EFFECTS OF THE PROBLEM-BASED LEARNING APPROACH ON SECONDARY SCHOOL STUDENTS' MOTIVATION AND ACQUISITION OF CRITICAL THINKING SKILLS IN PHYSICS IN ISIOLO COUNTY, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented for examination in this or any other university for the award of a degree.

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DEDICATION

This thesis is dedicated to the memory of my late mother Nuriah Hussein, siblings, wife Artho Ahmed, and our children Najma, Fahym, and Naima

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ABSTRACT

Physics is an important subject because of the role it plays in the industrial, technological, and economic development of countries. Despite its importance, students' performance in physics in Isiolo County has generally been low. The unsatisfactory performance could be due to low levels of motivation to learn physics and critical thinking skills. Teaching approaches have been cited as some of the factors that affect students' motivation to learn and physics critical thinking skills. This study investigated the effects of the problem-based learning (PBL) approach on students' motivation to learn and acquire critical thinking skills in physics. The study employed Solomon's Four Non-Equivalent Control Group design. The target population was 640 form two students in public co-education secondary schools in Isiolo County. The accessible population comprised 265 form two students in public co-education schools in Isiolo Sub County. Simple random sampling technique was used to select four co-educational schools which participated in the study. Two of these schools were in the experimental group while the other two were in the control group. The sample size comprised 128 form two students from the 4 selected schools. Critical Thinking Skills Physics Test (CTSPT) and Learner's Motivation Questionnaire (LMQ) were used to collect data. Experts in Curriculum and Instruction, Egerton University, examined the content and face validity of the two instruments. The reliability coefficients of CTSPT and LMQ were estimated using the Kuder Richardson (KR) 20 formula and Cronbach Alpha method. The reliability coefficient of CTSPT was 0.741 while that of LMQ was 0.793. Data were analyzed with the aid of the Statistical Package for Social Science version 25. Frequencies and percentages were used to describe and summarize data while the Analysis of Variance (ANOVA) and t-test were used to test the hypotheses at $\alpha = .05$ level. The findings indicated that PBL led to increased motivation and acquisition of critical thinking skills by students in physics. However the increase in student's motivation was not statistically significant'. These findings may be used by Physics teachers as reference material to improve learners' acquisition of physics critical thinking skills. The findings may also assist physics teacher trainers in strengthening their training programs by incorporating PBL in them. This may go a long way in equipping teacher trainees with pedagogical skills that can enable them to motivate and impart critical thinking skills to their learners.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA Analysis of Variance

CIEM Curriculum Instruction and Educational Management

CBC Competency-Based Curriculum

CTSPT Critical Thinking Skills Physics Test

CEMASTEA Center for Mathematics, Sciences and Technological Education in Africa

CT Critical Thinking

ERS Economic Recovery Strategies

ETS Educational Testing Service

GED General Education Department

GOK Government of Kenya

GPS Global Positioning System

KICD Kenya Institute of Curriculum Development

KNEC Kenya National Examination Council

LMQ Leaner Motivation Questionnaire

MOE Ministry Of Education

MRI Magnetic Resonance Imaging

NACOSTI National Commission for Science, Technology, and Innovation

PBL The problem-based learning

SDT Self - Determination Theory

SPSS Statistical Package for Social Science

STI Science Technology and Innovation

TIMSS Trends in International Mathematics and Science Study

UNESCO United Nations Educational Scientific and Cultural Organization

CHAPTER ONE
INTRODUCTION

1.1 Background information

Physics is a branch of science that examines the causes of natural phenomena, and the laws and principles that govern them. It is concerned with the properties of matter, energy, motion, and force. The performance of the subject in schools and colleges has been poor and several reasons have been stated to explain the poor performance in Physics. Low motivation to learn physics and poor critical thinking skills have been cited as some of the factors that affect performance in the subject (Njoroge et al., 2014). One of the factors that drive students to learn and gain knowledge is motivation (Kwarikunda et al., 2020*).* Motivation is a psychological term that stems from the desire to want something and continuously pursue that desire (Rapiudin, 2019). It refers to an internal process that activates, guides, and maintains individuals' behavior over time (Tokan & Imakulata. 2019). Motivation is enhanced through exposure to learning environments and teaching approaches that are learner-centered. It is thus important for educators to arouse the interest of learners if they are to improve their motivation, and consequently their achievement in Physics.

Critical thinking is 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 (Tyagi, 2017). Critical thinking skills are essential for good performance in physics as they enable learners to answer questions that require higher-order cognitive abilities such as evaluation, analysis, and application (Spector & Ma, 2019). It is important to acquire critical thinking skills because our thinking left to itself, is biased, distorted, partial, uninformed, or downright prejudiced. Excellence in thought, however, must be systematically cultivated through the acquisition of critical thinking skills through training and experience. Critical thinking skills have been associated with good performance in physics because they enhance their ability to answer examination questions that require higher-order cognitive abilities. The inability of students to answer examination questions that require critical thinking skills at the national level and Isiolo County suggests that their critical thinking skills are low (KNEC, 2019). Consequently, concepts and procedures created by physics are used by other sciences (Kugler & Turvey, 2015). Many sectors of economies of countries benefit from the knowledge generated by physicists. For example, the majority of tools and equipment that are employed in agriculture to enhance production have been developed through physics (Agboghoroma, 2014). Physicists played a critical role in the development of the transistor, radio, television, computers, and telecommunications. Other inventions where physics was applied are the Global Positioning System (GPS) which uses satellites to give locations, and the Hologram used on credit cards and driver's licenses to prevent fraud (Kaku, 2011). Physics-based companies also make a substantial contribution to global economies. According to a survey conducted by the Institute of Physics, over 40% of industrial jobs in the United Kingdom require knowledge and skills in Physics (Shishigu et al., 2018).

Physics contributes significantly to the development of equipment used in the health and agricultural sector (Changeiywo & Wambugu, 2008). Medical Imaging Procedures (MIPs) such as the sonogram and Magnetic Resonance Imaging (MRI) techniques that employ radiation and charged particle accelerators are examples of how physics plays a role in the health sector. In Rwanda, a nutrition program uses equipment developed by medical physicists and an epidemic-tracking system that is based on information technology (Brinkel et al., 2014). Concerning agriculture, irrigation systems, and rainfall gathering all use physics and engineering to help rural communities obtain clean drinking water (Datta et al., 2020).

Physics plays an important role in the economic development of nations. This explains why the Government of Kenya launched Vision 2030, through which it aspires to transform the country into an industrialized, middle-income economy (Bolo & Nkirote, 2012). The Vision calls for the use of Science, Technology, and Innovation (STI) to increase productivity and efficiency in its economic, social, and political pillars. The Vision aims to transform Kenya into a successful country with a high standard of living and competitive globally by 2030 (Kibe, 2021). Kenya intends to become a knowledge-driven economy wherein, creation, adaptation, and use of knowledge will be among the most critical factors for rapid economic growth. Vision 2030 recognizes that science, which Physics is part of, and technology, play a central role in boosting wealth creation, social welfare and international competitiveness of nations (Daniels, 2018). Physics is among the science subjects that are taught in secondary schools, tertiary institutions, and universities in Kenya. This could be due to the significant role the subject plays in industrial and technological, development, which are among the pillars of Vision 2030. The subject is introduced in the first and second years of secondary school education but is made an optional subject in the third and fourth years (Kitavi, 2019). The objectives of secondary school physics are:

i. To equip learners with knowledge, skills, and attitudes for solving problems in their environment.

ii. Be able to construct appropriate scientific devices from the available resources;
iii. Contribute to the technological and industrial development of the nation
iv. Develop capacity for critical thinking in solving problems in any situation;
v. Appreciate and explain the role of Physics in promoting health in society;
vi. Acquire knowledge in Physics for further education and/or training (Kenya Institute of Education [KIE], 2007).

Physics has been recognized as one of the important science subjects and students have encouraged students to learn it (Kitavi, 2018). However, the number of students who enroll in physics is generally low as they tend to avoid physics when they are provided with alternatives (Njoroge et al., 2014). In Britain and Australia, the number of students who enroll for the subject in high schools has steadily been declining (Lyons et al., 2005). Similarly, the number of the number of students who enroll in physics in Kenya is generally low as they tend to avoid physics when they are provided with alternatives (Njoroge et al, 2014). Students' performance in the subject has also been low as shown by results from the Kenya National Examination Council (KNEC, 2015- 2021) in Table 1.

Table 1

Students' National Mean Score in KCSE Physics between 2016 and 2021

Year	2016	2017	2018	2019	2020	2021
Mean score (%)	37.50	35.05	34.27	32.59	35.52	29.70

Data in Table 1 shows that students' achievement in Physics nationally between the years 2016 and 2021 ranged from 29.70% to 35.52%. There were fluctuations in the means scores with 2020 recording the highest and the mean of 2021 being the lowest. Generally, performance in the subject was unsatisfactory since all the mean scores for that period were below 50%. Performance in KCSE physics was also unsatisfactory in Isiolo County as shown in Table 2.

Table 2

Students' Physics Performance in KCSE in Isiolo County

Year	2016	2017	2018	2019	2020	2021
Mean score	29.98	30.10	31.08	27.59	29.52	21.70

The results in Table 2 reveal that the students' mean scores for the years 2016 to 2021 ranged from 21.70% and 31.08%. There were fluctuations in the means scores with 2018 recording the highest and 2021 being the lowest. Performance in the subject was low as all the mean scores were below 40%. There was, therefore, a need to conduct a study in Isiolo County given the low performance in KCSE physics. Isiolo County comprises three sub-counties, Isiolo, Merti, and Garbatula. However, during the study, samples were drawn from only the Isiolo sub-county. The sub-county was selected because it has been recording the lowest performance in Physics as compared to the other two sub-counties as shown in Table 3.

Table 3
Students' KCSE Percentage Mean Scores in Physics in the Sub Counties of Isiolo, 2016 - 2021

Sub County	Year				
	2016	2017	2018	2019	2020
Garbatula	29.42	24.91	25.11	21.09	19.23
Merti	25.89	25.42	28.90	23.89	19.90
Isiolo	22.91	27.89	23.97	19.06	18.99

Data in Table 3 reveal that the mean scores of the Isiolo sub-county were the lowest compared to those of Merti and Garbatula. It is this consistently low performance that informed the selection of the Isiolo sub-county as the location of this study. The Kenyan government recently adopted a new curriculum, the Competency-Based Curriculum (CBC) through the Ministry of Education (Jane et al., 2020). CBC was developed by the Kenya Institute of Curriculum Development (KICD) and emphasizes the importance of acquiring skills and knowledge and applying them to real-life scenarios (Diana, 2020). Critical thinking is among the skills emphasized by this new curriculum. This is considered important for countries struggling to improve their economies through innovations and the application of new technologies (Blocken, 2015). Physics is one of the key science subjects in the CBC curriculum because of its many applications in the fields of engineering and technology.

Evidence in the literature shows that students' motivation to learn and acquisition of critical thinking skills is affected by several factors (Fukuzawa et al., 2017). These include the intelligence of the learners, discipline, a supportive and conducive climate that makes students comfortable, availability of physical facilities, and instructional materials, leadership, teachers' qualification and experience, and teaching methods and approaches (Basweti et al., 2019). The teaching method refers to the general principles, pedagogy, and management strategies used for classroom instruction (Hirsha et al., 2022). A teaching approach on the other hand is a set of principles, beliefs, or ideas about the nature of learning that is translated into the classroom (Bigozzi et al., 2018*).* It is a way of looking at teaching and learning that gives rise to methods, the way of teaching, use of classroom activities or techniques to help learners learn (Cao et al., 2019). The difference between the two is that method is a way of teaching using prescribed objectives and guidelines and the teacher has little or no leeway when it comes to implementation. An approach is a way of teaching whose principles can be applied in many different ways (Kalam & Munna, 2021).

According to Mwangi et al. (2021) physics instruction remains the dominant factor behind poor performance in the subject. Saito and Atencio (2013) noted that the conventional approach to teaching and learning has dominated classrooms and is full of many shortfalls that do not allow students to actively construct their knowledge and perform well in Physics. Conventional teaching methods are instructional models where teachers are the primary source of information, instead of acting as facilitators and assuming the role of knowledge disseminators. Conventional teaching methods frequently employ the use of chalk and discussion (Raja & Najmonnisa, 2018). The teacher moderates and regulates the flow of information and knowledge in situations where conventional teaching methods are employed while students are expected to continue developing their knowledge of a subject outside of school through homework exercises (Alessa & Hussein, 2023). Conventional teaching methods have been associated with low acquisition of skills and poor performance since students do not play active roles in the learning process and teacher-student interaction is limited and does not enhance learners' cognitive understanding of concepts (Qizi, 2021). According to Krahenbuhl (2016) performance can be enhanced by adopting teaching approaches that expose students to experiences that boost meaningful learning, understanding, and development of critical thinking skills. This calls for a shift to a more student-centered approach such as problem-based learning (PBL) which has the potential to boost students' motivation to learn, acquisition of critical thinking skills, and performance (Argaw et al., 2017).

PBL is a teaching approach in which students are taught concepts and principles via the use of challenging real-world problems rather than through the presentation of facts and concepts. Extant literature shows that it has the potential to promote the development of critical thinking skills, and problem-solving abilities, and boost students' motivation to learn (Alismail & McGuire, 2015). It also provides students with opportunities to work in groups, find and evaluate research materials, and engage in life-long learning. Working in groups is an integral part of the PBL, as each student takes on a formal or informal role within the group, which is frequently switched. The approach focuses on the student's ability to develop their learning through reflection and reasoning, clarifying words, defining the problem(s), brainstorming, organizing, and hypothesis, learning objectives, individual study, and synthesis are all part of the PBL process (Wechsler et al., 2018).

The foregoing discussions have shown that students' performance in physics in Isiolo County has generally been unsatisfactory over the years (KNEC, 2019, 2022). Lack of motivation to learn and low critical thinking skills have been cited as determinants of performance (Njoroge et al., 2014). Extant literature has shown that teaching approaches such as PBL enhance motivation critical thinking skills and performance (Jabarullah et al., 2019). It thus can be used to enhance performance in physics. This study investigated the effect of PBL on students' motivation to learn and acquisition of Physics critical thinking skills in Isiolo County. The study focused on the topic of Measurement II. The topic was selected because skills acquired through the topic such as measurement, analysis, and reporting, find application in other physics topics in forms three and four (Kenya Institute of Curriculum Development [KICD], 2017). The study was deemed necessary due to consistently poor performance recorded in KCSE Physics examinations by schools in the Sub-County. In addition, there are hardly any published works on the effects of the Problem-Based Learning approach on student's motivation to learn physics and acquisition of critical thinking skills in Isiolo.

1.2 Statement of the Problem

Physics is among the science subjects taught in secondary schools in Kenya because of the important role it plays in industrial and technological development. Despite its role in industrialization and technological development, students' performance in the subject in Isiolo County has been poor, as evidenced by KNEC reports. The poor performance in the subject could be due to low motivation to learn the subject and unsatisfactory acquisition of Physics critical thinking skills. The KNEC reports reveal that students have problems answering examination questions that require critical thinking skills such as analysis, evaluation, and interpretation. This unsatisfactory performance in physics not only denies students admission to engineering and technology-oriented courses but could also de-accelerate the country's pace towards industrialization as envisioned in Kenya's vision for 2030. Teaching approaches such as PBL have been cited as one of the factors that enhance students' motivation to learn, acquisition of critical thinking skills, and performance in Physics. This study investigated the effect of PBL on students' motivation to learn and acquisition of Physics critical thinking skills.

1.3 Purpose of the Study

The purpose of this study was to investigate the effects of the PBL approach on secondary school students' motivation to learn and acquisition of critical thinking skills in physics, concerning the topic, Measurement Two.

1.4. Objectives of the Study

The study was guided by the following objectives:

i. To find out the effect of Problem-Based Learning (PBL) approach on students' motivation to learn Physics in secondary schools in Isiolo County.

ii. To find out the effect of Problem-Based Learning (PBL) approach on students' acquisition of critical thinking skills in secondary schools in Isiolo County.

1.5 Hypotheses of the Study

The study tested the following hypotheses:

$H0_1$: There is no statistically significant difference in motivation to learn physics between secondary school students taught through the PBL approach and those taught using conventional methods.

$H0_2$: The is no statistically significant difference in the acquisition of critical thinking skills between secondary school students taught through the PBL approach and those taught using conventional methods.

1.6 Significance of the Study

The findings of this study may provide physics teachers who intend to use PBL with an insight into effective ways of implementing the approach for enhanced' acquisition of critical thinking skills. Universities and colleges that train teachers could use the findings to strengthen the educational courses offered to their trainees by incorporating PBL in them. The findings may also be used by KICD to make the physics curriculum more effective by incorporating aspects of PBL when reviewing the subject's syllabus. Further, it is hoped that findings may be used as reference material by future researchers in physics education.

1.7 Scope of the Study

This study was conducted in the Isiolo County and involved only form twos in co-education public schools. It examined the effects of PBL on students' motivation to learn Physics and the acquisition of the subject's critical thinking skills. The critical thinking skills that the study focused on were analyzing, synthesizing, evaluating, and applying skills. These skills are the most applied ones in the learning of physics in secondary school. The topic Measurements II was covered, during the study. The topic was selected because it has been rated difficult for students by the Center for Mathematics, Sciences and Technologic Education in Africa (CEMASTEA) baseline survey (Protus & Shikuku, 2020).

1.8. Assumptions of the Study

The following assumptions were used to conduct this study:

(i) The measurements made during the study experiments were accurate as they were done using calibrated equipment.

(ii) The students were honest when responding to items in the motivation questionnaire.

1.9. Limitations of the Study

The study was conducted in Isiolo County, therefore the findings should be generalized to other counties in Kenya with similar characteristics but with caution due to differences in facilities and social environments.

1.10 Operational Definition of Terms

The following are definitions of the key terms:

Acquisition of critical thinking skills: The state of having attained an attribute as indicated by a measurable characteristic such as achievement (Tayyeb, 2013). In this study, acquisition of critical thinking skills refers to the cognitive process of students acquiring skills and it will be measured using the Physics Critical Thinking Test.

Conventional teaching approach: Refers to teaching approaches that involves instructors and the students interacting in a face-to-face manner in the classroom (Yap, 2016). In this study conventional teaching approaches will mean the regular approaches used by the teachers and are majorly teacher centered and does not involve problem based learning activities .It limits student's participation in the learning process.

Co-educational schools: These refer to male and female students being taught together in the same school or institution rather than separately (Knauth, 2008). In this study co-education means male and female students being taught in the same classroom.

Critical thinking skills: Critical thinking is a self-regulatory judgment that lead to interpretation, analysis, evaluation, and inference, as well as an explanation of the evidentiary, conceptual, methodological, or contextual aspects that led to that result (Lorencová et al., 2019). In this study, Critical Thinking Skills refer to students' abilities to

Analyze -This refers to a learner's capacity to break down a complex idea into its component elements and comprehend the organization and relationships between them.

Synthesize -This is the learner's ability to mentally assemble complicated ideas and experiences from a variety of sources into a new integrated and meaningful pattern within certain diaries.

Evaluate -this is a learner's ability to examine ideas or procedures based on external evidence or self-selected criteria supported by observations or rationalization.

Apply -the ability of students to apply concepts and principles to new situations, as well as laws and theories to real-world situations. The student's acquisition of the above mentioned skills were measured using their scores in CTSPT.

Effect: Refers to a change as a result or consequence of an action or other causes (Patte, 2019). In this study, effects refer to differences in motivation to learn and acquisition of physics critical thinking skills between students taught using PBL and conventional methods

Motivation to learn: It has been defined as an internal mechanism that energizes, directs, and sustains individual behavior (Wijnia et al., 2011). Motivation to learn Physics was assessed using the students' scores in the LMQ.

The problem-based learning (PBL): It is a teaching-learning process where Students learn through supervised problem-solving, working in small groups to solve problems that cover actual discipline-based knowledge (Mohammadi, 2017). In this study, PBL was adopted by a teacher facilitating learning of topic measurement 2 using the PBL module. It was characterized by students working together in small groups of about 5 members, solving a problem that forms a basis for learning new knowledge.

Teaching method: refers to the general principles, pedagogy, and management strategies used for classroom instruction (Hirsha et al., 2022). In this study method refers to a way of teaching using prescribed objectives and guidelines and the teacher has little or no leeway when it comes to implementation.

Teaching approach: is a set of principles, beliefs, or ideas about the nature of learning that is translated into the classroom (Bigozzi et al., 2018*).* In this study it refers to a way of looking at teaching and learning that gives rise to methods, the way of teaching, use of classroom activities or techniques to help students learn

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review. It covers the role of physics in society, the objectives of teaching physics in Kenya, the performance of physics in Kenya, Physics and Critical Thinking skills, Physics Instructional methods and their effectiveness, Problem-Based Learning approach (PBL), PBL and Motivation to learn Physics, PBL and Critical Thinking, PBL approach in teaching and learning of physics. Also covered is the theoretical and conceptual framework that guided the research.

2.2 Physics in Society

Physics is the study of the natural world from microscopic particles to macroscopic space. It has transformed societal knowledge of the universe, its philosophy, and its way of life. Before the advent of physics, most people believed that all answers to the unknown came from a supernatural or heavenly source. Scientists are now able to offer verifiable and testable answers to the mysterious questions of nature using Physics. In this way, they can change humanity's perspective, allowing people to see how scientific theories and discoveries have benefited mankind (Galesic et al., 2021) Many aspects of modern life would not have been possible without important physics-related innovations. The development of modern technologies is based on these insights. Discoveries such as magnetism, electricity, conductors, and others enabled modern conveniences such as television, computers, phones, and other business and residential equipment. Modern technologies of transportation, such as planes and telecommunications, have brought people from all corners of the globe closer together, and they all rely on physics concepts (De Weck et al., 2012).

2.3 Physics in Kenyan Secondary Schools

The objectives of teaching Physics in Kenya have been derived from the national goals of education. The content of a physics lesson is usually geared toward enabling learners to acquire knowledge, skills, and attitudes that should lead to the development of the individual and the Nation (Mutai et al., 2014). It is assumed that when physics lessons enable learners to acquire these desirable behavioral changes then the specific objectives of teaching physics have been achieved. 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 (Taran et al., 2016).

The teaching of physics in Kenya is intended to promote scientific knowledge about the physical world among the Kenyan people. 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 (Abungu et al., 2014). Unfortunately, only a few people study physics beyond high school; for this reason, the level of physics knowledge in Kenya is below expectations (Basweti, 2019). As a result, culture and religious beliefs influence peoples' understanding of the physical world. Another reason for teaching physics in schools is to sharpen Kenyans' logical thinking skills and promotion of scientific attitudes among the youth (Njoroge et al., 2014). Regrettably, only a few scientific investigations and practical work are conducted in schools. This is partly due to the inability of teachers to implement the Physics curriculum well and the fact that the majority of schools are inadequately equipped for practical work (Wambugu et al., 2017).

Technological development has also been among the aims of teaching physics in Kenyan schools (Kiptum, 2016). However, little progress has been made in this direction due to limited engagement in research, engineering, and industrial development. As a result, many problems such as crime, insecurity, and climate change have lacked lasting resolution due to inadequate knowledge of physics and the allied sciences (Uside et al., 2013). For the Kenyan secondary school curriculum to contribute significantly towards addressing issues like waste management affecting the country today, better ways of teaching physics and other sciences have to be found. The methods of Instruction used should prepare learners for further education, address vital issues like technological development, and lead to mastery of basic skills that are relevant to the everyday life of a learner and the world of work (Njoroge et al., 2014). It is expected that the findings of this study will promote better ways of instruction that lead to enhanced motivation to learn physics and the development of critical thinking skills in learners.

2.4 Performance in Physics in Kenya Secondary Schools

Physics performance in Kenyan schools has long been measured using students' grades in the subject in the National Examinations. Reports from the Kenya National Examinations Council (KNEC, 2018) have shown that the number of students who do not do well in Physics examinations has continually remained high. Besides the low performance, a large number of school leavers who did physics are not able to apply it to solve problems they encounter in their everyday life (Musasia et al., 2012). Several factors have been associated with low performance in Physics. Lack of instructional materials, inadequate laboratory facilities, and the limited number of trained physics teachers have been cited as factors that affect performance in Physics (Chala & Wami, 2020). According to Musasia et al. (2012) teaching physics in schools is ineffective and performance is low due to an inadequate number of teachers and laboratory technicians to help with organizing practical sessions well and increase the understanding of concepts.

Effective instructional leadership and management of schools have also been cited as the factors that affect performance in Physics (du Plessis, 2015). This is because good leadership and management create conducive environments for teaching and learning. Other factors associated with performance in physics include attitudes to the subject, school environment, teacher characteristics, motivation, and teaching methods (Taştan et al., 2018). The teaching of physics should be effective for school leavers to be equipped with knowledge and skills that are necessary for them to contribute effectively toward National development and technological advancement (Barnes, 2007). Instructional methods that are likely to help learners achieve innovativeness, skills development, and problem-solving ability should be embraced to ensure that school leavers are well-equipped for the challenges of everyday life and their world of work (Njoroge et al., 2014). The foregoing discussions show that instructional methods enhance students' critical thinking skills and performance in physics. However, there is hardly any literature on the association between instructional methods and students' acquisition of critical thinking skills and performance in Isiolo.

2.5 Physics Critical Thinking Skills

Critical thinking is a self-regulatory judgment that results in interpretation, analysis, evaluation, and inference, as well as an explanation of conceptual, methodological, or contextual factors that led to that outcome (Gholami et al., 2016). Reasonable reflective thinking focused on deciding what to believe or do is how critical thinking (CT) is characterized (Aizikovitsh & Amit, 2010). Teaching critical thinking skills entails instructing students on how to use concepts, principles, and procedures effectively to produce useful outputs and critical judgments (Yang & Gamble, 2013). Besides, critical thinking has significant implications for knowledge transfer and problem-solving abilities application in new settings (Dwyer et al., 2015). In this study, critical thinking will be viewed as the skillful conceptualization of information as a means of regulating beliefs and actions through reflective judgment. This position is opposed to the popular view in many instructional contexts in Kenya where students are often viewed as passive receptors of information (Shelly, 2017).

Critical thinking skills must be learned and used in academic courses as well as in decisions that students make (Yousefi & Mohammadi, 2016). CT skill's importance in the classroom can be seen in its involvement 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, the inclusion of provisions that foster the development of these skills may be more readily adopted as a necessary part of the instruction (Frederickson, 1979). This demands that a deliberate effort is made to ensure that instruction is embedded with aspects of CT for the effective development of the skills to be realized. Several critical thinking skills have been identified in the teaching of physics at secondary school. These include analyzing, synthesizing, evaluating, and applying (Drew, 2012). The meaning and significance of some of these skills are discussed in the sections that follow concerning the teaching of physics in Kenya.

2.5.1 Analyzing Skills

This refers to a learner's capacity to break down a complex idea into its component elements and comprehend the organization and relationships between them. In illustrative behavioural terms, a learner should be able to do the following: recognize logical mistakes in reasoning, analyze elements and relationships between elements, compare and contrast alternatives, and justify the adoption of certain procedures (Tyagi, 2017). 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 (Tyagi, 2017).

2.5.2 Synthesizing Skills

This is the learner's ability to mentally assemble complicated ideas and experiences from a variety of sources into a new integrated and meaningful pattern within certain diaries. The skill is expressed for instance when a learner assembles parts of a machine 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. Learners' responses to problems structured with verbs like categorize, combine, compile, compose, create, organize, devise, design, explain, generate, modify, organize, plan, re-arrange, reconstruct, relate recognize, revise, rewrite, summarize, tell, and write demonstrate their ability to synthesize (Tyagi, 2017).

2.5.3 Evaluating Skills

This is a learner's ability to examine ideas or procedures based on external evidence or self-selected criteria supported by observations or rationalization. It is the process of making value judgments regarding ideas or things; for example, when trying 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, compare, defend, describe, discriminate, explain, interpret, justify, relate, summarize, support (Tyagi, 2017).

2.5.4 Applying Skills

A learner can apply information and concepts in several contexts, as well as solve issues and create charts and graphs. The ability of students to apply concepts and principles to new situations, as well as laws and theories to real-world situations, demonstrates how to use a method or procedure correctly (Spiro et al., 1995). To evaluate the application, test items comprising crucial verbs like compute, discover, illustrate, manipulate, modify, operate, predict, prepare, relate, show, solve, and use can be employed. This is an example of how a learner can utilize Newton's third law of motion to calculate a rocket's takeoff speed. Students gain skills such as a scientific way of thinking, which is useful in many areas of life, the capacity to comprehend new material quickly and efficiently, and the ability to follow a rational and systematic path of thought (Moseley et al., 2005). The CT abilities mentioned are only a few instances to show how diverse the field is. The occurrence of the skills is determined by the learners' level and the subject matter at hand.

2.6 Physics Teaching Approaches

Teachers utilize a wide range of instructional approaches when teaching Physics. In a teacher-centered lesson, knowledge is assumed to be owned by the teacher and should be transmitted to the learners (Damico & Miranda, 2015). Without the teacher, there is little prospect that learners shall acquire the knowledge (Njoroge et al., 2014). This however is untrue given that learners may acquire a significant amount of knowledge from their everyday life and previous experiences. Extreme teacher-centered instruction, on the other hand, is regarded as a less effective way of teaching science because it does not promote the active participation of learners (Abungu et al., 2014).

The teacher's responsibility in the learner-centered approach is primarily to initiate learning and guide students. The teacher guides the learners through small steps of instructional materials as they step through a learning task. The approach is characterized by opportunities created for learners to predict, explore, and investigate scientific phenomena as they construct the required knowledge and skills. Modern thinking strongly favors a learner-centered approach to physics training since it enables students to participate more actively in the learning process. The strategy encourages the development of self-directed learning, which has been identified as a critical skill for encouraging lifelong learning (Abungu et al., 2014). 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 (Smith et al., 2018). Due to the limitations of either extreme of the teaching approach range, it is the consensus of the majority of educators that a teacher should adopt a blend of instructional methods that reasonably integrate both approaches to maximize effectiveness in instructional delivery (Njoroge et al., 2014). The meaning and significance of Physics Instructional Methods and the effectiveness of each are discussed in the sections below.

2.6.1 Class Experiments

As one of the methods of teaching science that teachers occasionally use, class experiments have been rated as the most effective approach to teaching physics. The method allows students to engage in hands-on learning activities which require them to gather data using apparatus while also learning how to manipulate data. For the method to be effective, the teacher must conduct experiments ahead of time, ensure that all apparatus are in working order, and provide students with clear and accurate directions (Orora et al., 2014). During experiments, teachers are required to maintain order and discipline in the laboratory as well as to ensure that learners can follow the required procedures in their work. 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 the apparatus is inadequate for all learners and when the available time is not enough for lengthy experiments. (Orora et al., 2014). The class experiment has little influence in terms of enhancing student knowledge and abilities, as a result, the efficiency of PBL as a secondary school alternative instruction technique is investigated in this study.

2.6.2 Class Demonstrations

A demonstration is an experiment that is performed by the teacher during physics instruction 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 (Okere & Mugendi, 2017). Through a demonstration, the teacher shows learners the procedure involved and with their help collects data and draws conclusions. To enhance the benefits associated with the method, it is recommended that the teacher should involve the learners as much as possible in experimenting, and where classes are too large, they should be divided into manageable group sizes to ensure that all can actively participate (Orora et al., 2014). A class demonstration is considered a traditional learning/conventional approach, since it is teacher-centered, with the teacher sharing or delivering knowledge. As a result, the efficiency of PBL as a secondary school alternative instruction technique is investigated in this study.

2.6.3 Class Discussion

A discussion is a conversation intended to achieve some specified goal. 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 proceedings of the discussion responsibly (Orora et al., 2014). The supervisory role of the teacher involves maintaining order and ensuring that all participants are given due attention and a 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. A discussion helps learners improve problem-solving skills, social skills, and divergent thinking by allowing them to exchange ideas. With good supervision, a discussion may enable the teacher to diagnose learners' difficulties and problems, and therefore be in a position to provide the necessary help. A badly monitored discussion, on the other hand, may allow students to become loud and reckless, preventing the lesson's objectives from being met (Orora et al., 2014). Science students have had little impact on the effectiveness of class discussions in terms of enhancing student knowledge and abilities. The impacts of PBL as an alternative instruction technique in secondary education are investigated in this research.

2.6.4 Informal Lecture

Lecture-based instruction refers to the type of teaching where the teacher provides information both orally and visually to students. Graphics organizers enable students to follow through with discussions and to build their understanding of concepts that are learned. The method is particularly helpful when teaching fact-based information. A major criticism against the lecture method has mainly been the way it passives students; learners are reduced to passive recipients of information with little provision for the development of science process skills. The method seems to be the most preferment mode of instruction when teaching large classes and when delivering a huge volume of content. Teachers are however encouraged to combine it with other methods such as class demonstration and discussions, to cushion the limitations it presents that inhibit its effectiveness (Wafula & Odhiambo, 2016). Because informal lecturing has had minimal impact on enhancing student knowledge and skills, this study examines the usefulness of PBL as an alternate instruction approach in secondary education.

2.6.5 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 from the analysis, and generalization. A project enables learners to achieve objectives in all the domains of learning. In the Current KICD curriculum in Kenya, 18 projects have been suggested for learners in physics. To enhance the utility of the projects to learners, it may be helpful if teachers would allocate enough time to their schemes of work as well as follow up each of the projects with intensive discussions on concepts, skills, and attitudes that may be deemed necessary (Wafula & Odhiambo, 2016). Because project work has had minimal influence on enhancing student understanding and skills, this study examines the usefulness of PBL as an alternate instruction technique in secondary education.

2.6.6 Excursions

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 a garage. Though expensive and time-consuming, the excursion can be very enriching to concepts taught in class, adding to their realism and also enhancing learners’ first-hand experience with them (Namasaka et al., 2017). When preparing students for an excursion, the teacher needs to ensure that learners have covered relevant topics. The teacher should also survey sites of interest to ensure that they conform to expectations that are necessary to meet the instructional objectives of the trip. If a field trip is not well coordinated, it may result in a loss of time and unwarranted interruption of the school program (Namasaka et al., 2017). This study looks into the effects of PBL as an alternative instruction technique in secondary school.

2.7 The problem-based learning Approach

In the present world, one of the main aims of science education is to aid students in developing scientific thinking. To achieve this, there is a need to create rich learning environments in which students are involved in inquiry-based tasks requiring cognitive processes used by scientists while conducting research. Such scientific thinking processes can be developed in students with the incorporation of PBL into the curriculum. (Han et al., 2016) .PBL works on multiple levels that may be broken down into three stages: the beginning stage, the PBL stage, and the end stage (Tsybulsky & Muchnik-Rozanov, 2019).

Group formation is the first activity in the first stage, which can be done administratively or by randomly allocating students to small groups during the first meeting session. Following that, the group is given a PBL task to study and comprehend (El-Shaer & Gaber, 2014). Identifying knowledge gaps, formulating hypotheses, identifying the learning difficulties and ideas to be learned, and defining "what they know," "what they don't know," and "what they need to know" are just a few of the specific steps taken at this stage. In this situation, the teacher serves as a facilitator, helping students through the PBL cycle (L’Heureux et al., 2012). Students begin the PBL stage by conducting an individual self-study (Dunlap, 2005), and then conduct a brainstorming and discussion session in groups (Puccio et al., 2020). They share and exchange knowledge about all of the learning challenges and hypotheses to arrive at an appropriate definition that is accepted by all members. Meanwhile, through direct observation and formative assessment, the facilitator keeps track of the group's development (Urhahne et al., 2010).

Direct observation includes coaching activities such as probing and questioning to provoke pupils' meta-cognition. Following formative assessment, the facilitator offers quick feedback and continually encourages students to conduct self-evaluation (Alrahlah, 2016). During the final meeting session of the stage, students prepare for a project presentation and assessment. Part of the students' solution suggestion is presented. Whether the students presented in groups or individually, the facilitator grades their work (El-Shaer & Gaber, 2014). Peer assessment is occasionally used to adjust a group's grade, resulting in individual marks for pupils. Other evaluation methods are also employed to track students' academic development (Panadero & Brown, 2017).

Educators in many disciplines have shifted away from traditional teaching and adopted student-centered approaches which are believed to enhance both thinking skills and the acquisition of knowledge (Fazio-Griffith & Ballard, 2016). It is an effective strategy for training students to work in a team, solve problems, and acquire communication and interpersonal skills needed to become active self-directed learners rather than passive receivers of information (Benadé, 2020). It was first used to teach medical students at McMaster University in 1968, but it is now used in different educational settings all around the world (Tarhan & Ayyildiz, 2015).

PBL has been very effective in many contexts where it has been used as evidenced by improved students' drive to reflect on their learning, problem-solving, and self-directed learning skills. Fostering critical thinking, conceptual comprehension, and intrinsic drive to become self-directed learners are some of the other important benefits associated with PBL (Gallagher, 2015). Many medical institutions in Sub-Saharan Africa and Kenya use PBL to train medical students because of its effectiveness in imparting knowledge and professional skills. The approach has also been used in secondary schools to enhance teaching-learning processes. However, there are hardly any published works on its effect on student’s motivation and physics critical thinking skills in Isiolo County, hence the need for the current study

2.8 PBL and Motivation to Learn Physics

The low enrolment in physics at the Kenya Certificate of Secondary Education is an indicator that most students are not motivated to learn physics (KNEC, 2010). One way the teacher can use to increase the student’s motivation to learn physics is by making physics learning enjoyable and interesting. PBL can be a valuable tool when it comes to bridging the gap between teaching and the student’s conceptual understanding of physics concepts. The proposed study intends to investigate the effects of using the Problem-Based Learning approach on student's motivation to learn physics and acquisition of critical thinking skills in Isiolo County. Motivation may be defined as the force that energizes, directs, and sustains behavior toward a goal (Arens et al., 2015). Researchers often find a correlation between motivation to learn and student achievement (Chamundeswari & Kumari, 2013). Many students today lack the motivation to be successful in school. This could explain the low levels of effort, inattention, poor task persistence, class cutting, and high rates of other discipline problems exhibited by students (Tran, 2019).

Two types of motivation: extrinsic, coming from external sources, are often tangible; and intrinsic, coming from within, are usually in the form of personal satisfaction (Goldstein et al., 2015). Students motivated by extrinsic factors strive for high grades and praise from teachers and family as rewards for achievement, whereas intrinsically motivated students enjoy learning the subject matter they are studying for its own sake (Wyk, 2012). Extrinsic inducements always work more quickly and powerfully than intrinsic ones, but extrinsic attractions must usually be offered indefinitely, for the behavior to continue.

Although intrinsic attractions work slower to motivate, they are usually more lasting once they take hold (Reid et al., 2015). Intrinsically motivated students are more interested in the subject matter, are more creative, and enjoy more difficult activities that challenge them. They take more risks in learning and explore more freely, and they have better study strategies that are efficient and logical (Deci, 1978). However, it is not always possible to intrinsically motivate students. According to Skaalvik et al. (2015) extrinsic motivations are often necessary to produce learning when the activity is one that students do not find of inherent interest or value.

One of the main causes of lack of motivation is the negative self-perception of students. Dweck (2013) found that students' self-perceptions of their ability (self-efficacy) could affect effort and level of persistence at difficult tasks. Learners with low self-efficacy tend to avoid challenges, expend little effort, and believe they are not in control of their learning (Schunk & Zimmerman, 2012). Many teenagers today are filled with self-doubt and are dealing with many internal problems, to begin with. Teachers must find a way to get students to believe in themselves to truly motivate them to learn.

Poor relationships between teacher and student are another cause of lack of motivation. Many students who choose to leave high school cite poor relations with teachers as among the most critical factors that influenced them to quit (Foussias et al., 2014). In a survey of twenty-five university graduates, many said they were victims of negative teacher influences. These negative influences ranged from a lack of interest in students and denigrating comments from teachers to a total lack of teacher support in high school (Cassady & Miller, 2012). The perception of supportive teachers is related to student outcomes in important ways. Perceived support from teachers is a significant predictor of young adolescents' motivation and academic achievement (Fan & Williams, 2018). When perceived support from parents, peers, and teachers is considered, perceived support from teachers has the most direct link to students' interest in school (Wentzel & Ramani, 2016). Teachers vary in the style they use to teach and motivate students. The quality of a student's motivation may depend on the quality of a teacher's instructional style (Weiner, 2014). According to Anderman and Koenka (2017) when students have a history of failure in school, it is particularly difficult for them to sustain the motivation to keep trying. Control, challenge, curiosity, and contextualization are the four C's that Ciampa (2017) uses to highlight complementary ways that can be utilized to improve intrinsic motivation. People are driven to exert control over their surroundings. The need for control or autonomy has long been recognized as a powerful drive. Bronson (2016) discovered that autonomy support is a significant component in enhancing an individual's intrinsic motivation after examining multiple studies. Giving pupils the option of choosing their learning activities boosts motivation. Even in the college classroom, reducing the instructor's authority over students increases students' motivation to learn (Ndungu, 2009). Teachers must find a method to give students a sense of control without giving up control. For at-risk kids, having a sense of control over their learning activities is critical.

According to Tulis and Fulmer (2013) students' motivation is strongly linked to how much control they think they have over their learning environments. When participants felt they had more control over decisions and options, they reported feeling more involved and competent. They were less bored, perplexed, and desirous of doing something else. People tend to seek out and appreciate things that are both tough and enjoyable. Many intrinsic motivation theories include this as a basic principle (Troia et al., 2012). The most motivating level of difficulty appears to be moderate. The activity should not be too simple or too difficult. Horak and Galluzzo (2017) discovered that students, particularly at-risk pupils, will report greater uncertainty and less competence if the difficulty is assessed to be excessively high. Curiosity is a powerful motivator. Teachers might pique a student's interest by presenting fresh material that is incongruent with existing knowledge (Fernandez-Rio et al., (2017). Demonstrations involving unusual circumstances can help pique students' interests. Motivation is increased through educational activities that promote contextualization of the subject matter. Seeing how skills may be applied in the "real world" gives students a sense of relevance and thus motivation to learn (Ciampa, 2017).

One type of instruction that has been demonstrated to increase student motivation is problem-based learning. PBL is a teaching method that has various potential benefits for pupils. Students must collaborate in groups to attain certain learning objectives in PBL. To be effective, PBL learning must have two crucial qualities. First and foremost, there must be shared objectives or good interdependence. To obtain any sort of recognition, grade, or incentive, students must work together as a group. Second, individual accountability is required. The groups must rely on each group member's particular learning (Wyk, 2012). Individual accountability gives the perception that each member of the group is important, whereas positive interdependence fosters a sense of "we," rather than "me." PBL intervention experiments have shown that students' intrinsic goal orientation improves for example, (Roh & Kim, 2015)discovered a rise in students' intrinsic goal orientation. Following the PBL intervention, children reported a stronger preference for challenging assignments, more curiosity, and a preference for figuring out problems on their own rather than seeking teacher assistance. Below are some motivation theories that support PBL's benefits in fostering critical thinking, conceptual knowledge, and intrinsic motivation to become a self-directed learner.

2.8.1 Self-Determination Theory (SDT)

A crucial concept is self-determination, which refers to an individual's ability to make decisions and manage their own life. This ability has a significant impact on the psychological health and well-being of the students. It provides students with a sense of control over their lives and decisions. It also has an impact on learners' motivation, as they are more likely to act if they believe their actions will have an impact on the outcome (Zee & Koomen, 2016). According to SDT, everyone should meet three fundamental psychological prerequisites to promote psychological growth and well-being: autonomy, competence, and relatedness. Internal control over study activities and the learning process is referred to as autonomy. Competence is the sensation of being capable of accomplishing study-related tasks. Finally, relatedness refers to the need to be consoled and supported by others, such as professors and classmates (Wijnia et al., 2019). As previously stated, SDT has been used in the learning context to claim that students are more likely to become intrinsically driven to study when the learning environment meets the three basic demands (Ommering et al., 2020). The degree of self-determination experienced is determined by the fulfillment of basic psychological desires.

Several types of extrinsic motivation are proposed as part of a self-determination continuum in SDT, which goes beyond the classic intrinsic-extrinsic incentive divide. In the classic distinction, an extrinsic incentive is seen to be harmful to learning performance. Extrinsic motivation, on the other hand, is not always detrimental to learning performance, depending on the level of autonomy (Ulstad et al., 2016). Instead, contrasting autonomous versus controlled motivation is a better way to illustrate the distinction between different types of motivation. A high amount of self-determination characterizes autonomous motivation. Individuals who are autonomously driven participate in an activity because it interests or fascinates them (intrinsic motivation) or because it allows them to grow personally (Ryan & Moller, 2017). Even though it is extrinsic, the latter argument is fully accepted and integrated with the self (i.e., the activity is not done for its purpose). Controlled motivation, on the other hand, is characterized by a lack of personal liberty. Students study to avoid embarrassment and gain pride, as well as to receive a reward or avoid punishment (i.e. external regulation) (i.e. introjected regulation). According to a prior study, autonomous motivation and learning behavior have a good relationship.

Taylor et al. (2014) revealed a robust, positive correlation between autonomous motivation and academic achievement in a meta-analysis. Studies from elementary school, high school, and college were included in the meta-analysis. Furthermore, autonomous motivation has been shown to improve deeper learning and persistence in a variety of educational programs in high school and college students (Mouratidis et al., 2018) better concentration and time management in Chinese university students, and lower dropout intentions in American high school students (Kryshko et al., 2020). Controlled motivation, on the other hand, is connected with undesirable study behaviors such as performance anxiety and dropout while being adversely correlated with focus and time management. The goal of PBL is to boost students' intrinsic (or self-motivation) motivation (Carrabba & Farmer, 2018).

The introductory conversation, the self-study phase, and the reporting phase are the three phases of PBL. The learning process begins with a collaborative discussion about a realistic topic (e.g., a description of a real-life experience). Students attempt to explain the problem using common sense and past knowledge. When the problem is utilized as the beginning point for the learning process, students' comprehension of the topic is restricted, therefore they cooperate to construct questions regarding the problem's to-be-learned components, which are referred to as learning concerns. Students look for and analyze acceptable literary sources on their own to address their learning challenges in the second PBL phase, self-study. Students return to the tutorial group after self-study to review the literature and work collaboratively on learning barriers (i.e. the reporting phase). During the initial chat and reporting phase, a tutor is present. When students spend too much time on issues that aren't important, a tutor can help by interrupting. Rather than providing students with factual information, he or she asks probing questions to ensure that they elaborate on course material (Wijnen et al., 2017). Certain features of PBL, it may be argued, enhance sentiments of autonomy, competence, and relatedness, and hence students' autonomous motivation. When students have a say and influence on their education, their desire for autonomy is stimulated (Kanat et al., 2017). PBL is designed to improve student autonomy in a variety of ways. Because it is student-centered, students have control over their learning, and tutors serve as facilitators. Teachers' facilitation or mentoring roles in student-centered learning are seen to assist students in meeting their autonomy demands in SDT (Gu, 2021).

Due to its emphasis on self-regulated learning, PBL also gives students a variety of options. Instead of receiving prepared learning worries from the teacher, students, for example, develop their learning challenges. Furthermore, kids gain autonomy by selecting and choosing their reading materials. In a PBL scenario Wijnia et al. (2015) discovered that allowing students to choose their literary resources resulted in greater autonomous motivation scores than giving them mandatory literature materials by an instructor. As they advance through the academic program in PBL, students gain more autonomy. For example, first-year students receive more help than third-year students (e.g., more tips in giving a reading and active scaffolding by the tutor).

When students feel accomplished in their studies, they are considered competent. Giving positive, constructive feedback is one approach to assist with this (Deci et al., 2001). The tutor provides formative input on how students behave during PBL tutorial group meetings (i.e. preparation for and participation in the reporting phase). Another strategy for anticipating feelings of competence is to assign activities that are based on real-life situations that must be explained or addressed. These "realistic" and "authentic" exercises may help students feel more competent and confident in dealing with situations they may face in real life and later in their careers (Dunlap, 2005). Students are more likely to feel confident in such situations if they believe they can handle them, which contributes to SDT's second demand, competence. A sense of belonging, the third need, has a favorable impact on pupils' intrinsic motivation (Wang et al., 2019). Students want to feel connected to and cared for by significant people in their lives, including teachers and classmates in the classroom. It is simpler for students to form friendships in a small, collaborative group setting (1–5 students), which helps to boost their sense of relatedness. This idea is supported by the fact that PBL students found collaborating in tutorial groups to be stimulating (Wijnia et al., 2014). During PBL small-group talks, a tutor is present. Because the groups are small, the tutor may provide more individualized advice as needed and demonstrate an interest in all of the students, fostering a sense of belonging.

2.8.2 Self-efficacy Theory of Motivation

People's views about their capacities to achieve particular levels of performance and exert control over events that affect their lives are referred to as self-efficacy. People's feelings, ideas, and behaviors are influenced by their self-efficacy beliefs (Pajares, 2012). A high sense of efficacy benefits human achievement and personal well-being in a variety of ways. People who are confident in their abilities view tough tasks as challenges to overcome rather than dangers to avoid. Intrinsic interest and deep engrossment in activities are fostered by such an effective outlook. They set challenging goals for themselves and stick to them with devotion. In the face of failure owing to insufficient effort or a lack of obtainable information and expertise, they do not increase their efforts. They approach dangerous situations with the confidence that they can handle them. Such a positive approach resulted in personal accomplishment, reduced stress, and reduced risk of depression. People who are unsure of their abilities avoid challenging tasks that they perceive as personal risks.

Academic motivation has also been demonstrated to be influenced by self-efficacy views. Students who believe in their skills are more likely to participate, study more, persevere longer, and have fewer negative emotional reactions when faced with obstacles than students who doubt their abilities (Skinner, 2016). Goal-setting, self-monitoring, self-evaluation, and strategy use are examples of self-regulatory practices that self-efficacy advocates say provide students a sense of control over their learning. The more capable students estimate themselves to be, the more difficult the goals they pursue (Zimmerman & Schunk, 2012). Schunk and Benedetto (2016) looked at how important self-efficacy is in academic learning. Students' perceptions of their abilities to learn new information, perform skills, master a subject, and so on shift at the outset of an activity. Self-efficacy is influenced by aptitude (abilities and attitudes) as well as prior experience.

Students' work is influenced by personal elements such as goal setting and information, as well as situational factors (such as rewards and teacher comments). These criteria give students information on how well they're learning, which they can use to assess their efficacy for future learning. When students believe they are making progress in their studies, they are more driven. As a result, students maintain a sense of self-efficacy for performing well as they work on projects and absorb more knowledge. The use of a PBL teaching style is expected to boost students' confidence in their abilities and their ability to perform academically in physics.

2.9 PBL and Critical Thinking Skills

Critical thinking, as well as creative thinking, problem-solving, and decision-making, are examples of higher-order thinking abilities (Dwyer et al., 2015). The formation of successful problem-solving and thinking is connected with critical and creative thinking (Wechsler et al., 2018). Complex cognitive skills may be taught systematically, according to evidence (Sumarni & Kadarwati, 2020). As a result, higher-order cognitive skills such as critical thinking have always been the ultimate purpose of education (Walker & Spendlove, 2018).

PBL is widely thought to help students improve higher-order thinking skills, particularly reasoning ability (Moallem, 2019). Students-centered learning is the core of PBL, which is based on constructivist learning theory theories. Knowledge acquisition becomes one of the criteria for strengthening students' critical thinking abilities in this scenario (Masek & Yamin, 2012). Knowledge and working memory, according to Masek (2012) are vital in the development of higher cognitive skills. This is especially true because knowledge is useful in both the practical, social, and psychological senses. Critical thinking, according to Dwyer and Walsh (2020) is rational and reflective thinking aimed at deciding what to believe or do. It's a method for making analytical decisions to arrive at a logical, rational, and reasonable solution to a problem.

Critical thinking, according to some authors, is the method by which a person who has been taught to reason solves an issue (Bezanilla et al., 2019). As a result, the analytical reasoning process must reach logical, rational, and reasonable conclusions inside a specified framework, as well as follow certain thinking rules (Spector, 2019). Furthermore, critical thinking inside a specific framework must be appropriate for the context. Others believe that critical thinking is tied to the importance of a person's judgment (Aizikovitsh-Udi & Cheng, 2015). This judgment value may have an impact on the students' answers in a given situation. Critical thinking, on the other hand, must be measured in terms of the overall structure of reasoning ability, regardless of context, when reasoning capacity is valued (Maulidiya & Nurlaelah, 2019). Additionally, according to Aloqail (2012) investigating the structure of reasoning is important since it expresses the wide meaning of reasoning capacity based on what an individual believes. PBL may promote critical thinking capacity through the problem-solving process, particularly during group brainstorming sessions, according to the above conceptual definition (Masek, 2012). Throughout these sessions, students critically evaluate the best possible answer for the topic at hand. Before making any conclusions, a facilitator oversees the process and is accountable for investigating their meta-cognitive thinking (Ahmadi & Ismail, 2012).

When students are given probing questions, it is considered that they are engaged in a systematic cognitive process that aids in the development of thinking abilities. Other procedures, such as debate, disputing, sharing, and educating one another, allow students to participate in a critical thinking setting (El-Shaer & Gaber, 2014). Interaction, reflection, and feedback in the problem-solving or formative assessment process help students improve critical thinking, particularly reasoning skills (Masek & Yamin, 2012). The positive impact of PBL on students' higher-order thinking skills, particularly critical thinking ability, is well documented. Experiential Learning Theory says that students acquire cognitive methods by addressing a problem, which supports the notion of "learning by doing" in the PBL methodology. The facilitator then urges students to think critically to come up with the best answer (Jabarullah & Hussain, 2019).

2.10 Theoretical Framework

This study was grounded on the Social Constructivism learning theory. It is based on Jerome Bruner's work which is regarded by many as the founding principle of the theory. The theory contend that learning occurs through interactions with the environment (Omodan, 2022). The learners have an active role in constructing their knowledge, and the existing cognitive structure of the learner determines how new information is perceived and processed (Francis, 2018). If the new information makes sense to the existing mental structure of the learner, then it is assimilated. However, if the new information is different from the existing mental structure of the learner, it is either rejected or accommodated (transformed in ways so that it fits into the structure). These ideas are the core concepts of the constructivist view of the learning process. Constructivists emphasize that learning is an active process in which learners construct new ideas or concepts based on their prior knowledge and experience (Cho, 2021). This they do by attempting to translate information into something meaningful to them, organizing it in their minds, and storing it in meaningful patterns that would allow satisfactory retrieval (Amineh & Asl, 2015).

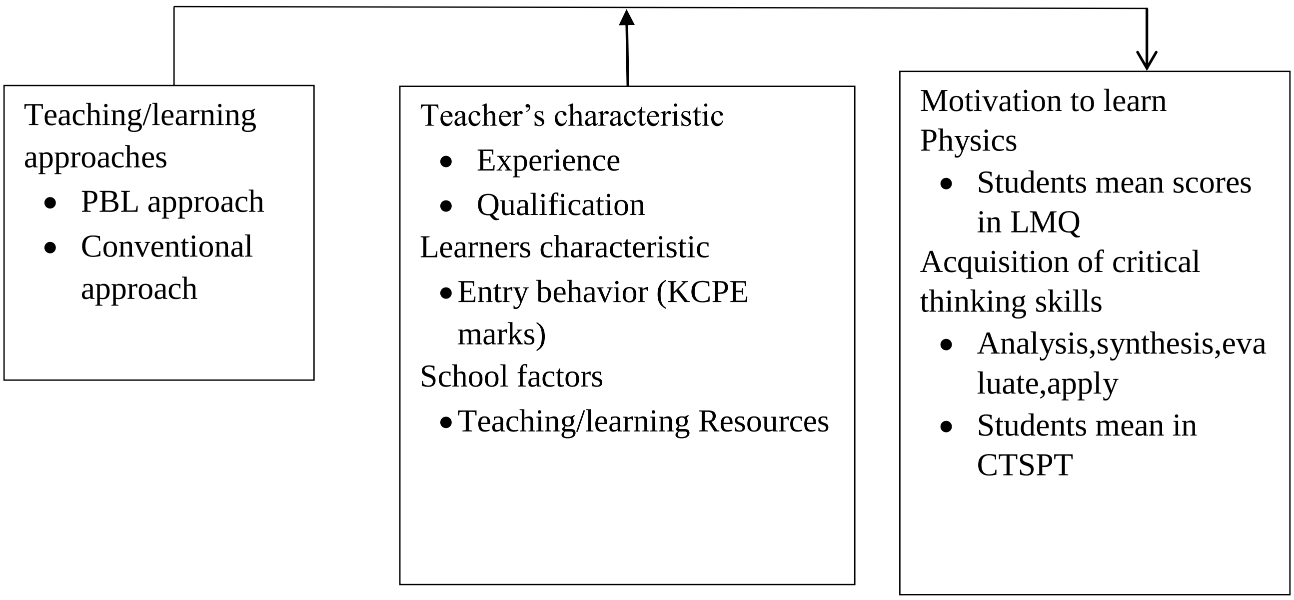
Constructivists view the learner as active in the learning process rather than as a passive recipient of knowledge, while the teacher is a facilitator, guiding so that learners can construct their knowledge (Judith, 2018). The constructivist theory was deemed appropriate because solving problems is the main learning activity in a social constructivist context; learning is active, reflexive, and collaborative, and involves activities that allow students to explore, manipulate objects, ask questions, and try things. Similarly, this study adopted PBL which is a student-centered approach that views learners as individuals who construct their knowledge and understanding of the world through experiences encountered when solving problems.

2.11 Conceptual Framework

This study was based on the foundation that motivation to learn Physics and the acquisition of critical thinking skills depends on the teaching approach utilized by the instructor. The relation between the variables is illustrated in Figure 1.

Figure 1

Conceptual framework showing interactions between Independent and Dependent Variable



Independent variable **Intervening variables** **Dependent variable**

Problem Based learning approach together with conventional teaching approach were treated as the independent variables in this study while motivation and acquisition of critical thinking skills were the dependent variables. Under ideal conditions motivation to learn Physics and acquisitions of critical thinking skills were dependent on teaching approach. Under real situation the students' motivation and acquisition of critical thinking skills may be influenced by students' characteristics such as entry behaviours, teachers' characteristics such as level of professional training and experiences and school characteristics especially facilities may determine the teaching approach a teacher uses and how effective the teacher used it may also influence students 'motivation and acquisition of critical thinking skills.

These factors are therefore treated as intervening variables and their effect was controlled by selecting students with similar academic abilities, selecting schools with almost the same facilities and involving teachers with a minimum qualification of a degree in education and with more than four years teaching experience.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The methodology that was adopted during the study is presented in this chapter. The chapter discusses the research design, location of the study, population, sampling procedures and sample size, the instruments, their validation, and reliability. The development and implementation of the instructional module, data collection and analysis procedures, and ethical considerations are also discussed in the chapter

3.2 Research Design

Three research approaches, qualitative, quantitative, and mixed methods are used when conducting studies (Creswell & Creswell, 2018). The quantitative approach was adopted during this study. The selection of the approach was based on the fact that this inquiry was mainly concerned with examining the effects of PBL on motivation and acquisition of critical thinking skills in physics by comparing quantitative data among groups. This study employed the Quasi-experimental Solomon Four Non-Equivalent Control Group research design. The design was deemed appropriate because secondary school classes exist as intact groups once they are formed, and school administrators dont allow such classes to be reconstituted for research purposes. The intact classes were randomly assigned to the four groups of this design. Figure 2 depicts the research design.

Figure 2

Solomon Four Non- -equivalent Control Group Design

Group	**Notation**		
E_1	O_1	X	O_2
C_1	O_3	_	O_4
E_2	_	X	O_5
C_2	_	_	O_6

Key:

X was the treatment where learners were taught using the PBL approach.

E_1 was the experimental group that received a pre-test, treatment X, and a post-test.

C_1 was the control group, which received a pre-test followed by the control condition and finally a post-test.

E_2 was given treatment X and a post-test.

C_2 received the post-test only.

C_1 and C_2 were taught using conventional teaching methods.

3.3 Location of the Study

The study was conducted in Isiolo County. The County is bordered on the north by Marsabit County, on the east by Wajir County, on the south by Garissa and Tana River counties, on the southeast by Meru County, on the southwest by Laikipia County, and the west by Samburu County. It covers an area of 25,336 square kilometers. The County comprises three sub-counties namely; Merti, Garbatula, and Isiolo. The Somali, Borana, Meru, Turkana, Samburu, and Rendile are the most populous ethnic communities in the County. The County's economy is based on pastoralism and agriculture. There were 38 secondary schools in the County, with 16 of them being co-educational. The study location was selected owing to the poor performance recorded in KCSE Physics examinations by schools. In addition, there was limited literature on the Isiolo County concerning the effects of the Problem-Based Learning approach on students' motivation to learn Physics and acquisition of critical thinking skills

3.4 Target Population of the Study

The population is the entire group of individuals, events or objects with observable characteristics of interest to the researcher. The study's target population was 640 form two students from all secondary schools in Isiolo County. The accessible population was 265, comprising form two students in Isiolo sub-county in co-education secondary schools which offer physics as an optional subject in KCSE. (Isiolo County Director of Education, 2021) The sub-county was chosen because it has been recording the lowest performance in KCSE physics compared to Merti and Garbatula (KNEC, 2017, 2019, 2022). Sub-County co-education public schools were chosen as a way of ensuring that those selected had similar characteristics in terms of teaching or learning resources, learners' entry behavior, and teachers' qualifications. The form twos was selected because the topic Measurements Two is taught at that level and it's also not a national examination class (Kigo et al., 2018).

3.5 Sampling Procedures and Sample Size

Four co-educational secondary schools participated in the study. Purposive sampling was used to select schools with the same characteristics. Resources and physics teachers experience were factors that were considered when selecting these schools (Etikan et al., 2016). Isiolo sub-county has four existing zones. This created four zones that were used as the strata. Stratified sampling was then used to group the qualifying schools into the four strata to control the diffusion effect. One school was selected randomly from each stratum, yielding four sample schools that were used in the study.

Simple random sampling was used to allocate the four schools into the experimental and control groups. The sampling unit was the schools rather than individual learners because secondary schools operate as intact groups. Each school provided one form two class to participate in the study. For experimental schools with more than one stream, all form two classes were taught using the PBL approach. Simple random sampling was used to select one stream after the post-test had been administered for data analysis. The sample size of students was 128, which was determined by summing up all the students in the four classes that participated in the study. Of these, 63 were eventually placed in the experimental groups while 65 were in the control groups.

3.6 Instrumentation

Learner's Motivation Questionnaire (LMQ), and the Critical Thinking Skills Physics Test (CTSPT) were used to collect data while a teaching manual was used by teachers who utilized PBL. Development of the test 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 (Golightly & Raath, 2015). This means that, by defining aspects of Critical thinking Skills to be measured for each of the items on the CTSPT test, learners' scores had a high likelihood of representing their acquisition of respective critical thinking skills.

3.6.1 Critical Thinking Skills Physics Test (CTSPT)

The Test was constructed by the researcher based on past KCSE Physics questions. The questions were moderated by two Physics teachers. It comprised of short answers questions. The test was used to assess the acquisition of critical thinking skills which are most commonly required to be acquired by students and whose reinforcement is simple to achieve (Basweti, 2019). The skills included analysis, synthesis, evaluation, and application. The test comprised 40 close-ended items, the first 10 measured analysis, the second 10 items elicited data on synthesis, the third 10 items were on evaluation, and the last 10 items measured application. The minimum score was zero, and the maximum possible score was one point per item. It was first administered as a pre-test to one experimental and one control group. It was also used to assess the students' prior knowledge. The items of the CTSPT were rearranged and then administered as a post-test to all groups after the treatment. The test was marked out of a total of 40 marks. A summary of acquired skills and how they were measured is presented in Table 4.

Table 4

Components of Physics Critical Thinking Skills

Skill	Items	Action verb
Analysis	Numbers 1 to 10	Point out, Identify, Outline Distinguish, Illustrate, Differentiate, Subdivide
Synthesis	Numbers 11 to 20	Design, Explain, Tell, Compose, Compile, Generate, Interpret, Categorize, Rewrite
Evaluation	Number 21 to 30	Generate, Interpret, Justify, Show, Critique, Evaluate, Explain, Judge, Appraise
Application	Number 31 to 40	Discover, Defend, Show, Prepare, Solve, Compute, Predict, Relate, Prepare, Solve

3.6.2 Learner's Motivation Questionnaire (LMQ)

A questionnaire was used to measure learner’s motivation to learn physics. The researcher adopted and modified Githua's (2013) student motivation questionnaire. It contained items on students’ socio-background and psychological concepts of motivation such as curiosity, persistence, learning, and performance. The instrument was constructed using 28 close-ended 5-point Likert scale items which generated responses that span from strongly disagree to strongly agree. It was administered as a pre-test to the E1 and C1 groups, as well as a post-test to all of the groups.

3.6.3 Teaching manual

A PBL manual which served as a teaching kit, was developed by the researcher. The manual aimed at organizing classroom activities into academic learning experiences. The study considered physics teachers teaching form two with four years and above teaching experience. Four teachers from the four sample schools participated in the study. Teachers in experimental group underwent a two weeks training facilitated by the researcher on how to use the manual in teaching. This manual covered twelve lessons in three weeks by the experimental group teachers. The experimental group were taught this twelve lessons using PBL approach. The control group was taught the same content for same duration of time but using the Conventional teaching approach. Upon the expiry of the twelve lessons, critical thinking skill physics post- test was administered to both experimental and control groups and the scores recorded by the researcher.

3.6.4 Validation of the Instruments

Experts from the Department of Curriculum Instruction and Educational Management, Egerton University were requested to examine the content and face validity of LMQ and CTSPT. Content validity establishes whether a test measures what it is intended to measure while face validity ascertains whether the content of the test appears to be suitable to its aims (Mohajan, 2017). The comments and recommendations of these experts were used to refine the instruments before they were used to collect data.

3.6.5 Reliability of the Research Instrument

The two instruments, LMQ and CTSPT were piloted to ensure their reliability. An instrument is considered reliable when it consistently provides the same results if used with the same respondents on different occasions (Taherdoost, 2016). The reliability of the tools was estimated using samples from schools that were not part of the study but located within the County. The reliability coefficient of LMQ was estimated using the Cronbach Alpha method. The method was selected because it is recommended for estimating the reliabilities of instruments constructed using close-ended Likert-type items, and are administered once (Warmbrod, 2014). LMQ yielded a reliability coefficient of 0.793. The reliability of CTSPT was estimated using the Kuder-Richardson (KR- 20) formula. The formula is considered ideal for estimating the reliability of tools constructed using items that have varying difficulties, are scored as either right or wrong, or whose means can be computed (Kara & Çelikler, 2015). CTSPT yielded a reliability coefficient of 0.741. Based on these observations, LMQ and CTSPT were believed reliable since their coefficients were above the 0.7 thresholds.

3.7 Data Collection

A permit to conduct the study was sought from the National Commission for Science, Technology, and Innovation (NACOSTI) after getting clearance from the Board of Post-Graduate Studies at Egerton University. Once the permit was issued, the researcher sought permission to collect data from the Isiolo County Commissioner and Director of Education. The researcher then formally contacted the physics teachers and students through their respective principals. The purpose of the study was explained to the respondents and their consent to take part in it was sought. Training on how to implement the module for teachers in the experimental schools was done by the researcher for one week. Thereafter, LMQ and CTSPT pre-tests were given to C1 and E1 groups before the commencement of teaching measurement 2. The experimental groups, E1 and E2 were taught utilizing the Problem Based Learning approach for three weeks, while the control groups C1 and C2 were taught using conventional methods. At the end of the teaching, LMQ and CTSPT were administered to each of the 4 groups (E1, E2, C1, C2), and the data generated was used as the posttests during analysis.

3.8 Data Analysis

The collected data were checked for errors and entered in a data file prepared using the Statistical Package for Social Science (SPSS). The Listwise deletion, which is a Statistical Package for Social Science (SPSS) package default standard was used to exclude missing items when analyzing data (Field, 2018). The ANOVA and t-test were used to test hypotheses at the .05 level of confidence. The statistical procedures were chosen because, when parametric assumptions are not violated, a t-test is ideal for determining differences between two groups, while ANOVA is recommended for comparing more than two groups (Field, 2018). Given that the groups were homogenous before the commencement of the program, differences in motivation to learn physics and critical thinking skills observed at the end of teaching the topic Measurement 2 were attributed to the effects of the treatment. The statistical procedures used in the inquiry are summarized in Table 5.

Table 5

A Summary of Data Analysis

Hypotheses	Independent variable	Dependent variable	Statistical Methods
HO_1 There is no statistically significant difference in student motivation to learn physics between those taught through the PBL approach and those taught using conventional methods	Teaching approach	Motivation to learn physics	Mean, ANOVA, t-test
HO_2 There is no statistically significant difference in the acquisition of critical thinking skills between students taught through the PBL approach and those taught using conventional methods	Teaching approach	Acquisition of critical thinking skills	Mean, ANOVA, t-test

3.9 Ethical Considerations

Ethics has been defined as a system of moral principles that people use to decide the rightness or wrongness of actions (Powell et al., 2018). In research, ethics is concerned with the dos and don'ts, to protect, respect, and ensure the safety of respondents (Daka, 2022). These concerns include; consent, courtesy and respect, privacy and safety of the subjects, and treating people equitably. Attempts were made to adhere to ethical guidelines during the study. The researcher began the data collection process only after receiving approval from the Egerton Ethics Committee, a permit from NACOSTI, and clearance from relevant education managers in Isiolo. Before the commencement of data collection, the participants were informed about the research objectives and procedures, and their consent to participate in the study was sought. The participants were also informed that they were free to withdraw from the study at any time they felt like. Anonymity and confidentiality were ensured by restricting access to the provided data using locked cabinets and passwords. Attempts were made to minimize plagiarism by listing in reference all the sources cited in the thesis.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the study. Both descriptive and inferential statistics are used during the presentation of the results. The results are organized in the following order:

i. Pre-test analysis
ii. Effects of the Problem-based Learning Approach on Secondary School Students' Motivation to Learn Physics.
iii. Effects of the Problem-Based Learning Approach on Secondary School Student's Acquisition of Critical Thinking Skills in Physics.

Each of the results was discussed in relationship with similar studies done in the past.

4.2 Pre-test Analysis

The entry behavior of the students was examined by pretesting groups E1 and C1 on motivation to learn Physics and acquisition of critical thinking skills before the commencement of the study. Pre-testing was conducted to ascertain whether the study groups were homogeneous as it is one of the assumptions of the Solomon 4 quasi-experimental Non-Equivalent control group research design adopted by this study. The pre-test entailed comparing students' mean scores on motivation to learn physics and critical thinking skills mean scores by teaching approach. The comparison was conducted using the t-test, the results of which are shown in Table 6.

Table 6

Results of the t-test comparing students' Motivation to Learn Physics and Critical Thinking Skills pre-test means scores by Teaching Approach

Scale	Teaching Approach	N	Mean	SD	Df	t-value	p-value
Motivation	E1	38	3.14	0.54	75	1.086	.281
	C1	39	3.26	0.47			
Critical thinking skills	E1	38	7.63	2.63	77	1.746	.085
	C1	39	6.62	2.51			

Motivation to learn Physics: Critical values (df = 70, t = 1.990, p = .05)
Critical thinking skills: Calculated values (df = 77, t = 1.086, p > .05)

Table 6 shows that concerning motivation, the mean score (M = 3.26, SD = 0.47) of C1 was not statistically significantly different from that (M = 3.14, SD = 0.54) of E1, t (75) =1.086, ρ > .05. Table 5 further shows that the difference between the critical thinking skills mean score of E1 (M = 7.63, SD = 2.63) and that (M = 6.62, SD = 2.51) of C1 was not statistically significant, t (77) = 1.746, p>.05. These results are evidence that the two groups were homogenous on both motivation to learn physics and acquisition of critical thinking skills before commencement of the research. The groups were therefore suitable for the study given that this is a requirement of the Solomon Four Non-Equivalent control group research design which was adopted.

4.3 Difference in Student's Motivation to Learn Physics by Learning Approach

Objective one of the study sought to find out the difference in motivation to learn Physics between students exposed to PBL and those taught using conventional methods. The difference was determined using post-test mean scores of groups E1, E2, C1, and C2. The motivation to learn Physics post-test mean scores and their standard deviations for the four groups are summarized in Table 7.

Table 7

Students' Motivation to Learn Physics Posttest mean scores and their SD

Group	N	Mean	SD
E1	36	3.24	0.73
E2	27	3.27	0.40
C1	35	3.23	0.43
C2	30	3.11	0.33

An examination of the results in Table 7 indicates that motivation to learn physics post-test mean scores of groups E1 (M = 3.24, SD =0.73) and E2 (M = 3.27, SD = 0.40) were higher than those of the control groups C1 (M = 3.23, SD = 0.43) and C2 (M = 3.11, SD = 0.33). The results further indicate that the standard deviations of all the groups were less than 1. This is an indication that there were small variations among individual mean scores in the groups. The higher mean scores of the groups (E1 and E2) that were exposed to PBL suggest that the teaching approach affected motivation to learn Physics.

The ANOVA test was used to find out whether the difference among the groups was statistically significant. This test compares variability in means scores between groups with that of within groups. The F-ratio, which is the variance between groups divided by variance within groups was computed and used as an indicator of differences. The results of the ANOVA test are presented in Table 8.

Table 8

Comparison of Motivation to learn Physics between students exposed to PBL and those taught using Conventional Methods

Scale	Sum of Squares	Df	Mean Square	F-ratio	p-value
Between Groups	.453	3	.151	.588	.624
Within Groups	31.856	124	.257		
Total	32.309	127			

Critical values: (df = 3,120, F= 2.680, p = .05)

Calculated values (df = 3,124, F = .588, p > .624)

The ANOVA test results show that the differences among the motivation mean scores of E1, C1, E2, and C2 were not significant at the .05 level, F (3,124) = .588, ρ > .05. An examination of the results in Table 8 show that the F-ratio was small, meaning that the variability within groups was wider than that of between groups. This implies that PBL was not more effective in boosting students' motivation to learn compared to the conventional teaching approach.

Additional analysis was conducted to find out whether there was a significant difference between the combined post-test means scores of treatment groups (E1 and E2) and control groups (C1 and C2). A t-test analysis was utilized during the comparison. The results of the test are in Table 9.

Table 9

Comparison of Students' Motivation to Learn Physics Post-test mean Scores between Control and Experimental groups

Category	N	Mean	SD	df	t-value	p-value
Experimental	63	3.25	0.60	126	.829	.409
Control	65	3.18	0.39			

Critical values (df = 120, t = 1.980, p = .05)

Calculated values (df = 126, t = .829, p > .05)

The t-test results revealed that the mean score of the treatment group was higher than that of the control group. However, the difference was not statistically significant, t (126) =

.829, p > .05. These results reveal that PBL did not have more impact on motivation compared to conventional methods.

Gain is the difference between the pre-test and post-test mean scores and is an indicator of changes (increase or decrease) in groups after undergoing treatment. Gain analysis was conducted to give an insight into the relative effects of treatment on groups that were pretested. The mean gains of E1 and C1 were calculated using their pre-test and post-test scores as shown in Table 10.

Table 10

Students' Motivation to Learn Physics means Gain and their Standard Deviations by Teaching Approach

Group	Pre-test		Post-test		Mean Gain
	Mean	SD	Mean	SD	
E1 (n = 40)	3.14	0.56	3.24	0.73	0.10
C1 (n = 39)	3.26	0.47	3.23	0.43	-0.03

Table 10 shows that the motivation to learn physics mean of E1 (M = 3.14, SD = 0.54) and C1 (M = 3.26, SD = 0.47) were similar before the treatment. After the treatment, the mean score of E1 increased to 3.24 (SD = 0.73) while that of C1 declined to 3.23 (SD = 0.43). The mean gains of E1 and C1 were therefore 0.1 and -0.03 respectively. The improvement in the mean score of E1 was thus higher relative to that of C1. A t-test was conducted to establish whether the difference between the mean gains of the two groups was significant. The results of the t-test are given in Table 11.

Table 113

Comparison of Students' Motivation to Learn Physics Mean Gain of E1 and C1

Category	N	Mean	SD	Df	t-value	p-value
Experimental	36	0.10	0.97	69	.704	.484
Control	35	-0.03	0.70			

Critical values (df = 70, t = 1.994, p = .05)

Calculated values (df = 69, t = .704, p > .05)

The t-test results indicate that the difference between the mean gain of E1 and C2 was not statistically significant, df (69) = .704, p> .05). All the analyses comparing students' motivation to learn physics by teaching approach posted statistically insignificant differences.

Based on these results, the first null hypothesis which stated that the difference in motivation to learn physics between secondary school students taught through the PBL approach and those taught using conventional methods is not statistically significant was rejected.

The comparisons done on motivation to learn Physics by teaching approach showed that the PBL approach was not more effective in improving students' motivation to learn Physics compared to conventional teaching methods. These findings are in line with those of a study by Argaw et al. (2017) which showed insignificant improvement in motivation to learn between students exposed to the PBL approach and those taught using conventional methods. They noted that PBL is effective only if students are organized and facilitated to work in groups, consulting and sharing experiences that arouse interest in learning and enhance their liking and value of a subject. These experiences which enhance motivation may not be realized if PBL is not implemented well.

These findings support those of a study by Fukuzawa et al. (2017) which revealed that PBL did not enhance students' motivation to learn in health sciences. The study attributed the observation to the pedagogical view that students require adequate background knowledge in a subject area to effectively engage in the problem-based learning processes. Perhaps this was lacking given that those who were involved in the study were form twos who had not covered much of the secondary school Physics curriculum.

However, the findings are contrary to Rotgans and Schmidt's (2019) assertion that exposure to PBL impacted positively students' motivation to learn a subject compared to conventional teaching methods. They argue that PBL arouses students' interest in learning and has a significant effect on their interest, liking, and value of the subject. The results are also not in harmony with those of Mahanan et al. (2021) who noted that the PBL strategy improves students' motivation to learn physics. The enhanced motivation was attributed to the fact that PBL provides students with opportunities to interact and make fun as they learn. The results are further not in line with those of Achuonye's (2010) study which revealed that the PBL approach improved secondary school students' motivation to learn Biology. The study attributed high levels of motivation among students exposed to PBL to its real-life nature and collaborative learning.

The findings of Mahanan et al. (2021) and Wijnia et al. (2014) which showed that PBL was more effective in improving motivation compared to conventional methods also contradict these findings. The insignificant effect of PBL on motivation could perhaps be due to the way it was implemented. Woodrow et al. (2020) argue that motivation is enhanced only if the students are provided with adequate learning materials, lessons are well-planned and organized, and the psychological needs of learners are taken care of. The insignificant effect of PBL could also be due to the Physics knowledge base of the students. The respondents have formed 2 students whose general knowledge of Physics was low as they have not covered a large percentage of the syllabus. Barber et al. (2015) contend that prior knowledge is a key determinant of the success of PBL in enhancing motivation to learn since group dynamics, interest, and achievement of knowledgeable students are higher.

The observed insignificant difference in enhancing students' motivation to learn physics between the PBL approach and conventional methods could also be attributed to the fact that it's not easy to change students' motivation to learn physics given that the treatment took only three weeks. Soh et al. (2022) argue that motivation is a construct that is affected by many factors and requires time to change. They further argue that motivating students requires not only a change in teaching methods but also greater knowledge of what motivates learners and ways of maintaining their engagement in academic activities.

4.4 Difference in Student's Acquisition of Critical Thinking Skills in Physics by Learning Approach

The second objective sought to establish the difference in students' acquisition of Physics critical thinking skills among groups E1, E2, C1, and C2. CTSPT was administered to the students (post-test) after they had been taught the measurement topic. The test measured four dimensions of critical thinking skills, namely; analysis, synthesis, evaluation, and application. Critical thinking skills mean scores of E1, E2, C1, and C2 were computed and used to determine the differences between the control and experimental groups. The descriptive statistics of Critical Thinking Skills in Physics post-test are presented in Table 12.

Table 12

Students' Critical Thinking Skills in Physics Post-test Mean Scores and Their Standard Deviations

Skill	E1 (n = 36)		E2 (n = 27)		C1 (n = 35)		C2 (n = 30)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Analysis (max = 10)	5.89	2.30	4.52	2.15	3.86	1 .87	3.47	1.53
Synthesizing (max = 10)	4.86	1.81	4.89	1.12	3.97	1.98	3.33	1.71
Evaluation (max = 10)	5.86	1.79	5.56	1.48	4.17	1.82	4.43	1.70
Application (max = 10)	2.83	2.34	4.22	1.74	2.20	1.92	4.03	2.19
Critical thinking skills mean scores (max = 40)	19.44	5.72	19.19	3.76	14.20	4.78	15.27	4.41

Table 12 shows that E1 had the highest analysis mean score (M = 5.89, SD = 2.30) while (M = 3.47, SD = 1.53) C2 was the lowest. The mean scores of synthesis ranged between 3.33 (SD = 1.71) for C2 and 4.89 (SD = 1.12) for E2 while evaluation means were between 4.17 (SD = 1.82) for C1 and 5.86 (SD = 1.76) for E1. Concerning application, the mean scores ranged between 2.20 (SD = 1.92) for C1 and 4.22 (SD = 1.74) for E2. The application mean scores were generally low, this could perhaps be due to difficulties students encounter when called upon to apply critical thinking skills to solve problems (Adeyemi, 2012). KNEC (2019) also noted that students tended to perform poorly in physics questions that require higher-order cognitive abilities such as analysis, evaluation, and application. The overall critical thinking skills mean scores of the groups ranged between 14.20 (SD = 4.78) for C1 and 19.44 (SD = 6.67) for E1. An examination of these results shows the overall critical thinking skills mean scores of the experimental groups, E1 and E2, were higher than those of the control groups C1 and C2. This suggests that PBL enhanced students' critical thinking skills.

The difference in Physics critical thinking skills between students taught using PBL and those taught using conventional methods was established by testing the second hypothesis**.** This hypothesis stated that the difference in critical thinking skills achievement between students taught using PBL and those taught using conventional methods was not statistically significant. The comparison was conducted using the ANOVA test. Table 13 shows the results of the ANOVA test.

Table 13

Differences in students' Critical Thinking Skills Achievement post-test scores among E1, E2, C1, and C2.

Group	Sum of Squares	Df	Mean Square	F-ratio	p-value
Between Groups	708.5	3	236.167	10.267	.000*
Within Groups	2852.43	124	23.003		
Total	3560.93	127			

Critical values: (df = 3, 120, F= 2.680, p = .05)

Calculated values (df = 3, 124, F = 10.267, p = .000)
*Significant at .05

The results in Table 13 reveal that the difference among the means scores of E1, C1, E2, and C2 was statistically significant at the .05 level, $F(3,124) = 10.267$, $\rho < .05$. This is an indication that there is a significant difference somewhere among the mean scores of the groups. The ANOVA test results only showed that there were statistically significant differences among the groups, but it did not reveal where the differences were, There was the need for further analysis to reveal the pairs groups with statistically significant differences. The difference between the pair groups was determined using the Post Hoc test, the results of the test are summarized in Table 14.

Table 14

Post Hoc test comparing Students' Critical Thinking Skills mean scores by Teaching Approach

Paired group		Mean Difference (I – J)	p-value
I	J		
E1	E2	0.26	.997
E1	C1	5.24	.000
E1	C2	4.18	.008
E2	C1	4.99	.001
E2	C2	3.92	.027
C2	C1	1.07	.850

Table 14 shows that the difference between pairs E1 and C1 ($p < .05$), E1 and C2 ($p < .05$), E2 and C1 ($p < .05$), and E2 and C2 ($p < .05$) were statistically significant. However, the difference between pairs E1 and E2 ($p > .05$), and C1 and C2 ($p > .05$) were not statistically significant. These results imply that the groups E1 and E2 were similar. They also imply that C1 and C2 were similar. However, the mean scores of the experimental groups were higher and significantly different from those of the control groups. The enhanced performance of the experimental groups could be attributed to the treatment. Additional analysis was carried out using the post-test mean score of the combined treatment groups (E1 and E2) and control groups (C1 and C2). It involved running a t-test, as shown in the summary of results in Table 15.

Table 15

Comparison of students' Critical thinking Skills post-test Mean score between Control and Experimental Groups

Category	N	Mean	SD	Df	t-value	p-value
Experimental	63	19.33	4.94	126	5.498	.000*
Control	65	14.69	4.61			

Critical values (df = 120, t = 1.980, p = .05)

Calculated values (df = 126, t = 5.498, p < .05)

Table 15 shows that the combined experimental group posted a higher mean (M = 19.33, SD = 4.94) than the control group (M = 14.69, SD = 4.61). The table further shows that the difference between the two means was statistically significant in favor of the experimental group, $t(126) = 5.498$, $p < .05$. The statistical significance could have been due to the impact of PBL. Additional analysis was done using the mean gains of groups that were pretested (E1 and C1) to ascertain whether the significant difference observed during previous tests was due to the effects of the treatment. The gain made by groups E1 and C1 is summarized in Table 16.

Table 16

Students' Critical Thinking Skills in Physics mean Gain and their Standard Deviations by Teaching Approach

Group	Pre-test		Post-test		Mean Gain
	Mean	SD	Mean	SD	
E1	7.63	2.63	19.44	5.72	11.81
C1	6.62	2.51	14.20	4.78	7.58

The results contained in Table 16 indicate that the pre-test mean scores of E1 (M = 7.63, SD = 2.63) and C1 (M = 6.62, SD = 2.51) were similar before the commencement of treatment. After the treatment, the mean of E1 and C1 were M = 19.44 (SD = 5.72) and M = 14.20 (SD = 4.78) respectively. The mean gains were thus 11.81 for E1 and 7.58 for C1. This means that the experimental group improved by a wider margin compared to the control group. Further analysis was conducted using the t-test to determine whether the mean gains of E1 and C1 were statistically significant. Table 17 presents the results of the test.

Table 17

Comparison of Students' Critical thinking Skills post-test Mean Gain between the Control and Experimental Groups

Category	N	Mean	SD	Df	t-value	p-value
Experimental	36	11.81	6.80	69	2.557	.013
Control	35	7.58	5.41			

Critical values (df = 70, t = 1.994, p = .05)

Calculated values (df = 69, t = 2.557, p < .05)

The results in Table 17 reveal that the difference between the mean gain of E1 (M = 11.81, SD = 6.80) and that of C1 (M = 7.58, SD = 5.41) was statistically significant, t (69) = 2.557, p < .05. It means that the improvement in the treatment group was significantly higher than that of the control. It suggests that PBL had a significant positive effect on critical thinking skills. All the comparisons of post-test critical thinking skills by learning approach done using ANOVA, t-test and the gain analysis revealed statistically significant differences in favor of the experimental group. These results do not support the second hypothesis which stated that the difference between the critical thinking skills of students taught through the PBL approach and those taught using other methods was not statistically significant. The hypothesis was thus rejected.

The pre-test analysis showed that before the commencement of the study groups E1 and C1 were similar. However, after the intervention, the critical thinking skill levels of the experimental groups were higher and significantly different from those of the control groups. This means the PBL approach was more effective at improving students' acquisition of critical thinking skills compared to conventional methods. These findings are in harmony with those of a study conducted in Sumatra by Rozi et al. (2021) which showed that PBL enhanced students' Physics critical thinking skills. The study attributed the improvement in critical thinking skills to the fact that PBL provides learners with opportunities to analyze problems and resolve them. These findings also support those of Wulandari and Shofiyah (2018) who observed that discussions in the realm of problem-solving had a positive impact on students' abilities to think critically. They noted that the students’ arguments during the PBL were based on concrete and valid evidence which activated their critical thinking skills. Ulger (2018) asserted that PBL enhances critical thinking because it is rich in debates, and provides students with opportunities to elaborate their answers by giving critical and logical explanations.

This study has demonstrated that PBL is effective in improving students critical thinking skills. However, other studies have noted results that are contrary to this one. Lapuz and Fulgencio (2020) established that there is no differential effect of PBL on the student's critical thinking skills. Alrahlah (2016) noted that PBL sometimes does not improve students’ critical thinking because of its shortcomings. The shortcomings identified were; that students tend to get frustrated easily when carrying out investigations, their access to questions from the teacher is reduced, and are less confident when learning independently. Fadilla et al. (2021) contend that the adoption of PBL is not a guarantee that students' critical thinking skills will be improved. Critical thinking skills are enhanced only when teachers and students can apply each stage of PBL well. The approach enhances critical thinking skills only if groups or teamwork are well organized, as this provides students with the opportunity to empower, hone, test, and develop the ability to think continuously.

Physics is considered one of the hardest subjects in secondary schools and is believed that only gifted students understand its concepts and practices which require critical thinking skills (Aini et al., 2019). However, these findings show that PBL improves students’ physics critical thinking skills. PBL improves skills because it is a student-centered teaching approach that promotes analysis, evaluation, understanding, and application of the concepts, rather than recall of factual knowledge (Lapuz & Fulgencio, 2020). PBL could therefore be used with other teaching approaches in secondary schools to enhance students’ acquisition of knowledge, critical thinking and skills in other areas, and performance in physics.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This study investigated the effects of the PBL approach on secondary school students' motivation to learn Physics and the acquisition of critical thinking skills in Physics. The study focused on the Physics topic Measurement II. The summary of findings, conclusions, recommendations, and suggestions for further research are presented in this chapter.

5.2 Summary of the Findings of the study

The study was guided by two specific objectives, the first one was to find out the difference in motivation to learn physics between students exposed to the PBL teaching approach and those taught using conventional methods. The results indicated that students exposed to PBL were less motivated compared to their counterparts taught using conventional teaching methods. Objective two was to find out the difference in acquisition of critical thinking skills of students taught using the PBL approach and those taught using conventional methods. The findings revealed that the critical thinking skill levels of students exposed to PBL were higher than those of their colleagues taught using conventional method.

5.3 Conclusions

Based on the findings of this study, the following conclusions were made:

i. PBL was less effective in improving motivation to learn physics when compared to the conventional teaching methods. This could be due to inappropriate utilization of the approach or other factors that enhance motivation such as the availability of equipment instructional materials and a conducive learning environment.

ii. The PBL approach was more effective in boosting students' acquisition of critical thinking skills compared to conventional teaching methods. This was attributed to the fact that, when PBL is utilized, students are taught concepts and principles using real-world problems rather than through the direct presentation of facts and concepts. This helps in the development of abilities to analyze, reflect reason, organize hypotheses, synthesize, define, and solve problems, attributes that are essential for critical thinking.

5.4 Recommendations

The study demonstrated that PBL enhances students’ acquisition of critical thinking skills. Based on the findings, the following recommendations are made:

i. Teachers be encouraged to blend PBL with other teaching approaches during Physics lessons as a way of enhancing the acquisition of critical thinking skills. This would boost students’ mastery of critical thinking skills, other higher-order cognitive skills, and performance in the subject.

ii. Regular seminars and workshops on teaching approaches for practicing physics teachers be organized by the Minister of Education and other stakeholders. This would sharpen the teachers’ pedagogical skills.

iii. Institutions that train teachers such as Universities and colleges may incorporate PBL in their teacher training programs. This would equip their graduates with the ability to utilize PBL and enhance teaching effectiveness upon completion of training.

5.5 Suggestions for Further Research

Several issues came up during this study that could form a basis for further investigation. They include:

i. A study of the effects of other correlates of motivation to learn Physics, given that the effectiveness of the PBL approach in enhancing motivation to learn Physics was comparable to that of conventional methods.

ii. This study was conducted in Isiolo County and involved only co-education schools in Isiolo Sub County. Even though the study provided valuable findings on the effects of PBL on the acquisition of critical thinking skills, it is believed that future studies involving both private and public schools from several counties would improve the generalizability of the results.

iii. The study covered one topic, Measurement 2, and demonstrated that PBL enhanced learners’ acquisition of critical thinking skills. It would be interesting to find out whether similar results would be realized with other topics in the secondary schools' physics curriculum. This calls for studies on other topics.

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APPENDICES

Appendix A: Form Two Critical Thinking Skills Physics Test For Students

The Critical Thinking Skills Physics Test (CTSPT) is a test given to students to measure their level of Critical Thinking Skills development 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 students at high school. All that is required is for a student to solve each test item to the best of their knowledge. Confidentiality is assured.

Time: 50 Minutes

Answer all questions in the spaces provided

School Code: ……………………..

No: ………………...

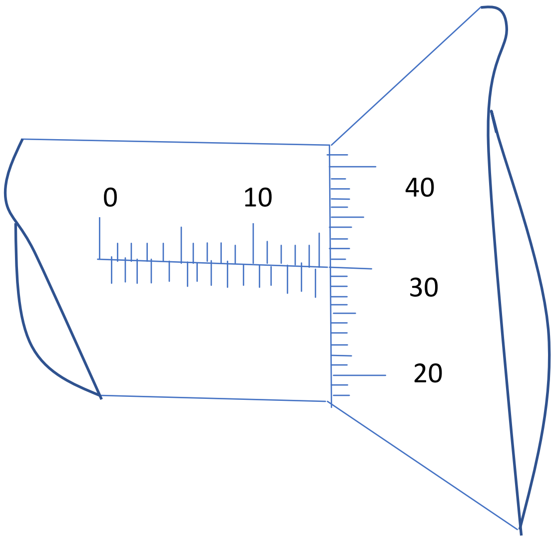
1. **Point out** one reason why the topic measurements are taken in Physics (1 mark)

2. **Identify** the instrument that would be the most suitable for measuring the thickness of one sheet of paper (1 mark)

3. **Outline** one limitation of using a micrometer screw gauge to measure (1 mark)

4. **Distinguish** between the main scale and a vernier scale in a vernier caliper (1 mark)

5. **Point out** the reading shown on the micrometer screw gauge represented in the figure below that has a thimble scale of 50 divisions. (1marks)



6. **Point out** the function of the ratchet in a micrometer screw gauge (1 mark)

7. **Outline** one advantage of a digital micrometer. (1 mark)

8. **Point out** one disadvantage of a digital micrometer (1 mark)

9. **What** is zero error as used in measurement? (1 mark)

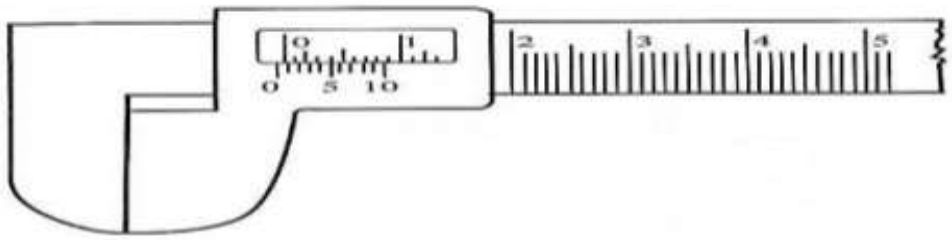
10. **Illustrate** zero errors using -0.24 on a Vernier Caliper. (1 mark)

11. **Design** a micrometer screw gauge with a zero error of +0.17 (1 mark)

12. **Explain** how you would measure the internal diameter of a $100cm^3$ beaker using a vernier Calipers (1 mark)

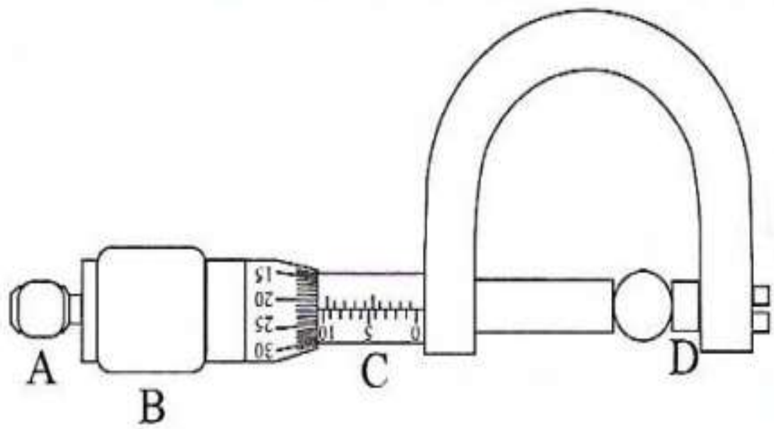
13. **Tell** ways in which the zero error is corrected in a Vernier caliper (1 mark)

14. **Compose** the zero Error of the vernier calipers in the figures below (1 mark)



15. If the correct diameter of the object in question 12 above is 3.65cm, **compile** the readings of the calipers for this diameter? (1 mark)

Use the figure of the micrometer screw gauge below to answer questions 14 to 18.



16. **Name** the part marked A (1 mark)

17. **Name** the part marked B (1 mark)

18. **Name** the part marked C (1 mark)

19. **Name** the part marked D (1 mark)

20. **Generate** the reading shown by the scale (1 mark)

21. A micrometer screw gauge reads 5.78mm. **Interpret** its actual reading if it has a zero error of -0.12 mm. (1 mark)

22. A micrometer screw gauge reads 6.78mm. **Justify** its actual reading if it has a zero error of +0.19mm (1 mark)

23. **what** is the standard form of 2670 (1 mark)

24. **Evaluate** standard form of 0.0000009057 (1 mark)

25. **Complete** the area of a rectangle measuring 3.93cm by 5.35cm. Relate your answer correctly to decimal places. (1 mark)

26. The diameter of the patch was estimated at 200mm for an oil drop with a radius of 0.25mm in an attempt to estimate the size of one oil molecule. **Justify** the diameter of the oil molecule. (1 mark)

27. A student used a vernier caliper to measure the internal diameter of a glass tube. The student repeated the experiment four times and recorded the result as shown in the table

Experiment	Diameter in cm
1	2.3661
2	2.3
3	2.36
4	2.36619

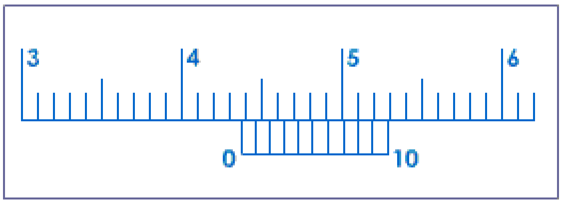
Explain the reading which was accurately taken (1 mark)

28. A vernier caliper with a negative zero error of 0.03 was used to measure the diameter of a spherical object and the measurement was recorded as 3.25cm. **Show** the correct volume of the sphere in cubic meters. (Take π as 3.14) (1 mark)

29. **Critique** the meaning of accuracy of an instrument? (1 mark)

30. **Explain** the meaning of the term least count as used in measurements 2 (1 mark)

31. The diagram shown is a section of Vernier Calipers. **Show** the least count of the instrument



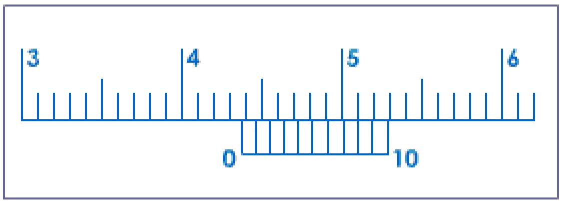
(1 mark)

.

32. Using the diagram on Question 31 above, **Compute** final reading, which is the thickness of a metal sheet? (1 mark)

33. **Predict** one environmental hazard that may occur when oil spills over a large surface area (1 mark)

34. **Relate** the thimble scales of two-micrometer screw gauges, one with a 0.5mm pitch and the other with a 1.0mm pitch. (1 mark)

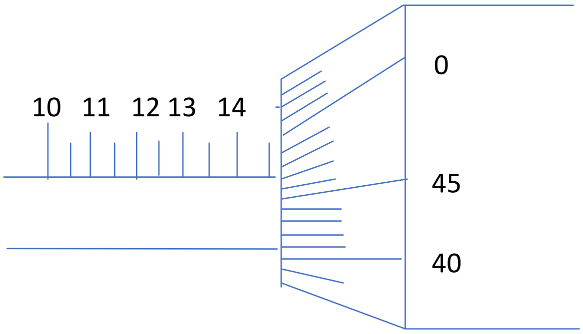


35. **Show** a micrometer screw gauge whose scale read 5.05 (1 mark)

36. **Show** how the least count in a vernier caliper is calculated (1 mark)

37. Give one advantage of using a micrometer screw gauge over the vernier calipers in measurement (1 mark)

38. **Prepare** the reading of the micrometer screw gauge in the figures below? (1marks)



39. In an experiment to estimate the thickness of an oil molecule, an oil drop of diameter 0.5mm spreads on the water surface to form a circular patch of diameter 200mm. **Compute** the volume of the oil drop. (1 mark)

40. **Solve** the area of the patch in Question 39 above. (1 mark)

Appendix B: Learners Motivation Questionnaire (LMQ)

School Code…………………………………………………………………….

Form/Stream………………………………………………………

Student Adm No…………………………………………………………………….

Directors For Students

My name is Siad Barre, and I am an Egerton University Master of Education Curriculum and Instruction student. I'm doing a study in secondary schools in Isiolo Sub County to see how the Problem-Based Learning Approach affects students' motivation and critical thinking abilities in Physics on the theme Measurements 2. The goal of this survey is to learn about your thoughts on the physics course. The information you provide in this survey will only be used for research purposes. This form investigates your readiness to take part in physics class. You will be asked to agree or disagree with each statement. There are no correct or incorrect replies. I'm looking forward to hearing what you have to say. Think about how well each item describes your desire to engage in physical activity. Please rate how much you agree with each of the assertions in the following questions. TICK the letters that best describe your level of agreement in the table.

Key

SD – Strongly Disagree

D – Disagree

U – Undecided

A – Agree

SA – Strongly Agree

	Questions	SD	D	U	A	SA
1.	Physics is one of my favorite subjects.					
2.	Physics is a difficult subject to understand.					
3.	I like the hours I spend doing Physics the most.					
4.	Physics is a subject that I am very willing to learn.					
5.	I find it hard to work independently on Physics problems.					
6.	I rarely expect to be able to apply Physics in life situations					
7.	I rarely anticipate succeeding in physics exercises assigned by the teacher in the classroom.					
8.	Physics provides me with opportunities for personal growth.					
9.	During the holidays, I practice solving Physics questions on my own.					
10.	I rarely expect to perform well in Physics-related subjects.					
11.	I expect to be able to solve Physics problems anywhere I come across them if they are of my level of education.					
12.	I can work independently in Physics exercises in and out Physics classroom.					
13.	I expect to get high scores on Physics tests.					
14.	I expect to be able to apply Physics easily to other situations in life.					
15.	I am satisfied with the way I learn Physics.					
16.	Learning Physics is in itself rewarding.					
17.	I am dissatisfied with my participation in Physics classroom activities.					

18.	I am satisfied with the way Physics is taught in the Physics classroom.					
19.	I am satisfied with my performance in Physics assignments, tests, and examinations. I aspire to study Physics after KCSE.					
20.	I am not sure whether there is a need for me to continue studying Physics.					
21.	I find activities in Physics lessons meaningful.					
22.	Physics subject is related to my daily experiences.					
23.	Physics is relevant to my needs and goals both in school and at home.					
24.	Physics gives me opportunities for choice, responsibilities, and interpersonal influence.					
25.	Physics lessons give me opportunities for cooperative social interaction.					
26.	I would like a career that does not require Physics.					

Appendix C: PBL Instructional Module and Teachers Guide

Topic: Measurements 2

Duration: 12 Lessons

Period : 3 Weeks

Specific Objectives

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

(a) Measure length using vernier caliper and micrometer screw gauge
(b) Express quantities with the incorrect number of decimal places and the correct number of significant figures
(c) Express measurement in standard form
(d) Estimate the diameter of an oil molecule
(e) Solve numerical problems in measurement

Topic Arrangement.

Measurement of length using vernier caliper and micrometer screw gauge (4 Lessons)

Decimal places, significant figures, and standard form (2 Lessons)

Estimation of the diameter of the molecule of oil, effects of oil spill on health and environment (3Lessons)

Numerical Problems Solving in Measurements 2 II (3 Lessons)

During the first lesson, the teacher facilitates the group formation of about 5 learners and each group picks a secretary and a chairperson. Learners will be made to understand that they will learn a new topic called "Measurements 2" for three weeks but using a new method of learning. The new method requires 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 will be led to understand that the problem will not be clearly defined for them given that it is similar to many other problems that they encounter in everyday life. For this reason, they will be asked to spend some time understanding what the problem requires to be done.

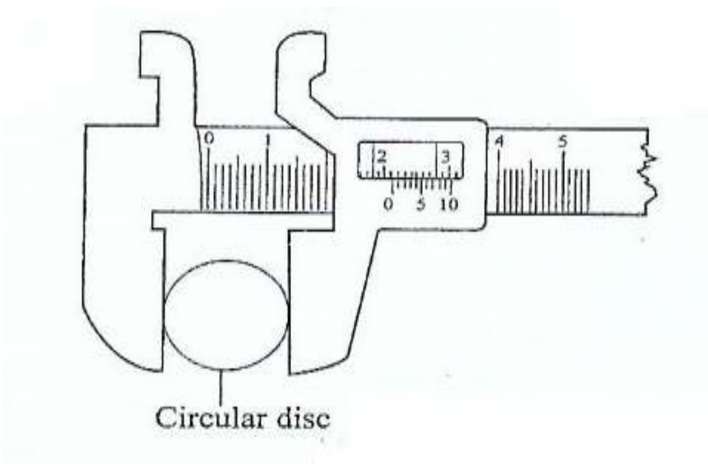
To be able to successfully solve the problem, they will be made to understand that they will have to search for as much relevant knowledge as they can from any sources they can identify. They will be encouraged to conduct experiments of their choice under the supervision of the teacher whenever they find that helpful. They simply don'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 would be able to solve any other problem on the topic including those in the textbooks as they have done previously using teacher-led discussions.

The class will be informed that the new method of learning will demand that they work in groups that will continue to the end of the topic

PBL Task 1 :

What is the diameter of the circular disc in the figure below?

Fig 1



Requirements

A vernier caliper, a thin wire, a ball bearing a test tube

Lesson Objectives. By the end of the lesson, the learners should be able to use a vernier caliper to measure the diameter of a circular disc and a ball bearing

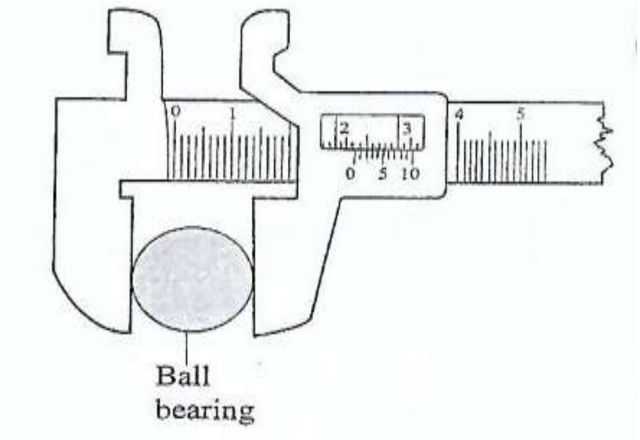
Procedure:

In measurement, the basic instrument for measuring length was the meter rule.

Measurement for lengths such as a diameter of a wire and that of a test tube, which cannot be obtained directly using an ordinary ruler, are done using calipers and a micrometer screw gauge.

How to measure the diameter of a wire, a ball bearing, and a test tube.

Set-up



Procedure

i. Place the object whose diameter is to be measured between the outside jaws. Close the jaws till they just grip the object

ii. Record the reading on the main scale, opposite and to the left of the zero mark of the vernier caliper (from the fig it is 2.3 cm)

iii. Read the vernier scale mark that coincides exactly with the main scale mark. The fourth mark of the vernier scale coincides exactly with the main scale mark. This gives the reading of the least count

= 4 x 0.01

= 0.04 cm

The sum of the vernier scale reading and the main scale reading gives the diameter of the ball bearing.

Therefore the diameter of the ball bearing using a magnified figure as shown below is

= (2.3 + 0.04) cm

= 2.34 cm

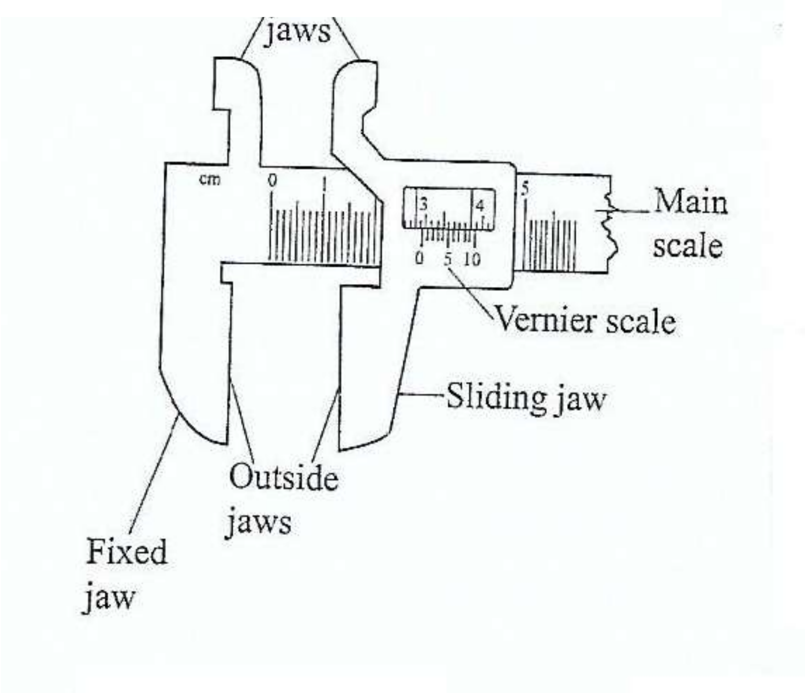
PBL task 2: Making a model of vernier calipers (25 min)

Requirements

Manila paper, glue, ruler, and razor

Lesson objectives. By the end of the lesson, the learner should be able to make a model of a vernier caliper using locally available materials and name all the parts of a vernier caliper

Set-up



Procedure

i. Using Manila paper make your vernier caliper. The main scale should run from 0 cm to 8 cm.
ii. Measure the diameters of different objects using your vernier caliper
iii. Repeat the procedure using a vernier caliper from the laboratory and compare your results.

What do you conclude about measurement 2?

PBL task 3: zero error (25 min)

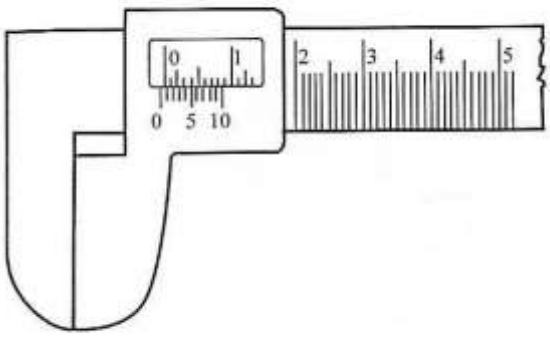
What is the Zero error of the vernier calipers below?

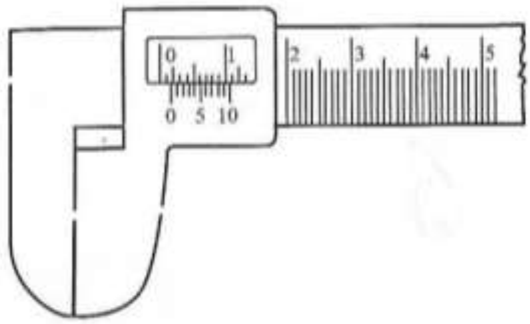
Requirements

Vernier calipers with positive and negative zero errors

Lesson Objectives. By the end of the lesson, the learner should be able to know what a zero error is, the types of zero errors, and how to correct them in real situations

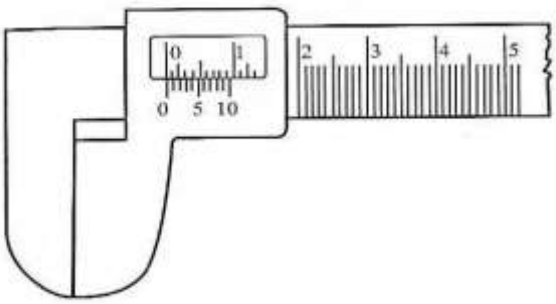
Set-up





Procedure

When the jaws of the vernier caliper are closed without an object between them, the zero mark of the main scale should coincide with the zero mark of the vernier scale as shown below

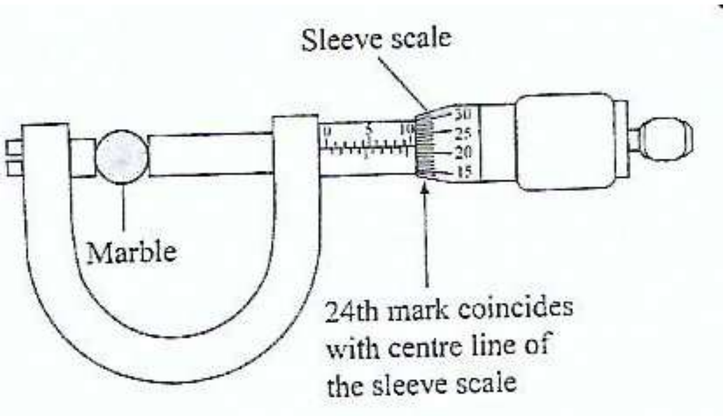


If the zero mark of the main scale is to the right of the zero mark of the vernier scale, in this case, the zero error is negative, hence the measured diameter is less than the actual diameter. This is corrected by adding zero errors to the reading.

When the error is positive, the zero error is subtracted from the measured diameter to get the correct value of the diameter.

PBL Task 4: Use a micrometer screw gauge to measure the diameter of a marble.

What is the reading of the micrometer screw gauge shown below?



From the figure, the sleeve reading is 10.5 mm and the thimble scale reading is 24/100 mm= 0.24 mm

Thus the diameter of the marble

= sleeve reading + thimble reading

= 10.5 mm + 0.24 mm

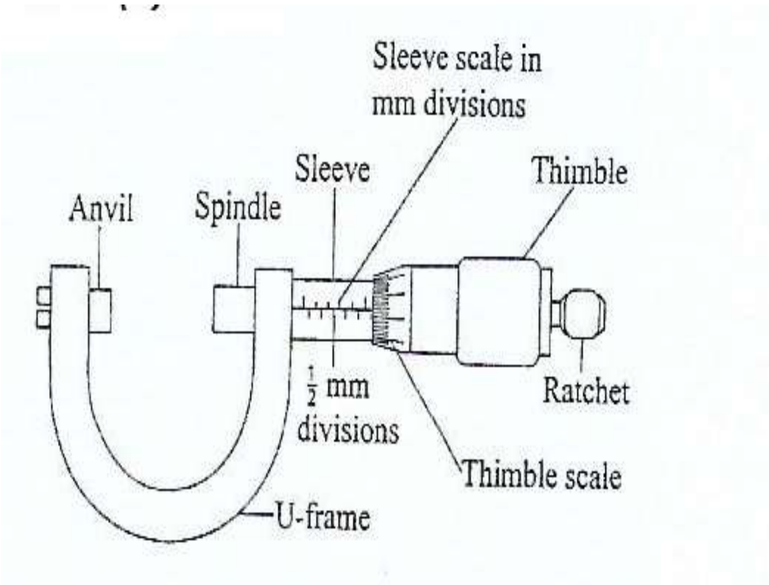
= 10.74 mm

Requirements

A micrometer screw gauge, a marble

Lesson Objectives. By the end of the lesson, the learner should be able to name all the parts of the micrometer screw gauge and use it to measure the diameter of a marble.

Set-up



Procedure

The object whose diameter is to be found is held between the anvil and spindle (jaws). The micrometer is closed using the ratchet until the object is held gently between the anvil and the spindle. The ratchet will slip when the object is held firmly enough to give an accurate reading.

A micrometer screw gauge is used to measure small diameters such as the diameter of a thin wire. A micrometer screw gauge consists of a U-frame carrying an anvil at one end a thimble that carries a circular rotating scale known as a thimble scale and a spindle that can move forward and backward when the thimble is rotated.

The sleeve has a linear scale in millimeters and the thimble has a circular scale of 50 equal divisions. The ratchet at the end of the thimble prevents the user from exerting undue pressure on an object when the micrometer screw gauge is in use. The linear scale has half-millimeter marks.

This distance moved by the spindle in one complete rotation of the thimble is known as the pitch of the micrometer. Since the thimble advances or retreats by 0.5 mm per complete rotation of the thimble, the pitch of the micrometer is 0.5 mm.
Thus, each division represents spindle travel of 0.5/50 mm =0.01 mm.

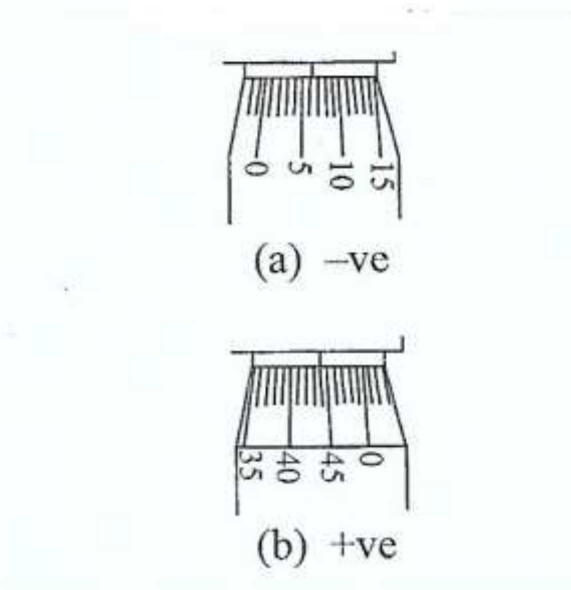
Hence, if the thimble rotates through one division, the spindle advances by 0.01 mm or 0.001 cm.

PBL task 5; Zero error

Lesson Objectives:

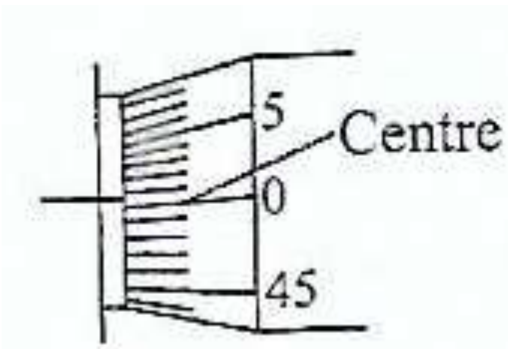
By the end of the lesson, the learner should be able to correct zero errors in a micrometer screw gauge.

What are the zero errors of the micrometer screw gauges in the figures below? (Micrometers are closed). If the micrometers were used to measure the diameter of a wire whose diameter is 1.00 mm, what would be the reading of each?

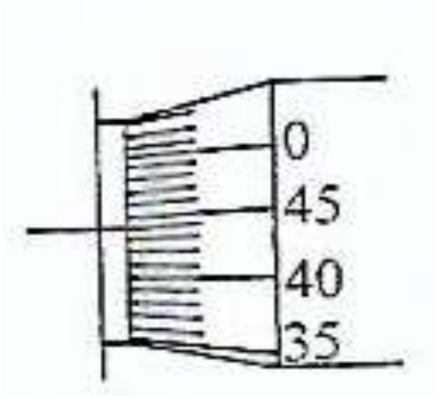


Procedure

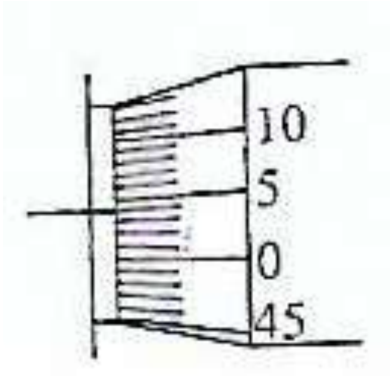
As in the case of the vernier caliper, there occurs zero error in the micrometer screw gauge. It arises when the zero mark of the thimble scale does not coincide exactly with the center line of the sleeve scale when the micrometer is closed. The anvil is usually used for the adjustment of the zero so that the micrometer has no zero error. As shown below.



The zero mark of the thimble scale coincides with the center line of the sleeve scale



The zero mark of the thimble scale does not coincide with the center line of the sleeve scale. A negative zero error adds an error in the reading



The zero mark of the thimble scale doesn't coincide with the center line of the sleeve scale positive zero error subtracts zero error from the reading

PBL task 6: Significant figures

Find the area of a rectangle that measures 4.26 cm by 2.77 cm and write your answer correctly too;

(I) Four significant figures

(II) Two significant figures

Solution

Area =4.26 cm x 2.77 cm

= 11.8002 cm^2

= 11.80 cm^2 to fours. f

= 12 cm^2 to two s. f

Lesson Objectives:

By the end of the lesson, the learner should be able to define significant figures and their answers in the correct significant figures required and also know when a zero is a significant figure and when it is not significant.

Procedures

Significant figures refer to the number of digits used to specify the accuracy of a value.

(I) The digits 1-9 are all significant when they appear in a number

(II) The first digit from the left of a number is the first significant figure

(III) The number of the significant figure is determined by counting the number of digits from the first significant figure on the left

(IV) Zero may be significant or not depending on the position of the digit

(IV) If zero occurs between non-zero digits it is significant.g.1004 (4sf), 15607(5sf), 180.45(5sf)

(VI) When zero occurs at the left end of a number it is not significant.g.0.00546 (3sf), 0.0002(1sf)

(VII) If the zero occurs at the right-hand end of an integer it may or may not be significant.E.g.60000.It can be a correct to significant figure therefore the zeros are not significant. If all the zeros are counted (ended) then it will be correct to 6 significant figures.

(VIII) If the zero occurs at the right-hand end after the decimal point, it is always significant e.g.2.000 (4sf),

Write down the number of significant figures in each of the following

a) 40000

b) 609

c) 0.000675

d) 5237.8

e) 0.0000600

f) 0.002304

PBL task 7; Standard form

Express the following in cm giving the answers in standard form

a) 0.1mm

b) 125mm

c) 3.8m

d) 0.015m

e) 7.8km

Lesson Objectives:

By the end of the lesson, the learner should be able to define the standard form and express positive and negative values in the standard form.

Procedure.

The range of lengths in the universe is extremely large, from the diameter of your hair to the estimated size of the universe. Writing down this very small and very large length is clumsy. This problem can be solved by writing such lengths in standard form.

The writing of a number especially a very large or very small number in which only one integer appears before the decimal point is termed standard form. A positive number is said to be in standard form when written as $A \times 10^n$, where A is such that $1 \leq A < 10$ and the index *n* is an integer e.g. $3567 = 3.567 \times 10^3$. If the number lies between zero and 1 then the index *n* becomes a negative e.g. $0.0003567 = 3.567 \times 10^{-4}$

PBL task 8; Decimal places

Find the volume of a cube whose side is 2.22cm. Express your answer correctly to 3 d.p

Lesson Objectives: By the end of the lesson the learner should be able to write different values in different decimal places.

Procedure

Refer to the number of digits to the right of the decimal point and this determines the accuracy of the number e.g. 6.0345(4d.p)

PBL task 9: The oil drop experiment.

In an experiment to estimate the diameter of the oil molecule 100 drops of oil are released from the burette and the level of oil in the burette changes from 0.5cm to 20.5cm. One of the drops is placed on water and spreads over a circular patch of diameter 20cm.

a) Determine:

(I) The volume of the oil drop

(II) The area of the patch covered by the oil

(III) The diameter of the oil molecule

b) State:

(i) Assumptions made in this experiment

(ii) Two possible sources of errors in this experiment

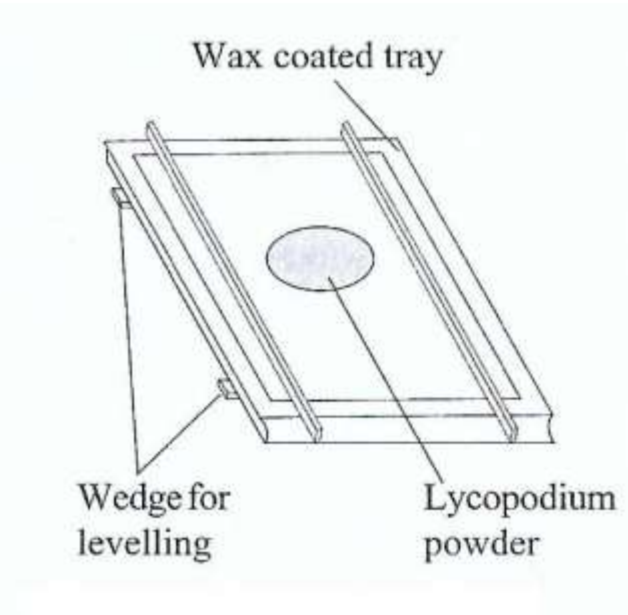
Lesson Objectives: By the end of the lesson the learner should be able to determine the volume of an oil drop, estimate the area of a patch covered by an oil drop, state the assumptions made in this experiment, and explain the natural hazards of the oil spill to the environment

Procedure

This is an experiment used in the estimation of the diameter /size/ thickness of a molecule.

A tray is filled with water to the brim, and lycopodium powder is lightly sprinkled on the water's surface. An oil drop is carefully placed at the center of the tray and allowed to spread on the surface of the water until it is one molecule thick. This forms a patch whose diameter is measured

The thickness of the oil molecule is estimated as **d**



The volume of oil drop=volume of the oil patch

$4/3\pi r^3 = \pi (d/2)^2 \times$thickness, t, of oil patch (or molecule)

Functions of lycopodium powder

1. It breaks the surface tension
2. It clearly shows the extent of the spread of the oil drop

The function of beams:

Used to estimate the diameter of the spread oil patch

Assumptions made in the oil drop experiment

a) The oil drop is perfectly spherical

b) The oil patch is perfectly cylindrical

c) The oil patch is one molecule thick.

Possible Sources of Error in the Experiment

a) Error in measuring the diameter (or volume) of oil drop

b) Error in measuring the diameter of the oil patch

PBL task 10; Solving numerical problems from the topic

Lesson objectives.

By the end of the lesson, the learner should be able to solve any mathematical problem from the topic measurements 2 without difficulties

Procedure;

Students are given numerical problems on the topic and given further assignments

Appendix D: NACOSTI Research Permit

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Date of Issue: **15/October/2021**

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Appendix E: Snap Shot of Abstract of Published Article

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IJARR International Journal of Advanced Research and Review

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EFFECTS OF PROBLEM BASED LEARNING APPROACH ON SECONDARY SCHOOL STUDENTS' MOTIVATION TO LEARN PHYSICS IN ISIOLO COUNTY, KENYA

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ABSTRACT

This study investigated the effects of Problem-Based Learning (PBL) approach on secondary school students' motivation to learn physics in Isiolo County, Kenya. Physics is an important subject because of the role it plays in industrial, technological, and economic development of countries. Despite the importance of physics, students' enrolment and performance in the subject in Isiolo County has generally been low. This has partly been attributed to low levels of motivation to learn physics. Teaching approaches have been cited as one of the factors that affect students' motivation. The study employed the Solomon's Four Non-Equivalent Control Group design. The target population was 640 form two students in public co-education secondary schools in Isiolo County. The accessible population was 265 forms two students in public co-education schools in Isiolo Sub County. Simple random sampling techniques was used to select the four co-educational schools which participated in the study. Two of these schools were in the experimental group while the rest were in the control group. The sample size comprised of 128 forms two students. A Teaching Manual was utilized to induce teachers from experimental schools on use of PBL approach for one week. Data was collected using the Learner's Motivation Questionnaire (LMQ). Analysis of Variance (ANOVA) and the t-test were used to test the hypothesis at $\alpha = .05$ confidence level. The findings indicated that students exposed to PBL had a higher level of motivation than their counterparts taught through conventional methods. The findings also indicated that the difference in motivation to learn physics between the two groups was not statistically significant. It was concluded that PBL boosts students' motivation to learn physics. However, the approach is not more effective in improving students' motivation to learn physics when compared to those taught using conventional teaching methods.

Keywords: Effects, motivation, problem-based learning approach.

INTRODUCTION

Physics is a branch of science that examines causes of natural phenomena, and laws and principles that govern them. It is concerned with properties of matter, energy, motion, and force. Physics is among the science subjects that are taught in secondary schools, tertiary institutions, and universities in Kenya. This could be due to the significant role the subject plays in industrial and technological development, which are among the pillars of Vision 2030. The Vision calls for use of Science, Technology, and Innovation (STI) to increase productivity and efficiency in economic, social, and political pillars of Kenya. The Vision aims to transform Kenya into a country with a high standard of living and be competitive globally by 2030 (Kibe, 2021).