionnaire: R-SPQ-2F. *British Journal of Educational Psychology*. 71,133-149
- Biggs, J., & Tang, C. (2011). *Teaching for quality learning at university*. England: Open university Press.
- Bruner, J. (1960). *The process of education*. Cambridge, MA: Harvard University Press
- Bybee, R. (2010a). *A new challenge for science education leaders: Developing 21st century workforce skills in Science education leadership Best practices for a new century*. Arlington, VA: NSTA Press.
- Bybee, R. (2010b). *The teaching of science: 21st-century perspectives*. Arlington, VA: NSTA Press.
- Cambridge Professional Development Qualifications. (2014). Enhancing teaching and leadership practice to improve student outcomes. <http://www.cambridgeinternational.org/>
- Carin, A. A., & Bass, J. E. (2001). *Teaching Science as inquiry* (9<sup>th</sup> Ed.). Upper saddle River, NJ: Prentice-Hall Inc.
- CEMASTE. (1998). *The baseline studies for SMASSE project*. SMASSE Project Bulletin, Unpublished
- CEMASTE. (2004). *Towards better teaching and learning physics*. SMASSE Project National Inset, Unit Physics Department: Self
- CEMASTE. (2014). *SMASSE Secondary Training Manual Module 1 - Fundamentals for Effective Teaching*. SMASSE Project National Inset, Unit Physics Department: Self
- CEMASTE. (2015). *SMASSE Secondary Training Manual Module 2 - Fundamentals for Effective Teaching*. SMASSE Project National Inset, Unit Physics Department: Self
- CEMASTE. (2016). *SMASSE Secondary Training Manual Module 3 - Fundamentals for Effective Teaching*. SMASSE Project National Inset, Unit Physics Department: Self

- CEMASTEА. (2017). *Training Module for Secondary Schools Teachers Module 4 - Inquiry Based learning in Mathematics and Science*. Nairobi: CEMASTEА.
- CEMASTEА. (2018). *Training Module for Secondary Schools Teachers on Inquiry Based learning in Mathematics and Science*. CEMASTEА , Nairobi.
- Center for Critical Thinking (1996). *Three definitions of critical thinking*. Available HTTP: <http://www.criticalthinking.org/University/univlibrary/library.nclk>
- Chamberlin, W. H. (2014). *The Russian Revolution, Volume I: 1917-1918: From the Overthrow of the Tsar to the Assumption of Power by the Bolsheviks*. Princeton: University Press.
- Changeiywo, J.A. (2001). Gender perspective in science and technology education in Kenya. *Journal of Education and Human Resources*, 1(1), 14-31
- Chapple, L., & Curtis, A. (2000). Content based instruction in Hong Kong: Students responses to films. *System*, 28(1), 419-433.
- Chin, C., & Chia, L. (2005). Problem-based learning: using ill-structured problems in biology project work. *Wiley Inter-Science*, 90(1), 44-67.
- Clowse, B. (1981). *Brainpower for the Cold War: The Sputnik crisis and National Defense Education Act of 1958*. Westport, CT: Greenwood Press.
- Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. New York, NY: Routledge Press.
- Cotton, K. (1991). *Teaching thinking skills*. <http://www.nwrel.org/scpd/sirs/6/cu11.html>
- Cronbach, L. J., & Richard J. S. (2004). My current thoughts on coefficient alpha and successor procedures. *Educational and Psychological Measurement*, 64(3), 391–418.
- David C. L. (2007). *The beginnings of Western science: the European Scientific tradition in philosophical, religious, and institutional context*, Second ed. Chicago: Univ. of Chicago Press.
- Dolhenty, J. (2008). *Logic and critical thinking*. <http://www.radicalacademy.com/logiccritthinking.htm>
- Doris, J. & Dillon, J. (2012). *Science Education Research and Practice in Europe: Retrospective and Prospective*, 1–11. © 2012 Sense Publishers.
- Du, X. M., & Han, J. (2016). A literature review on the definition and process of project-based learning and other relative studies. *Creative Education*, 7, 1079-1083. <http://dx.doi.org/10.4236/ce.2016.77112>
- Effandi, Z., & Zanaton I. (2006). Promoting cooperative learning in science and mathematics education: A Malaysian perspective. *Eurasian Journal of Mathematics Science & Technology Education*, 3(1), 35-39

- Ennis, R.H. (2003). "Critical Thinking Assessment" In Fasko, *Critical Thinking and Reasoning: Current Research, Theory, and Practice*. New York, NY: Mc Grawhill
- Ertmer, P. A., & Simons, K. D. (2006). Jumping the implementation hurdle: Supporting PBL in K-12 classrooms. *The Interdisciplinary Journal of Problem-Based Learning*, 1(1), 41-56.
- Eshiwani, G. S. (1993). *Education in Kenya since independence*. Nairobi: East African Educational Publishers.
- Field, A. (2013). *Discovering statistics using SPSS (4th ed.)*. Sage Publications.
- Fisher, A. (2001). *Critical thinking an introduction*. United Kingdom: Cambridge University Press.
- Fitzmaurice, G. M., Laird, N. M., & Ware, J. H. (2004). *Applied longitudinal analysis*. Hoboken, NJ: Wiley.
- Fraenkel, J. R., & Wallen, N. E. (2006). *How to design and evaluate research in education with PowerWeb (6th ed.)*. New York, NY: McGraw-Hill
- Friedl, H. (1995). *Symposia Gaussiana, Conf. B, Eds.:* Mammitzsch/Schneeweiss, Walter de Gruyter:Berlin, New York, 217-226.
- Gachathi, P. J. (1976). *Report of the national committee on educational objectives and policies [Gachathi Report]*. Nairobi: Government Printer.
- Gall, J. P., Gall, M. D., & Borg, W. R. (2010). *Applying educational research: How to read do, and use research to solve problems in practice (6th ed.)*. New York: Allyn & Bacon.
- Gerace, W. J., & Beatty, I. D. (2005), "Teaching vs. Learning: Changing Perspectives on Problem Solving in Physics Instruction", An invited keynote talk at the 9th Common Conference of the Cyprus Physics Association and Greek Physics Association (Developments and Perspectives in Physics: New Technologies and Teaching of Science), *Nicosia, Cyprus*, Feb 4-6 2005.
- Glaserfeld, E. V. (1995). *Radical constructivism : a way of knowing and learning*. Washington, D.C. : Falmer Press
- Glaze, A.L., & Goldston, M.J. 2015. Evolution and science teaching and learning in the United States: A critical review of literature 2000–2013. *Sci. Educ.*, 99, 500–518.
- Gorbachev, M. (1996), *Interview in Johnson, Thomas: The battle of Chernobyl on YouTube, [film], Discovery Channel*. retrieved 19 February 2014.
- Gorghiu, G., Drăghicescu L. M., Cristea S, Petrescu A., & Gorghiu L. M. (2014). Problem-based learning - an efficient learning strategy in the science lessons context. *Procedia - Social and Behavioral Sciences* 191 (2015) 1865 – 1870 (<http://www.sciencedirect.com>)

- Gwee, M. C. E. (2009). Problem-Based Learning: A Strategic Learning System Design for the Education of Healthcare Professionals in the 21st Century. *Kaohsiung Journal of Medical Sciences*, 25, 231-239. [http://dx.doi.org/10.1016/S1607-551X\(09\)70067-1](http://dx.doi.org/10.1016/S1607-551X(09)70067-1)
- Haber-Schaim, U., Dodge, J. H., Gardner, R., Shore, E. A., & Walter, F. (1991). *PSSC Physics (7th ed)*. Dubuque, Iowa: Kendall/Hunt.
- Hall, V. D. (2008). *Microprocessors and Interfacing, Revised (2nd Ed.)*. New Dheli, Tata McGraw-Hill
- Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235-266.
- Hoffman, M. (2011). "Learning in the Laboratory: The Introduction of 'Practical' Science Teaching in Ontario's High Schools in the 1880s." In *Learning by Doing: Experiments and Instruments in the History of Science Teaching*, edited by P. Heering and R. Wittje, 177-205. Stuttgart: Franz Steiner Verlag.
- Hohmeyer, O. & Bohm, S. (2015). "Trends toward 100% renewable electricity supply in Germany and Europe: a paradigm shift in energy policies". *Wiley Interdisciplinary Reviews: Energy and Environment*. 4: 74–97. doi:10.1002/wene.128.
- Howell, D. C. (2007). *Statistical methods for psychology (6th ed)*. Belmont, CA: Thomson Wadsworth.
- Huang, R. (2003a). Justification in mathematics classroom in Hong Kong and Shanghai: Verification or proof? *Journal of Mathematics Education*, 12(4), 13-19.
- Huang, R. (2003b). Comparison of classroom exercise in Hong Kong and Shanghai: A new interpretation of "practice makes perfect". *Journal of Mathematics Education*, 12(2), 42-45.
- Huck, S. W. (2004). *Reading Statistics and Research (4th Ed.)*. New York: Pearson Education Inc.
- Jacobson, M. J., & Reimann, P. (2010), *Designs for Learning Environments of the Future: International Perspectives from the Learning Sciences*, DOI 10.1007/978-0-387-88279-6\_2, © Springer Science Business Media, LLC 2010.
- Kamunge, J. M. (1988). *Report of the presidential working party on education and manpower training for the next decade and beyond [Kamunge report]*. Nairobi: Government Printer.
- Kay, S. (1975). Curriculum innovations and traditional culture: A case history of Kenya. *Comparative Education*, 11: 183–191. [Taylor & Francis Online]
- Keane, M. (2008). Science education and worldview. *Cultural Study of Science Education*, 3, 587–621.

- Kelly, M. (2017). *Pretests Effective Tools to Target Instruction*. <https://www.thoughtco.com/importance-and-uses-of-pretests-7674> Retrieved 15-6-2018
- Kenya Institute of Education. (2002). *Secondary school syllabus*. Nairobi: Kenya Institute of Education.
- Kenya Institute of Education. (2006). *Secondary physics teachers' handbook*. Nairobi: Kenya Institute of Education.
- Kenya Institute of Education. (2009). *Secondary summative stakeholders*. <http://www.kie.ac.ke/images/stories/secondary-summative-stakeholders>. Retrieved 5-4-2018
- Kenya National Examinations Council. (2004). *The Year 2003 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2005). *The Year 2004 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2006). *The Year 2005 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2007). *The Year 2006 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2008). *The Year 2007 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2009). *The Year 2008 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2010). *The Year 2009 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2011). *The Year 2010 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2012). *The Year 2011 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2013). *The Year 2012 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2014). *The Year 2013 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2015). *The Year 2014 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.

- Kenya National Examinations Council. (2016). *The Year 2015 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2017). *The Year 2016 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya National Examinations Council. (2018). *The Year 2017 Kenya Certificate of Secondary Education (K.C.S.E) examination report (Volume 2)*. Nairobi: KNEC.
- Kenya School Magazine. (2010). *Educational data collected by Teachers Service Commission (TSC), Kenya National Examination Council (KNEC), Joint Admission Board (JAB) and the Ministry of Education*.
- Keselman H. J., Algina J., Lix L. M., Wilcox R. R., & Deering K. N. (2008). A generally robust approach for testing hypotheses and setting confidence intervals for effect sizes. *Psychol. Methods* 13, 110–129. doi:10.1037/1082-989X.13.2.110 [PubMed] [Cross Ref]
- Kiboss, J. K. (2002). Impact of computer-based physics instruction program on pupils' understanding of measurement concepts and methods associated with school science. *Journal of Science Education and Technology*, 11(2), 193-198.
- King, A. (1995). Designing the instructional process to enhance critical thinking across the curriculum: Inquiring minds really do want to know: Using questioning to teach critical thinking. *Teaching of Psychology*, 22 (1), 13-17.
- Kleves, J. P., & Aikenhead, G. (1995). *Science Curriculum in a changing World*. Fraser, B. J. & Walberg H.J. Illinois, National society for the Study of Education (NSSE).
- Koech, D. K. (1999). *Totally integrated quality education and training (TIQET): Report of the Commission of Inquiry into the Education System of Kenya [Koech report]*. Nairobi: Government Printer.
- Kothari, C. R. (2004). *Research Methodology: Methods and Techniques*. New Delhi: Wiley Eastern Ltd.
- Lee, D. K., In, J., & Lee, S. (2015). Standard deviation and standard error of the mean. *Korean J Anesthesiol.* 68:220–223. [PMC free article] [PubMed]
- Levy, F., & Murnane, R. J. (2005). *The new division of labor: How computers are creating the next job market*. Princeton, NJ: Princeton University Press.
- Lewin, K. M., 1992, "Science Education in Developing Countries: Issues and Perspectives for Planners", UNESCO, Paris
- Lewin, K. M., 1992, "Science Education in Developing Countries: Issues and Perspectives for Planners", UNESCO, Paris
- Lillis, K. M. (1981). "Expatriates and processes of secondary curriculum innovation in Kenya". In D. Phil thesis, University of Sussex.



- Little, A.W. 1990. Understanding culture; a precondition for effective learning. Paris: UNESCO. (Conference paper, World Conference on Education for All, Jomtien, Thailand).
- Lund, H. (2006). Large-scale integration of optimal combinations of PV, wind and wave power into the electricity supply. *Renewable Energy*. 31 (4), 503–515. doi:10.1016/j.renene.2005.04.008.
- Macmillan Education. (2002). Macmillan English Dictionary for Advanced Learners (2<sup>nd</sup> ed). New York, Macmillan Publishers Ltd.
- Mayer. R. E. (1990). Problem Solving in W. M. Eysenck (ed). The Blackwell Dictionary of Cognitive Psychology, Basil, Blackwell, Oxford, 284-288.
- McGuinness, C. (1999). *From Thinking Skills to Thinking Classrooms: a review and evaluation of approaches for developing pupils' thinking*. Research Report RR115. Nottingham: DfEE.
- McMay, D. V., Grade, K., & Scott C. (2013) Using Problem Based Learning to Develop Class Projects in Upper Level Social Science Courses: A Case Study with Recommendations. *Creative Education*. 4(1), 62-70 (<http://dx.doi.org/10.4236/ce.2013.41009>)
- Meziobi, K. A., & Meziobi, K. C. (2014). *Teacher Education Curriculum and Teaching at the tertiary Education level in Nigeria*. In U.M. Ivowi (ed) *Curriculum and teaching in Nigeria*. Lagos: Foremost Educational Services Ltd.
- Minishi, O., Muni, E., Okumu O., Mutai P., Mwangasha G., Omolo H., & Munyeke F. (2004). *Secondary physics form one 3rd ed*. Nairobi: Kenya Literature Bureau.
- Ministry of Education Science and Technology. (2014). *Nakuru District Education Day Held on 6<sup>th</sup> June 2014 at St. Mary's Primary School*.
- Ministry of Education, Science and Technology. (2004). *Sessional paper on a policy framework for education, training and research: Meeting the challenges of education, training and research in Kenya in the 21st century*. Nairobi: Government Printer.
- Ministry of Education. (1988). *Sessional paper no. 6 of 1988 on education and manpower training for the next decade and beyond [based on Kamunge report]*. Nairobi: Government Printer.
- Moore, G. A. (2009). Infants' and mothers' vagal reactivity in response to anger. *The Journal of Child Psychology and Psychiatry*, 50(11), 1392–1400.
- Morgan, G. A., Leech, N. L., Gloeckner, G. W., & Barrett, K. C. (2004). *Spss for introductory statistics: use and interpretation (2<sup>nd</sup> ed.)*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Mugenda, O. M., & Mugenda, A. G. (2008). *Research methods: quantitative and qualitative approaches*. Nairobi: Acts Press

- National Research Council. (2010a). *Knowing what students know: The science and design of educational assessment*. Washington, DC: National Academies Press.
- National Research Council. (2010b). *Exploring the intersection of science education and 21st century skills: A workshop summary*. Margaret Hilton, Rapporteur; National Research Council. Washington, DC: National Academies Press.
- National Science Teachers Association. (2004). *NSTA position statement: Scientific inquiry*.
- National Science Teachers Association. (2006). *NSTA position statement: Professional development in science education*.
- National Science Teachers Association. (2007). *NSTA position statement: The Integral Role of Laboratory Investigations in Science Instruction*.
- Nechepurenko, I., & Fountain, H. (29 November 2016). "Giant arch, a feat of engineering, now covers chernobyl site in ukraine". The New York Times. ISSN 0362-4331. Retrieved 23 December 2016.
- Noddings, N. (2004). High stakes testing: why? *Theory and Research education*, 2(3), 263-269.
- Noddings, N. (2006). *Critical lessons: what our schools should teach*. New York: Cambridge University Press.
- Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory*. (3rd ed.). New York: McGraw-Hill.
- Nyakan, P. O. (2008). *The influence of science process skills on students' gender disparity in enrolment and performance in secondary schools physics in nakuru district*. Egerton University, Un-published Thesis.
- OECD. (2005). *Teachers matter: attracting, developing and retaining effective teachers*. Paris: OECD. [http://www.oecd.org/document/9/0,3343,en\\_2649\\_39263231\\_11969545\\_1\\_1\\_1\\_1,00.html](http://www.oecd.org/document/9/0,3343,en_2649_39263231_11969545_1_1_1_1,00.html)
- OECD. (2010). *The nature of learning: using research to inspire practice*. Paris: educational research and innovation. OECD Publishing. <http://www.oecd.org/education/ceri/50300814.pdf>
- OECD. (2013). *Innovative Learning Environments*. Paris, France: Educational Research and Innovation, OECD Publishing. <https://doi.org/10.1787/9789264203488-en>
- Oech, M. K. (1982). "Life science curriculums in kenya: a study of a secondary school science project biology" Doctoral Dissertations Available from Proquest. AAI8210338. <https://scholarworks.umass.edu/dissertations/AAI8210338>
- Okere, M. I. O. (1996). *Physics Education. A textbook of methods for physics teachers*; Egerton University: Egerton Press & Lectern Publications Ltd.

- Okere, M. I. O. (2006). *Physics the role of creativity in science education in national development: OOSREA Kenya chapter national workshop*, Kakamega: Bishop Stam Pastoral Centre.
- Olaniyan, A. O., Omosewo, E. O., & Nwankwo, L. I. (2016). Effect of polya problem-solving model on senior secondary school students' performance in current electricity. *European Journal of Science and Mathematics Education*, 3(1) 97-104
- Oliveira, A. R. E. (2012). *The concept of work in the development of applied mechanics: carnot and coriolis*. Invited talk in 32nd International Congress of the Italian Society of Historians of Physics and Astronomy, Rome.
- Oliver, H., & Utermohlen, R. (1995). An innovative teaching strategy: Using critical thinking to give students a guide to the future. *Eric Document Reproduction Services*, 389 (702)
- Oruc, A., & Arslan, A. (2016). The impact of self-regulated learning on reading comprehension and attitude towards Turkish course and meta-cognitive thinking. *Educational Research and Reviews*, 11(8), 523-529, 23 April, 2016. <http://www.academicjournals.org/ERR>
- Osborne, J. & Dillon, J. (2008). *Science Education in Europe: Critical Reflections*. London: The Nuffield Foundation
- Page-Jones, R. (1978). "Science for all those who matter—a sociological critique of Nuffield O-level physics". In Unpublished M.A. dissertation, University of London, Institute of Education.
- Paul, R. W., & Elder, L. (2008). *The Miniature Guide to Critical Thinking Concepts and Tools*. Dillon Beach: Foundation for Critical Thinking Press.
- Paul, R.W., & Elder, L. (2007) *Defining Critical Thinking*. [www.criticalthinking.Org/about/CT/define\\_critical\\_thinking.cfm](http://www.criticalthinking.Org/about/CT/define_critical_thinking.cfm)
- Petryna, A. (2002). *Life Exposed: Biological Citizens after Chernobyl*. Princeton, NJ: Princeton University Press.
- Pijl-Zieber, E. M. (2006). History, philosophy and criticisms of problem based learning in adult education. University of Calgary. 1-13.
- Radido, S. (2017). *Homeless money, understanding the secrets to attracting money & creating wealth*. Nakuru: Zionpearl Publishers.
- Rani, S. T. (2004). *Educational measurement and evaluation*. New Dheli-110002, Discovery Publishing House.
- Rao, V. K., & Reddy, R. S. (2003). *The nature of educational technology*. New Dheli-110 002: Commonwealth Publishers.
- Renner, J.W. (1972). *The Laboratory and Science Teaching*. In Renner, J.W. and Stafford, D.G. *Teaching Science in Secondary Schools*. New York: Harper and Row

- Republic of Kenya. (1981). *Report of the presidential working party on the second university [MacKay report]*. Nairobi: Government Printer
- Rezba, R. J., Sprague, C. S., Fiel, R. L., Funk, H. J., Okey, J. R., & Jaus, H. H. (1995). *Learning and assessing science process skills (3rd ed.)*. Dubuque, IA: Kendall /Hunt Publishing Company.
- Rigden, J. S. (2006). *With PSSC, teachers and students had to think*. American Association of Physics Teachers, Department of Physics, Washington University in St. Louis, MO 63130
- Romanenchuk, K. V. (2006). Reforming Russian Educational Institutions in the System of Education of Kazakhstan in 1991-2004. A review of doctoral dissertation. Saint Petersburg.
- Rosenbaum, S. H. (2015). Statistical methods in anesthesia. In: R. D. Miller, N. H. Cohen, L. I. Eriksson, L. A. Fleisher, J. P. Wiener-Kronish & W. L. Young (eds). *Miller's Anesthesia*. 8th ed. Philadelphia: *Elsevier Inc*; pp. 3247–3250.
- Rudolph, J.L. 2005a. "Epistemology for the Masses: The Origins of 'The Scientific Method' in American Schools." *History of Education Quarterly* 45(3), 341-376.
- Rudolph, J.L. 2005b. "Turning Science to Account: Chicago and the General Science Movement in Secondary Education, 1905-1920." *Isis* 96(3), 353-389.
- Rudolph, J.L. 2005c. "Inquiry, Instrumentalism, and the Public Understanding of Science." *Science Education* 89(5), 803-821.
- Schleicher, A. (2013). *Preparing Teachers and Developing School Leaders for the 21st Century: Lessons from around the World*. Paris: OECD Publishing. <http://www.oecd.org/site/eduistp2012/49850576.pdf>
- Schmidt, H. G., Rotgans, J. I., & Yew, E. H. J. (2011). The process of problem-based learning: what works and why. *Health Professions Education* 45 (8), 792–806
- Schucany, W. R., & Ng, H. K. T. (2006). Preliminary goodness-of-fit tests for normality do not validate the one-sample Student. *Commun. Stat. Theory Methods* 35, 2275–2286.
- Scriven, M., & Paul R. (1987). *Critical thinking*. The 8th Annual International Conference on Critical Thinking and Education Reform, C.A.
- Scriven, M., & Paul, R. (1996). *Defining critical thinking: A draft statement for the National Council for Excellence in Critical Thinking*. Available HTTP: <http://www.criticalthinking.org/University/univlibrary/library.ncl>
- Sharma, S. R. (2003). *Educational technology*. New Delhi-110002: Mohit Publications,.
- Siegel, H. (1986). Critical thinking as an intellectual right. *New Directions for Child Development*, 33, 39-49.

- Simpson, J., & Weiner, E (2010). *The New Oxford Dictionary of English for Advanced Learners* (2nd ed). Oxford, Oxford University Press.
- Sovacool, B. K. (2010). A critical evaluation of nuclear power and renewable energy in asia. *Journal of Contemporary Asia*, 140(3), 393–400.
- Srivastava, D. S., & Kumari, S. (2005). *Education assessment, evaluation and remedial*. D-43 Prithviraj Road, Adarsh Nagar: Dheli-110033: Isha Books.
- Sungur, S., & Tekkaya, C. (2006). Effects of problem- based learning and traditional instruction on self-regulated learning. "*The Journal of Educational Research* ", 99(3), 307-317.
- Tavakol, M., & Dennick, R. (2011). Making Sense of Cronbach’s Alpha. *International Journal of Medical Education*. 2:53-55 Editorial
- Tobias, S., & Duffy, T. M. (2009). *Constructivist instruction: Success or failure?* New York: Taylor & Francis.
- Tooley, M. (1994). *Electronic circuits handbook second edition*. New Delhi, Manish Jain.
- Tortop, H. S., & Ozek, N. (2013). The meaningful field trip in project based learning; the solar energy and its usage areas topic. *H. U. Journal of Education*, 44, 300-307.
- UNESCO. (1999). *World conference on science: The future of physics*. Debrecen (Hungary): UNESCO, Internal Workshop.
- UNESCO. (2005). “*Education for all global monitoring report: The quality imperative*”. Paris: UNESCO.
- Urban, W. J. (2010). *More than Science and Sputnik: The National Defense Education Act of 1958*. Tuscaloosa: University of Alabama Press
- Valentino, C. (2000). *Developing science skills (discovery works)*. Houghton Texas, Houghton Mifflin Company.
- Varga, J. (2007). Who becomes a teacher? An empirical analysis of teaching career choices. *Közgazdasági Szemle*, 54 (7–8), 609–627. <http://www.mktudgy.hu/?q=system/files/VargaJ.pdf>
- Veloo1, A., Nor1, R., & Khalid, R. (2015). Attitude towards physics and additional mathematics achievement towards physics achievement. *International Education Studies*; 8(3), 35-43; URL: <http://dx.doi.org/10.5539/ies.v8n3p35>
- Venthan, A. M. (2006). *An insight into secondary science education in Singapore classrooms*. Singapore: Nanyang Technological University.
- Wade, C. (1995). Using writing to develop and assess critical thinking. *Teaching of Psychology*, 22(1), 24-28.

- Walker, S. (29 November 2016). "Chernobyl disaster site enclosed by shelter to prevent radiation leaks". The Guardian. ISSN 0261-3077. Retrieved 23 December 2016.
- Wambugu P. W., & Changeiywo J. M. (2008). Effects of mastery learning approach on secondary school students' physics achievement. *Journal of Mathematics, Science & Technology Education*, 4(3), 293-302
- Willingham, D. (2007). Critical thinking: Why is it so hard to teach? American educator. *The Quarterly Journal of the American Federation of Teachers*, 31(2), 8-19.
- Wilson, D. (1975). A history of South and central Africa. London: Cambridge University Press.
- Windschitl, M. (2009). *Cultivating 21st century skills in science learners: How systems of teacher preparation and professional development will have to evolve*. Presentation given at the National Academies of Science Workshop on 21st Century Skills, Washington, DC.
- Yew, H. J., & Goh, K. (2016). Problem-based learning: an overview of its process and impact on learning. *Health Professions Education* 2, 75–79 ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)
- Zahoyao, M. (2002). Physics education for the 21st Century: Avoiding a crisis. *Physics education* 37(1), 18-24.
- Zinbarg, R., Revelle, W., Yovel, I., & Li, W. (2005). Cronbach's ,Revelle's , and McDonald's : Their relations with each other and two alternative conceptualizations of reliability. *Psychometrika*, 70, 123–133.

## APPENDICES

### APPENDIX A: PBL Instructional Module and Teachers Guide

Topic : Heating Effect of Electric Current

Duration : 15 Lessons

Period : 3 Weeks

#### Specific Objectives

By the end of the topic, a learner should be able to

Perform and describe experiments to illustrate heating effect of electric current

State the factors affecting heating effect of electric current

Derive the equations for electrical energy and power

Identify devices in which heating effect of electric current is applied

Solve numerical problems involving electrical energy and electrical power

#### Topic Arrangement

Experimental Illustration of Heating Effect of Electric Current (3Lessons)

Factors affecting Heating Effect of Electric Current (3Lessons)

Equation for Electrical Energy and Power (3Lessons)

Application of Heating Effect of electric current in Everyday Life (3Lessons)

Numerical Problems Involving Electrical Energy and Electrical Power (3Lessons)

During the first lesson, learners were made to understand that they were going to learn a new topic called “heating effect of electric current” for three weeks but using a new method of learning. The new method required them to search for ideas and knowledge that will eventually enable them to solve a problem they are likely to encounter in their everyday life. They were made to understand that the problem was not clearly defined for them given that it

was similar to many other problems that they encounter in everyday life. For that reason they were asked to spend some time to clearly understand the problem they were required to solve.

To be able to successfully solve the problem, learners were made to understand that they will have to respond to three fundamental questions: What they know about the problem?; Whatever else they needed to know?; and how they would find whatever they wanted to know? (Kain, 2003). They were encouraged to conduct experiments of their choice under the supervision of the teacher whenever they may find that helpful. They simply didn't have to wait for the teacher to give them the knowledge but rather the guidance on how to proceed through the problem. Successful completion of the task meant that they will be able to solve any other problem in the topic including those in the text books like they have done previously using teacher led discussions.

The class was informed that the new method of learning will demand that they work in groups that will continue to the end of the topic. The teachers will help the students formulate discussion groups before beginning the task.

PBL Task 1 : In our everyday life, we observe heating appliances such as iron boxes and electric ovens generating heat and performing their heating roles. We are left wondering how they are able to do these. We would like to understand the process of heating that takes place in electric devices such as an electric kettle, why some devices produce more heat than others and why this phenomenon is important to us.

#### Experimental Illustration of Heating Effect of Electric Current

Learners can be encouraged to perform an experiment that demonstrates heating effect of electric current, record and explain their observations.

The wire is red hot.

Why the Steel wool is burning (15 min)

#### **Requirements**

Three Cells and a cell holder, Ammeter (0-5A), a switch, ordinary steel wool for multipurpose cleaning, five Connecting wires



### Set-up

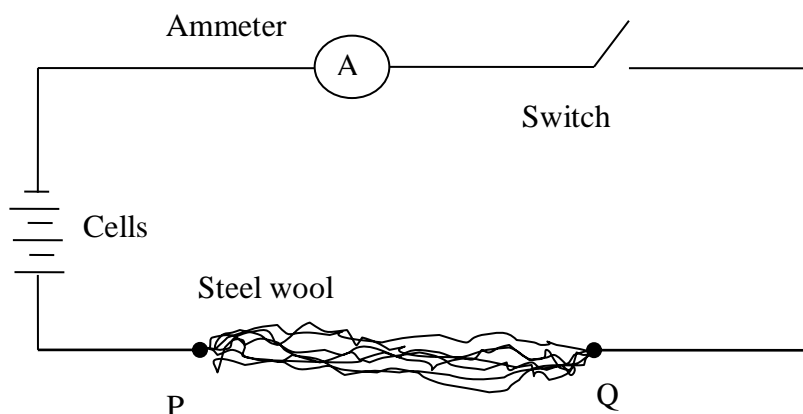


Figure 3: Burning of Steel wool using electric current

### Procedure

- i. Set up an experiment as shown in figure 1.7. Connect the circuit as shown, press on the switch and observe any changes on the steel wool. Record your observation.
- ii. Using steel wool of a different thickness, repeat procedure I. and record your observations.
- iii. Using steel wool of a different length, repeat procedure I. and record your observations
- iv. What can one conclude about electric current when allowed to flow through a steel wool?

Experiment 2: Heating effect of electric current in a Nichrome wire (15 min)

### Requirements

Three Cells and a cell holder, Ammeter (0-5A), a switch, a piece of nichrome wire of length about 20 cm, five Connecting wires

### Set-up

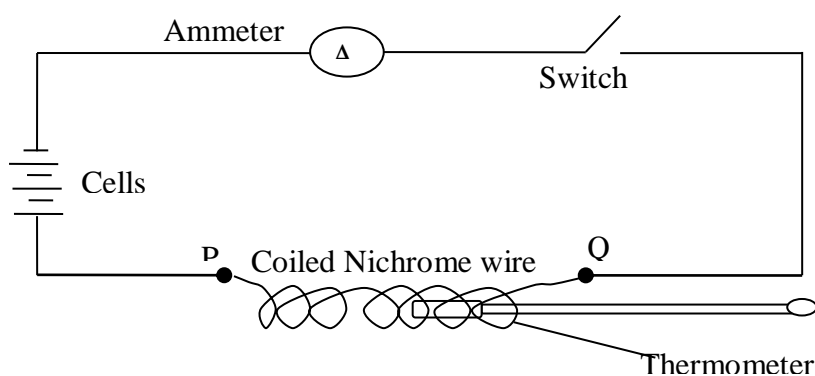


Figure 4: Heating effect of electric current in a thin Nichrome wire

## Procedure

Set up an experiment as shown in figure 1.7. Connect the circuit as shown, press on the switch and observe any changes on the thermometer. Record your observation.

Using a nichrome coil of a different lengths or number of turns, repeat procedure i. and record you observations.

What do we conclude about electric current when allowed to flow through a nichrome coil?

Experiment 3: Heating of water using electric current in a Nichrome wire (15 min)

## Requirements

Accumulator, Ammeter (0-5A), a switch, a piece of nichrome wire of length about 40 cm, five Connecting wires

## Set-up

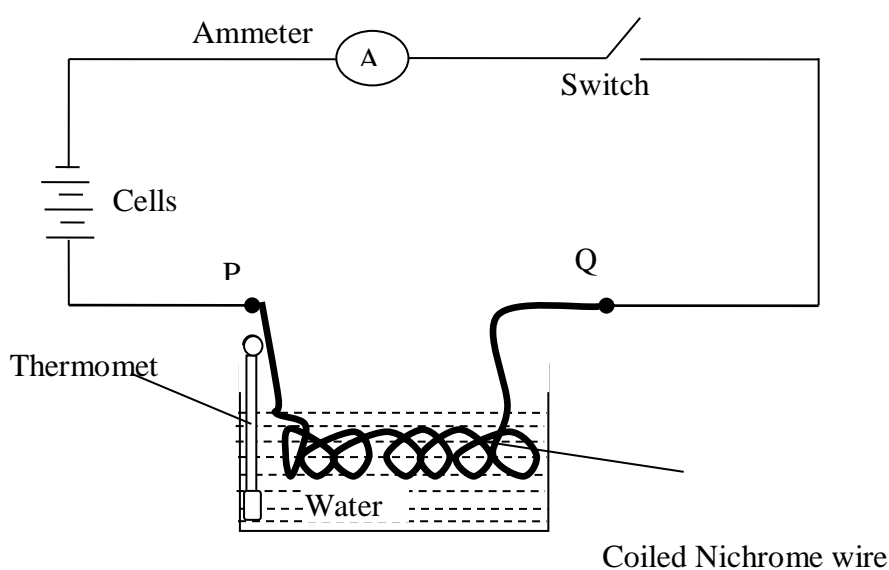


Figure 5: Heating of water using electric current in a coiled Nichrome wire

## Procedure

1. Set up an experiment as shown in figure 1.7. Connect the circuit as shown, press on the switch and observe any changes on the thermometer. Record your observation.
2. Using a nichrome coil of a different lengths or number of turns, repeat procedure i. and record you observations.

3. What do we conclude about electric current when allowed to flow through a coil of nichrome immersed in water?

### Factors Affecting Heating Effect of Electric Current

PBL Task 2(a) : Does the type of material a conductor is made of affect the amount of heat generated when a current flows through it?

Experiment 4: Heating effect of Electric Current in wires of high resistance (15 min)

### Requirements

Three Cells and a cell holder, Ammeter (0-5A), a switch, a piece of nichrome SWG-28 wire of length about 20 cm, a piece of constantan wire SWG-28 wire of length about 20 cm , a piece of nichrome SWG-28 wire of length about 20 cm five Connecting wires

### Set-up

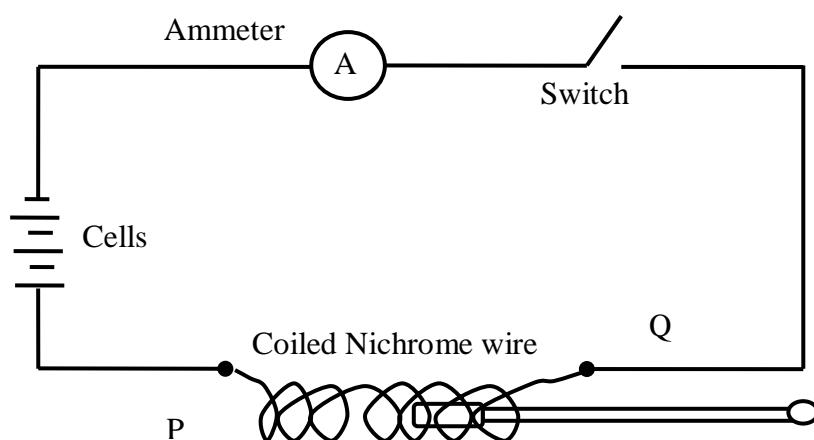


Figure 6: Heating effect of Electric Current in a Gauge-28 Nichrome wire

### Procedure

1. Set up an experiment as shown in figure 5. Connect the circuit as shown, press on the switch and observe any changes on the thermometer. Record your observation.

2. Using copper wire SGW-32, Repeat the experiment in figure 1.7. After Connecting the circuit as shown, press on the switch and observe any changes on the thermometer. Record your observation.
3. Using constantan wire SGW-32, Repeat the experiment in figure 1.7. and record your finding as before

What can we conclude about the amount of heat generated in different materials when electric current flows through them?

PBL Task 2(b): Does the amount of current in a conductor affect the amount of heat generated when a current flows through it?

Experiment 4: effect of amount of current on heating effect of a Nichrome wire (15min)

Requirements

Five Cells and cell holders, Ammeter (0-5A), a switch, a piece of nichrome SWG-28 wire of length about 20 cm, five Connecting wires

Set-up

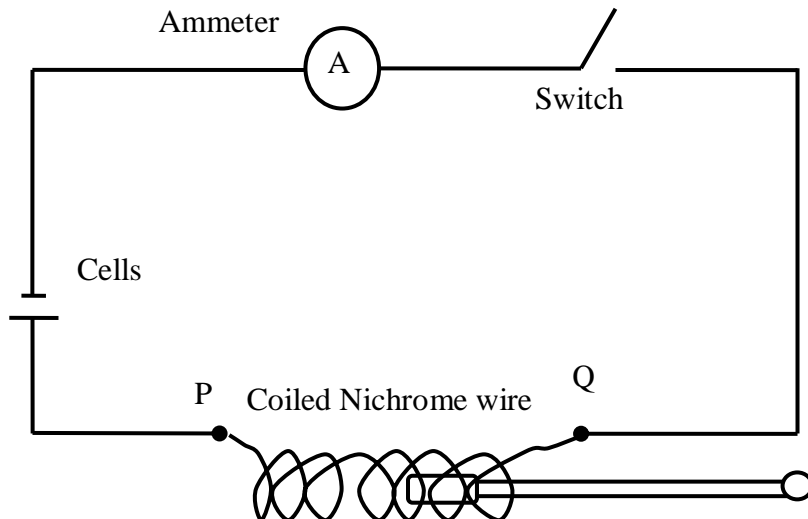


Figure 7: Heating effect of Current through a Nichrome wire

## Procedure

Set up an experiment as shown in figure 5 Connect the circuit as shown, press on the switch and observe any changes on the thermometer. Record the current and the final reading on the thermometer in the table below.

Number of cells	1	2	3	4	5
Current					
Final temperature					

Repeat procedure i. above with the number of cells indicated in the other columns of the table and for each case record the final temperature in the table above.

Plot a graph of temperature (t) against the square of current ( $I^2$ ) in the axes provided below

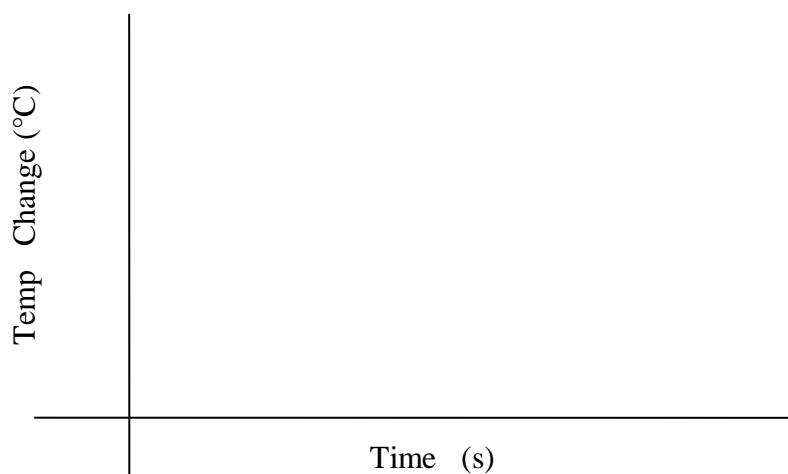


Figure 8: A graph of square of current against temperature

What can we conclude about the amount of heat generated in a materials when different amount of current flows through it

PBL Task 2(c) : Does the duration of heating effect of electric affect the amount of heat generated when a current flows through a material?

**Experiment 5: Effect of duration of heating effect of electric of on the amount of heat generated (15 min)**

Accumulator, Ammeter (0-5A), a switch, a piece of nichrome wire of length about 40 cm, Seven Connecting wires, a stop watch.

**Setup**

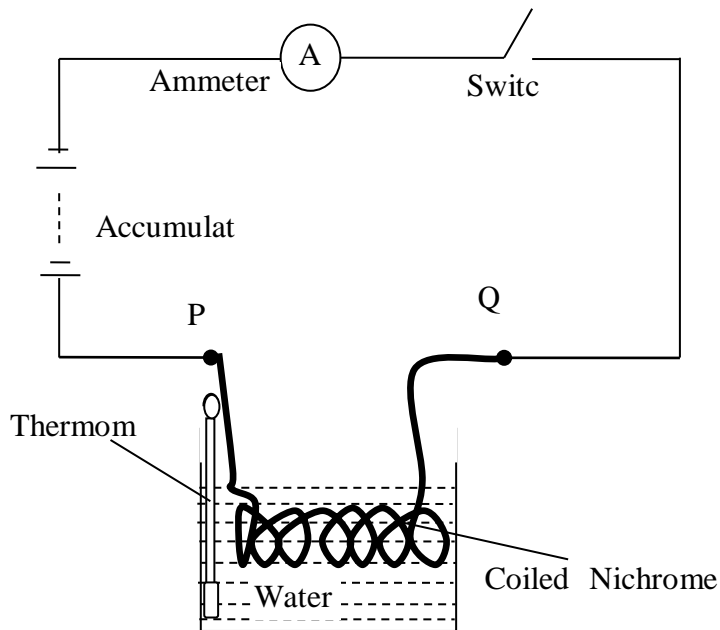


Figure 9: A graph of square of current against temperature

**Procedure**

Set up an experiment as shown in figure 8 above. By switching on the circuit and simultaneously starting the stop watch, observe the changes on the thermometer.

Record your observation in the table below.

Time in Seconds	10	20	30	40	50
Temperature					

Plot a graph of temperature against time in the axes below

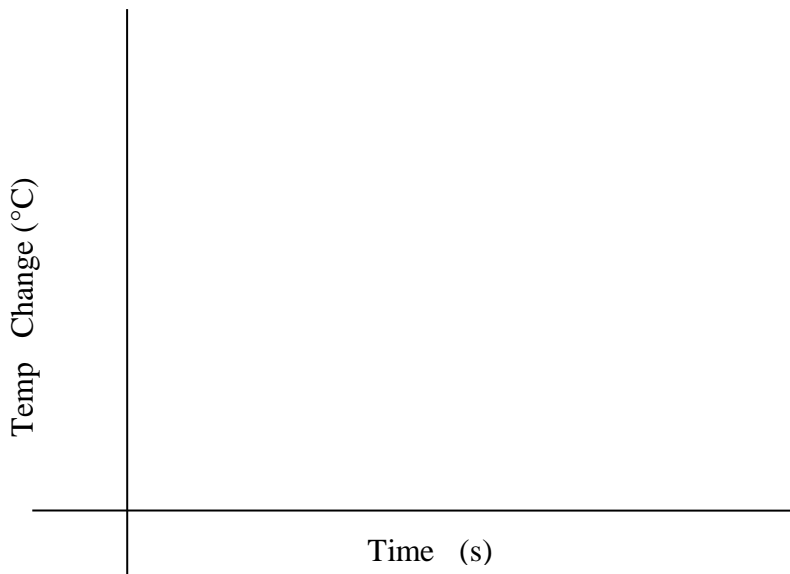


Figure 10: a graph of change in temperature against time

What do we conclude about the amount of heat generated in a conductor with time?

**Equations of Heat Energy and Power by an Electric Current**

PBL Task 3(a) : Can the amount of heat generated in a conductor be determined numerically using well defined mathematical equations?

Summary on Factors affecting heat energy in a conductor

Heat energy developed in a conductor is directly proportional to the time the current flows in the conductor..... (1)

$H \propto t$

Heat energy developed in a conductor is directly proportional to the square of the current in the conductor .....(2)

$H \propto I^2$

Heat energy developed in a conductor is directly proportional to the resistance (r) of the conductor .....(3)

$$H \propto R$$

From (1), (2) and (3), it is easy to notice that when these factors are jointly in action, then the amount of heat generated varies as

### Equations of Electrical Energy

$$H \propto I^2 R t$$

Or

$$H = K I^2 R t \quad \text{where } K \text{ is a constant of proportionality}$$

From the definition of a Joule, K can be obtained and its value is  $K=1$

$$\text{Hence, } H = I^2 R t$$

Since  $V = IR$ , it is easy to note that  $H = V I t$  or  $H = \frac{V^2 t}{R}$

### Exercise 1.

A water heater has a coil that provides 4800j/min when a p.d. of 120V is applied across its terminals. If the cross-sectional area of the wire making the coil is  $1 \times 10^{-7} \text{ m}^2$  and its resistivity is  $1 \times 10^{-6} \Omega \text{m}$ , calculate the length of the wire.

Two nichrome wires of the same length were used to heat a room using a simple circuit as shown. When the wires were connected to the power outlet one at a time, the room became warmer much faster with a thick nichrome wire than with a thin wire. Give an explanation for this observation.

Copper wires are rarely hot even when connecting heating appliances such as iron boxes to the power line. Give an explanation for this difference in temperatures.

### Equations of Electrical Power

PBL Task 3(b) : Can the power of electric heating device be determined numerically using simple mathematical equations?



The electrical energy (H) dissipated as heat is the work done in pushing an electric charge around a circuit is given as;

$H = VIt$ , represents the work done i.e.

Since Power is the work done over the time taken, then

$$p = \frac{w}{t}; \text{ Then } p = \frac{vit}{t}; \quad \text{or} \quad p = VI$$

Since  $V=IR$

Power can be represented as

$$p = VI \text{ Or } \quad p = I^2R \quad \text{or} \quad p = \frac{V^2}{R}$$

Exercise 2.

A house has twenty-five bulbs all rated at 60watts, a 1KW water heater and three 550 watts security light. If all the appliances are running on a line whose nominal value is 240V, determine the current drawn from the power supply.

A domestic circuit for lighting is rated 240 Watts and fused with a fuse of 15A. Determine the maximum number of 75Watts bulbs it can when running safely?

An iron box whose rating is 2.5KW is connected to power through a cord of resistance  $2\Omega$ . Determine the efficiency of the electric system when operating from a line rated 230Watts.

Devices in which heating effect of electric current is applied

PBL Task 4(a) : Are there devices applied in our everyday life that are based on heating effect of electric current?

## **ELECTRIC LIGHTING DEVICES**

### **Filament Lamp**

A filament lamp consists of a tungsten filament enclosed in a glass envelope. Air is removed from the envelope to prevent oxidation of the filament. To prevent oxidation of the filament, a mixture of argon and nitrogen is added. Light is emitted by the hot filament when it becomes white hot.

### **Fluorescent Lamp**

A Fluorescent lamp consists of a pair of tungsten filaments enclosed in a glass envelope containing mercury vapour. The glass envelope is coated with a phosphor on the inside. When the lamp is switched on, the mercury vapour emits UV radiation and this makes the tube to fluoresce with brilliant white light.

### **Electric Heating Devices**

Domestic heating appliances consist of a heating element as part of their basic make up. Heat is generated when current flows through a nichrome wire embedded in the element and this is channeled to relevant parts of the device to produce heating as required.

### **Electric Fire or Radiant Heater**

In a radiant heater, heat is generated in an element and then directed into a room by means of a polished surface.

### **Electric Iron box**

In an iron box the heat generated is absorbed by the steel sole through a thin sheet of insulating mica. A thick pad of insulating asbestos limits the upward flow of heat from the element thus keeping the upper parts of the iron relatively cold with respect to the sole. The temperature of the iron is regulated by a thermostat that can be adjusted to limit temperatures to values suitable for different garments.

### **Electric Kettle**

The heating element of an electric kettle is fitted at the bottom to ensure that it is covered with the liquid that is heated. As heating proceeds, heat that is generated is distributed throughout the liquid by convection.

### **Electric Cooker**

The element of an electric cooker is kept in contact with the cooking pot. As the element turns red hot, heat is absorbed by the pot through conduction.

Exercise 3.

Explain the working of the following devices

Deep immersion water heater

Electric deep fryer

Problem Solving and Heating Effect of Electricity

PBL Problem-solving Model

PBL Task: 5 A house has twenty-four bulbs all rated at 60watts, a 1.5 KW water heater and three 550 watts security light. During the peak hours of the evening, all appliances are likely to run concurrently on the domestic power line whose nominal value is 240V, 60A. Determine whether the operation of the power line is sustained within safe limits.

### **Solution Modeling**

The process of solving the given task should begins with understanding that the problem involved is ill-defined, unstructured and open-ended. A learner should therefore be equipped with knowledge on how to address correctly the critical components that constitute the solution to the problem. These components may be organized logically insteps as follows.

Step : 1 Construction of a structured presentation of the physical situation.

For many learners, the first source of difficult in a problem of this kind is associated with its structure – it is ill-defined, open-ended and generally unstructured. The learners are unable to understand the problem well while in this implicit form. Therefore, it is prudent to train them

on how to construct an easy-to-understand mode of presentation of the physical situation in which the problem is embedded. A learner should be able to reformulate the problem into a well-defined and structured presentation.

Generally, there are four fundamental elements that often characterize a well-defined physical problem. The elements include a graphic representation of the situation, a list of relevant known information, a list of required unknown information and list of equation (or laws) that may be used to determine what is unknown using the available information.

**Step : 2 Numeric Evaluations**

This is a step where computation is done; it involves selection of the appropriate formula, substituting known values into the relevant equations and then using appropriate algebraic steps to solve for the unknown information. Ideally, Values for substitution must be expressed in units that are appropriate so as to generate results that are meaningfully and easy to interpret.

**Step : 3 Validation of the Solution**

Naturally, the tendency to obtain various values for the answer to a numerical problem lurks in most numerical tasks. Nevertheless, it is only one or a limited range of values that have the legitimacy of being acceptable. Therefore, it is expedient to train learners on practices that minimize the likelihood of taking a wrong answer for the correct value. Since there is no one easy way to ascertain that the answer obtained to a numerical problem is the correct one, it is only wise to train learners on how to accept answers judiciously. For instance, it is prudent to ensure that the value obtained is reasonable, mathematically correct and expressed in appropriate units.

**Instructional Assumptions**

Learners may often find that the knowledge they have is inadequate for them to solve many of the problems they encounter in physics. When a student analyzes a problem and finds that prior knowledge is insufficient for effective formulation of the solution, the unanswered question should become the guide and motivation for independent and self-directed learning as the learner seeks to find the solution. With well-designed problems, it is possible to

increase learners' knowledge, develop their understanding and perhaps enhance their generic problem solving skills in the subject.

### Modeling the Solution

Let us now construct the solution to this problem using the strategy presented in the foregoing sections.

Step : 1 Construction of a structured presentation of the physical situation.

Task : A house has twenty-four bulbs all rated at 100watts, a 1.5 KW water heater and three 550 watts security light. During the peak hours of the evening, all appliances are likely to run concurrently on the domestic power line whose nominal value is 240V, 40A. Determine whether the operation of the power line remains within safe limits during peak operation.

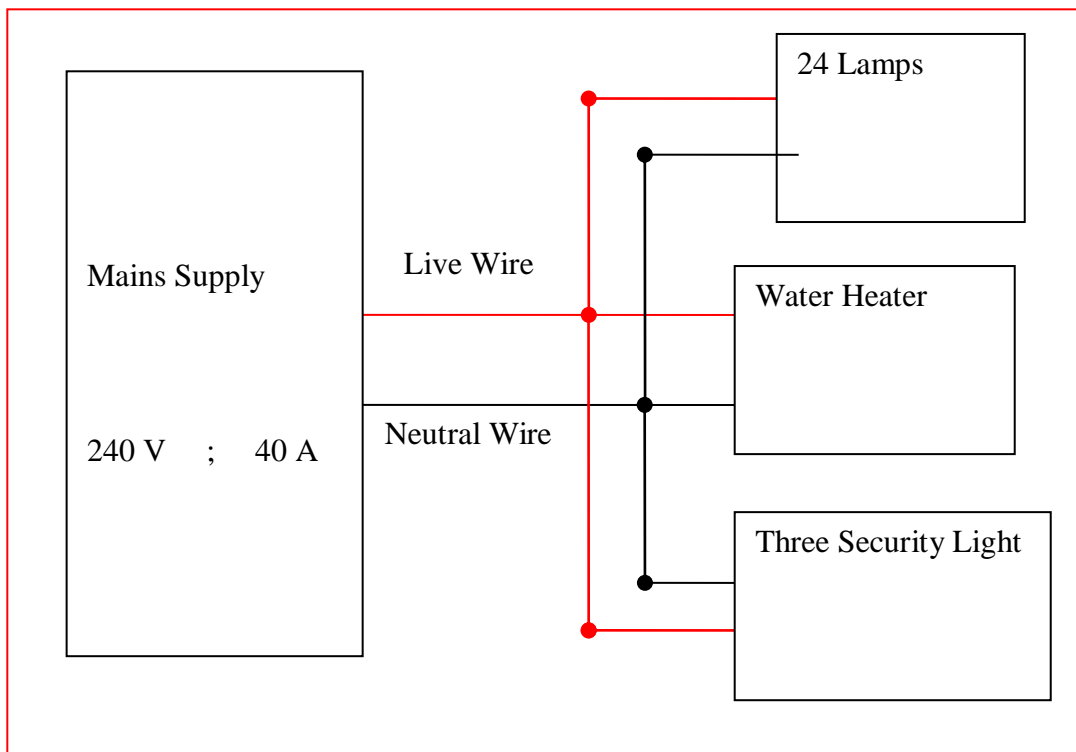


Figure 11: Structured presentation of the physical Problem

List of

Relevant Known Information

Mains Supply :

Voltage = 240 ;      Maximum allowed Current  $I = 40A$ .

Lighting Circuit      Requirements :

No. of Lamps = 24;    Voltage = 240;      Power output per lamp = 100 W.

Security Lighting Requirements

No. of Lamps = 3;    Voltage = 240;      Power output per lamp = 500 W.

Water Heater Circuit Requirements

1.5 KW water heater

- List of required unknown information
- A learner is required to find out whether operation of the power line remains within safe limits during peak operation. There are two ways a learner may be able to establish
- A learner may resort to compare the total power output of all devices in the house to the maximum power output capability of the supply to the house
- A learner may as well compare the total current output of all devices in the house to the maximum current output capability of the supply to the house
- Assuming that a learner goes by the first option, then the learner shall have to determine the following;
  - ✓ maximum power output capability of the supply
  - ✓ Power output of the Lighting circuit
  - ✓ Power output of the Heater Circuit
  - ✓ Power output of the Security lighting circuit
  - ✓ The Total power output of the circuit

List of equations for determining required information from the available information

This step involves identifying and selection of one or more equations of linear motion that can use the given information to determine what is required. The list of equations that a learner can easily use to determine electric power includes the following;

$$P = VI \dots \dots (1) \quad \text{Or} \quad P = \frac{V^2}{R} \dots \dots (2) \quad \text{or} \quad P = I^2R \dots \dots (3)$$

Step : 2 Numeric Evaluations

This is the step whereby the known values are substituted into the relevant equations and then appropriate algebraic steps performed so as to obtain the unknown values.

In this example, equation (1) is used to obtain 'P', the maximum power output capability of the supply as follows;

$$\begin{aligned} P &= VI \\ &= 240 \times 40 \\ &= 9600W \end{aligned}$$

The power output of the Heater is already given; there is no calculation involved in any way.

$$P = 1.5 \text{ KW water} \dots \dots \dots (*)$$

The power output of the 24 lamps in the lighting circuit is easily determined as proportional part of the output of one lamp i.e.

$$\begin{aligned} &1 \text{ Lamp gives } 100W; \text{ what about } 24 \text{ Lamps} \\ &= 24 \times 100 \\ &= 2400W \dots \dots \dots (**)$$

The power output of the 3 security lamps in the security lighting circuit may be easily determined as proportional part of the output of one light as follows:

$$\begin{aligned} &1 \text{ lamp gives } 500W; \text{ what about } 3 \text{ Lamps} \\ &= 3 \times 500 \\ &= 1500W \dots \dots \dots (***) \end{aligned}$$

From (\*), (\*\*) and (\*\*\*), it follows that the total power output of the circuit becomes:

$$\text{Total Power} = 1.5\text{Kw} + 2400\text{W} + 1500\text{W}$$

$$= 5400\text{W} \quad \text{or} \quad 5.4\text{Kw}$$

This value indicates that the power consumption of devices in the house is less than the maximum power output capability of the supply to the house. Since 5.4 KW (total consumption) is less than 9.6KW (maximum supply), it follows that the power line is able to remain within safe limits during peak operation.

### Step: 3 Validation of the Solution

The value obtained is reasonable, mathematically correct and expressed in appropriate units. Therefore, one can confidently declare that it is the correct answer.

## **SUMMARY ON SOLVING NUMERICAL PROBLEMS**

This example is presented here for the purpose of illustrating that if solving numerical problems in physics is done systematically and accurately, then a learner can maximize the likelihood of obtaining the right answer. Most numerical problems in physics can be analyzed and evaluated along the model discussed in the foregoing example. A learner is therefore encouraged to try and extend the ideas discussed above to other numerical problems they encounter in the topic or in other topics in physics.

## **NON-NUMERICAL PROBLEMS**

Learners often find difficulties when solving non-numerical problems that are open-ended, ill-defined or unstructured. For this reason, they should be trained on how to construct an easy-to-understand mode of presentation of the physical situation in which the problem is embedded, so that they may be able to understand the problem more clearly and perhaps solve it more effectively. Perhaps this would be achieved during instruction if learners are guided to know how to reformulate problems into well-defined and structured presentations that facilitate effectiveness in working out the solutions.

Generally, there are four fundamental elements that often characterize a well-defined non-numerical problem. The elements include a graphic representation of the situation, a list of relevant known information, a list of required unknown information and list of laws that are



likely to be used to determine what is unknown using the available information. Given that non-numerical problems are characterized by similar elements as those for numerical type, it may be prudent to apply the models for solving numerical problems to both types of problems. All that might be important is to use the model to equip learners with the ability to assess the reasonableness and usefulness of facts and ideas, and at the same time applying them correctly in determining solutions to problems based on the available information. Provided learners are able to construct solutions to non-numerical problem on the equivalent out line as that describe for numerical problems, little difference is likely to arise in the solving of both types of problems.

**APPENDIX B: Core Critical Thinking Skills Physics Achievement Test for students.**

The Core Critical Thinking Skills Physics Achievement Test (CCTSPAT); is a test administered to students to determine their level of achievement of core critical thinking skills in physics. The test is not an examination nor is it intended for examination in any way. Its findings shall however be of great contribution towards a study intended to improve the way physics is taught to learners at high school. All that is required is a learner to solve each test item to the best of their knowledge. Confidentiality is assured.

KCPE MARKS..... GENDER.....

QUESTIONS

Section A

1. Electrical energy can be converted to heat. Using one example of electric devices indicate whether the statement is true or false.

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2. In Some electrical devices, heat must be produced though heating is never the intention. Using one example, indicate whether this is a true claim or not.

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3. “In all electrical devices electrical energy is partly converted to heat”. Based on one example of all devices you know, support or deny the claim.

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4. In some electrical devices, conversion of electrical energy to heat is a nuisance. With the help of one example indicate whether this is true or false.

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5. Two electric lamps were plugged into lamp holders in a room. Though the lamps appeared to be similar, it was observed that one was brighter than the other. Explain why their brightness was different.

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6. A lamp was blown out by electricity in Janet's living room. On replacement, Janet observed that the room had become less bright than before. Explain the possible cause of the difference.

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7. Electricity has the potential to cause fire. Describe any one circumstance under which fire outbreak may happen.

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8. Two electric kettles were fitted with heating elements. In one kettle, the heating element was fitted at the bottom of the container while in the other; the element was placed at the top. With a reason, indicate whether both designs are acceptable or not.

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9. Copper wires are rarely hot even when connecting heating appliances such as iron boxes to the power line. Give an explanation for this difference in temperatures.

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10. Two nichrome wires of the same length were used to heat a room using a simple circuit as shown. When the wires were connected to the power outlet one at a time, the room became warmer much faster with a thick nichrome wire than with a thin wire. Explain the observation.

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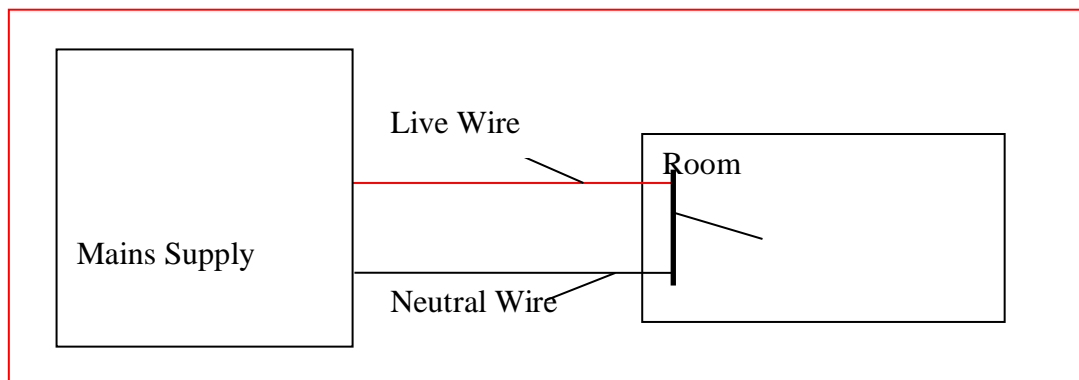


Figure 12: Heating of a room

11. Electrical energy is released wastefully when some heating electrical devices are operating. Using a suitable example describe one of the ways this may happen.

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12. Most electric equipments in the home or in the office are commonly fitted with a plug containing a fuse. The fuse blows when performing its protective role on the device. Explain why this is necessary.

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Section B

13. Rachael once noticed that her bedroom was warmer when the lights were left on overnight than when they were off. Therefore, she resolved to leave the lights on everyday to ensure that her room was kept warm. By giving by a reason indicate whether this was an efficient way of warming the room.

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14. A house has twenty-five bulbs all rated at 60watts. If all lights are on, determine the current drawn from the power supply rated 240V.

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15. A domestic circuit for lighting is rated 240 volts and fused with a fuse of 15A. Determine the maximum number of 75Watts bulbs it can support when running safely?

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16. An iron box whose rating is 2.5KW is connected to power through a cord of resistance  $2\Omega$ . Determine the efficiency of the electric system when operating from a line rated 240V.

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17. States why evacuated glass envelopes of electric lamps are usually filled with a mixture of nitrogen and argon.

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18. Why are fluorescent tube coated with a white material.

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19. A deep immersion heater is used to heat 2kg of water at ordinary room temperature of 200 to boiling point. If the heater is rated 1.5KW, calculate the time it takes the water to boil given that the specific heat capacity of water is 4200J/kg/K

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20. Electric cables often generate heat even when it is undesirable. State and explain two possible ways the amount of heat that is generated may be minimized in a cord of electric iron box.

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21. Occasionally, electricity may cause a fire in a house or burn equipment. State one condition when this is likely to happen and explain how the accident may be avoided.

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22. The heating element of an iron box is usually surrounding by a pair of protective mica slabs. Explain why the mica is a necessary provision in the design of heating element.

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23. Explain why electric fans are often part of the design of devices such as computers and amplifiers.

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24. Explain why use of a fan in a computer is justified even when it is known that a fan may release some its electric energy in ways that are never intended

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25. An iron box is rated has resistance of  $50\Omega$  and takes a current of 10A. Calculate the amount of heat it develops in 1 minute.

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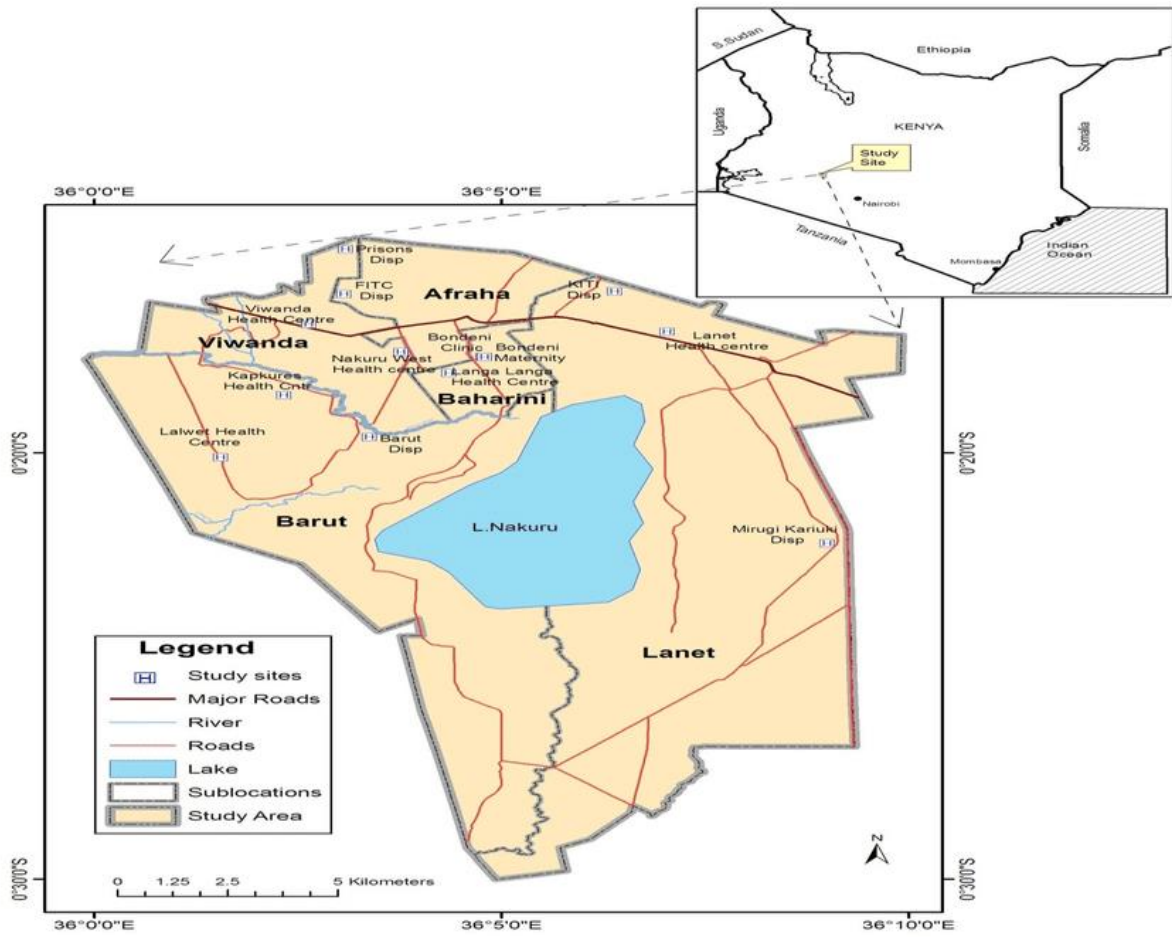
**APPENDIX C: List of Mixed Secondary Day Schools in Nakuru District**

Stratum	School in the Locality	Sample School
Eastern Block	Lanet Secondary Hillcrest Secondary Nairobi Road Secondary	
Central Block	Afraha High Flamingo Secondary Langalanga Secondary Nakuru Central Secondary Kenyatta Secondary	
SouthernBlock	Kelelwet Secondary Mogoon Secondary Tumaini-house Secondary Nakuru West Secondary	
NorthBlock	Crater View Secondary Moi Secondary Upper-hill Secondary Uhuru Secondary	

Source: MOEST Office Nakuru (List of Public Schools)



# APPENDIX D: MAP OF NAKURU COUNTY



**APPENDIX E: RESEARCH PERMIT**

THIS IS TO CERTIFY THAT:  
MR. BENSON NYAUNGA BASWETI  
of EGERTON UNIVERSITY, 10308-20100  
NAKURU, has been permitted to conduct  
research in Nakuru County

Permit No : NACOSTI/P/15/6551/4378  
Date Of Issue : 23rd June, 2015  
Fee Received : Ksh 1,000

on the topic: *EFFECTS OF  
PROBLEM-BASED LEARNING ON  
LEARNERS' ACQUISITION OF CORE  
CRITICAL THINKING SKILLS IN A  
SELECTED TOPIC IN PHYSICS IN  
NAKURU DISTRICT SECONDARY  
SCHOOLS, KENYA*



for the period ending:  
27th December, 2015

*[Signature]*  
Applicant's  
Signature

*[Signature]*  
Director General  
National Commission for Science,  
Technology & Innovation

**CONDITIONS**

1. You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2) hard copies and one(1) soft copy of your final report.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice.



REPUBLIC OF KENYA



National Commission for Science,  
Technology and Innovation

**RESEARCH CLEARANCE  
PERMIT**

Serial No. A **5482**

CONDITIONS: see back page

ORIGINAL

AC: 04607

# OFFICIAL RECEIPT

Station

NITRR

Date

20/1/2015

Received from

Benor Arjun Singh

Shifting

On 20/1/2015

on account of

Bank pass book

State

R.P.S

Part



Serial

111

Check

10000


Check No.

USED	10000
Kshs	10000
AC	10000
Per	10000

Signature of Officer-in-charge

[Signature]

## APPENDIX F: RESEARCH AUTHORIZATION BY NACOSTI



**NATIONAL COMMISSION FOR SCIENCE,  
TECHNOLOGY AND INNOVATION**

Telephone: +254-20-2213471,  
2241349, 310571, 2219420  
Fax: +254-20-318245, 318249  
Email: secretary@nacosti.go.ke  
Website: www.nacosti.go.ke  
When replying please quote

9<sup>th</sup> Floor, Utalii House  
Uhuru Highway  
P.O. Box 30623-00100  
NAIROBI-KENYA

Ref. No. Date:  
**23<sup>rd</sup> June, 2015**

**NACOSTI/P/15/6551/4378**


Benson Nyaunga Basweti  
Egerton University  
P.O Box 536-20115  
**EGERTON.**

**RE: RESEARCH AUTHORIZATION**

Following your application for authority to carry out research on *“Effects of problem-based learning on learners’ acquisition of core critical thinking skills in a selected topic in physics in Nakuru District Secondary Schools, Kenya.”* I am pleased to inform you that you have been authorized to undertake research in **Nakuru County** for a period ending **27<sup>th</sup> December, 2015.**

You are advised to report to **the County Commissioner and the County Director of Education, Nakuru County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

  
**SAID HUSSEIN**  
FOR: DIRECTOR-GENERAL/CEO

Copy to

The County Commissioner  
Nakuru County.

The County Director of Education  
Nakuru County.

*National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified*

**APPENDIX G: RESEARCH AUTHORIZATION BY MOEST**

**MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY**  
State Department of Education

Telegrams: "EDUCATION",  
Telephone: 051-2216917  
Fax: 051-2217308  
Email: cdenakurucounty@yahoo.com  
When replying please quote  
Ref. NO. CDE/NKU/GEN/4/1/21 VOL.III/47



COUNTY DIRECTOR OF EDUCATION  
NAKURU COUNTY  
P. O. BOX 259,  
NAKURU.

27<sup>th</sup> JULY, 2015

Sub-County Director of Education  
Nakuru Sub-County  
P.O. Box 1028  
NAKURU

**RE: RESEARCH AUTHORIZATION – BENSON NYAUNGA BASWETI**  
**PERMIT NO: NACOSTI/P/15/6551/4378**

Authority is hereby given to the above named to carry out research on *"Effects of problem-based learning on learners acquisition of core critical thinking skills in a selected topic in physics in Nakuru District Secondary schools, Kenya"* for a period ending **27th December, 2015.**

Kindly accord him the necessary assistance.

A handwritten signature in blue ink, appearing to read 'George O. Ontiri', written over a faint circular stamp.

**GEORGE O. ONTIRI**  
**FOR: COUNTY DIRECTOR OF EDUCATION**  
**NAKURU COUNTY**

**Copy to:**

Egerton University  
P.O. Box 536-20115  
**EGERTON.**

## APPENDIX H: KCSE PHYSICS PERFORMANCE BETWEEN 2013-2017

Year	Paper	candidature	Maximum Score	Mean-score	Standard Deviation
2013	1	119,819	80	36.03	19.66
	2		80	21.34	14.37
	3		40	22.85	7.98
	<b>Overall</b>		<b>200</b>	<b>80.2</b>	<b>38.07</b>
2014	1	131,410	80	30.41	17.24
	2		80	27.62	16.15
	3		40	19.68	6.78
	<b>Overall</b>		<b>200</b>	<b>77.68</b>	<b>37.3</b>
2015	1	139,100	80	36.01	17.81
	2		80	28.92	15.98
	3		40	22.71	7.62
	<b>Overall</b>		<b>200</b>	<b>87.36</b>	<b>37.58</b>
2016	1	149,790	80	32.49	19.3
	2		80	29.91	19.19
	3		40	17.15	6.56
	<b>Overall</b>		<b>200</b>	<b>79.53</b>	<b>42.4</b>
2017	1	160,182	80	24.57	15.82
	2		80	26.22	18.22
	3		40	19.33	8.33
	<b>Overall</b>		<b>200</b>	<b>70.09</b>	<b>39.59</b>

Source : KNEC KCSE 2017 Examination Report page 35

The overall performance dropped from a mean of 79.53 in 2016 to 70.09 in year 2017

**Appendix I: TRAINING PROGRAMME FOR PBL**

TRAINING PROGRAMME FOR PBL (EXPERIMENTAL GROUPS) TEACHERS			
DAY	TIME	TOPIC / SUB-TOPIC	FACILITATOR/ DAY'S CHAIR
WEDNESDAY 9/9/2015	09.00 – 09.30 hrs	TRAINING GUIDELINES & OBJECTIVES; LEVELLING OF EXPECTATIONS	BENSON
	09.30 – 10.30 hrs	PBL PEDAGOGY AS A FORM OF INQUIRY BASED LEARNING	"
	10.30 – 11.00 hrs	HEALTH BREAK	
	11.00 – 13.00 hrs	MEANING OF PROBLEM-BASED LEARNING (PBL)	"
THURSDAY 10/9/2015	09.00 – 10.30 hrs	PREPARATION OF INSTRUCTIONAL ACTIVITIES	"
	10.30 – 11.00	HEALTH BREAK	

	hrs		
	11.00 – 13.00 hrs	CLASSROOM ORGANIZATION IN PBL CONTEXT	"
FRIDAY 11/9/2015	09.00 – 10.30 hrs	PBL INSTRUCTIONAL MODULE AND ITS APPLICATION	"
	10.30 – 11.00 hrs	HEALTH BREAK	
	11.00 – 12.30 hrs	LESSON PREPARATION , PEER TEACHING AND POST-LESSON DISCUSSION	"
	12.30 – 13.00 hrs	SETTING OF PBL IMPLEMENTATION DATES AND CLOSING	"

#### WAY FORWARD

- PRE-TEST - First Day of the treatment season
- TREATMENT - Three continuous weeks (15 lessons)
- POST-TEST - Last Day of the treatment season

#### END OF THE EXPERIMENT