UNIVERSITY OF CAPE COAST

COMPARISON OF LEARNING CYCLE AND TRADITIONAL TEACHING APPROACHES ON STUDENTS' UNDERSTANDING OF SELECTED CONCEPTS IN ELECTRICITY

BY

GODWIN KWAME ABOAGYE

THESIS SUBMITTED
TO THE DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION
OF THE FACULTY OF EDUCATION, UNIVERSITY OF CAPE COAST,
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE,
IN SCIENCE EDUCATION

MAY 2009

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:.................................... Date:..15 \03\10........

Name: Godwin Kwame Aboagye

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature:.................................. Date:....15/03/2010........

Name: Dr. Theophilus Aquinas Ossei-Anto.

Co-Supervisor's Signature:.................................... Date:.15/03/10....

Name: Mr. Eugene Adjei Johnson.

ABSTRACT

This study was purported to compare the learning cycle approach which is based on the constructivist theory to the traditional approach on senior secondary school students' understanding of selected concepts in direct current electricity.

Two intact science classes from two of the six senior secondary schools offering physics as elective in the New Juaben Municipality were randomly sampled using the computer generated random numbers to participate in the study. In all 101 students participated in the study. The experimental group consisted of 59 students and the control group had 42 students.

The main instruments used for data collection were Current Electricity Concept Achievement Test (CECAT) which comprised 30 items and students' learning cycle activity sheets. The t-test for independent and dependent samples, regression, percentages and thematic content analysis were used to analyze data.

The results of the study showed that the experimental group which was instructed using the learning cycle approach performed better on the posttest compared to the control group who were instructed using the traditional approach. The results also revealed that the learning cycle approach was more effective in teaching most of the interrelated concepts and a number of different aspects of the selected concepts in direct current electricity than the traditional approach. It also revealed that the learning cycle activities were effective in identifying students' preconceptions about concepts in direct current electricity.

As a result of these findings, it was suggested that in teaching concepts in direct current electricity, the learning cycle approach should be adopted.

ACKNOWLEDGEMENTS

I wish to express my indebtedness to my supervisors, Dr. T. A. Ossei-Anto and Mr. Eugene Adjei Johnson of the Department of Science and Mathematics Education, University of Cape Coast who sincerely dedicated their precious time to guide me in this research, especially at a time when they were busily engaged in other important assignments. Their supervisory roles in this research showed their absolute commitment to the study. God richly bless you for your encouragement and valuable guidance.

I thank the management of the PRACTICAL Project and the University of Cape Coast, for the financial assistance, which made it possible for me to complete this research. I am equally grateful to Prof. Joseph Ampiah Ghartey and Mr. Anthony Krueger for their tremendous help and advice.

I am thankful for the support, encouragement and the important discussions I have received from Mr. Alfred Mensah and Mr. Maxwell Bunu. Special thanks go to all my fellow M.Phil. Students of the PRACTICAL project. We have had a lot of fun together during these years of our study. I want to thank them for their inspiring discussions, suggestions, advice and fellowship.

My heartfelt gratitude is expressed to Rev. I. K. Amoako and Madam Mary Ansah for their support and prayers over the years. Special thanks to Mr. John Bempong for his valuable assistance and encouragement during this study.

DEDICATION

To the late Mrs. Elizabeth Ama Marfowa Amoako and my wife Faustina.

TABLE OF CONTENTS

CONTENT PAGE

CHAPTER

LIST OF TABLES

LISTS OF FIGURES

FIGURE PAGE

CHAPTER ONE

INTRODUCTION

Background to the Study

With increasing technological developments in the past twenty years, there have been fundamental changes in educational systems with respect to factors such as teachers, students and learning environment (Yilmaz & Cavas, 2006). Each country often changes and redesigns its curricula to include new teaching methods and techniques in order to help students develop scientific concepts better. Many researchers in science education, addressing effective concept development, base their studies on the constructivist perspective of learning. Constructivists view the learner as an active participant in the learning process who comes to the science class already holding ideas about natural phenomena, which is used to make sense of everyday experiences and new situations (Wheatley, 1991). In this view, the most important ingredient or factor in the process of learning is the interaction between the new knowledge constructed and the existing knowledge.

Students' preconceptions in science, while they interact with their physical and social environment, often conflict with the concepts as intended by scientists and this affect learning (Küçüközer & Kocakülah, 2007). Many such research findings support strongly the assertion that learners of all ages hold their own views about a wide range of physical phenomena prior to their formal learning of science in schools (Gunstone, 1991). Previous research has also shown that it is difficult for students to change their initial ideas in physics because their own beliefs are grounded in long personal experiences (Osborne, 1983; McDermott, 1991; Wandersee, Mintzes, & Novak, 1994).

Direct current electricity is one of the major topics in physics studied and taught in pre-tertiary schools and tertiary institutions in Ghana. Understanding of electricity-related concepts, such as 'electric current', 'voltage' and 'resistance' form the bases or prerequisite for the understanding of topics like 'series and parallel circuits', 'electric potential', 'electrical energy' as well as other concepts in physics. However, several studies have indicated that many students in science classes have difficulties in understanding and learning these concepts. For instance, Engelhardt and Beichner (2004) studied students' understanding of direct current resistive electrical circuits and found that both high school and university students' reasoning patterns regarding direct current resistive electric circuits often differ from the currently accepted explanations.

Pfister (2004) reported that many beginning physics students have harder times understanding basic concepts of electric circuits which arise due to the fact that students cannot see electric charge carriers (electrons) move through electric wires. Not being able to clearly understand these topics contributes to limited performance on tests and negatively affects students in learning further academic concepts. Carlton (1999) also reported that electricity is a difficult concept for students to come to terms with. The invisible nature of what is happening in the wires in an electrical circuit makes it an abstract topic. What is required is that the student develops a mental model which can be used to make predictions about the outcome of examples of electrical circuits. This approach is much more beneficial than the ability to recall and state received knowledge without internalizing the concept. Even university students who undertake advanced physics courses whilst in high schools have difficulties in understanding basic concepts on topics related to electricity, as do middle-school students (Choi & Chang, 2004). The Chief Examiner's reports on the Senior Secondary School Certificate Examination (SSSCE) held in the years 2000, 2001, 2002, 2003 and 2006, also indicate that students have difficulties in understanding concepts in direct current electricity. These consequently lead to poor performance of students in the SSSCE and also result in low enrolment at the tertiary levels.

While researchers have identified some learning difficulties of students resulting from their preconceptions and misunderstanding of concepts in science, consensus has not been reached on appropriate pedagogical strategies to address adequately these difficulties (Ates, 2005). Over the last two decades, a vast body of evidence in literature has echoed the need for science educators to understand students' understanding of science concepts, processes and phenomena as a prerequisite to improving teaching and learning in science. The more important task is to insightfully design learning strategies and activities that start with students' viewpoint rather than the teacher's or scientist's to foster conceptual change (Liew & Treagust, 1998).

Several research-based pathways have emerged following the constructivist perspective on teaching and learning of concepts in electricity. Some studies suggest analogies and analogical reasoning as a vehicle for inducing conceptual change (Psillos, 1998; Scott, Asoko & Driver, 1991) whiles others suggest the use of cognitive conflict and the solution of the conflict to foster conceptual change (Posner, Strike, Hewson, & Gertzog, 1982; Marek, Laubach & Pedersen, 2003). The three-phase learning cycle method (exploration, term introduction and concept application) is one of the constructivist's teaching methods and it is based on Piaget's developmental theory (Lawson, 2001). The learning cycle is an approach of teaching and learning which increases the likelihood that students are engaged in the type of thinking that constructivists argue is necessary for productive thinking. This approach has proven effective at helping students to construct concepts and conceptual systems as well as develop more effective reasoning skills (Yilmaz & Cavas, 2006). However, the traditional teaching method still dominates most science instructions where teachers transmit most of the knowledge to students with heavy emphasis on formulas and solving of quantitative problems (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001; Yanfeng, 2004). The effectiveness of a method on students understanding of concepts can be determined only by comparing it to another method. Hence, the preference of the learning cycle approach to the traditional approach should be based on the inclination of research findings.

This study therefore compares the learning cycle approach and the traditional approach on senior secondary school students' understanding of selected concepts in direct current electricity, it investigates the effectiveness of the learning cycle approach in teaching all the aspects and interrelated concepts in direct current electricity, and also determines how effective the learning cycle teaching activities are in identifying students' preconceptions of concepts in direct current electricity.

Statement of the Problem

Physics is one of the science subjects taught at the senior secondary school and the university levels in the Ghanaian educational system. Despite the importance of this subject as one of the fundamental ingredients of technology, it is plagued by persistent low enrolments at the university or tertiary institutions. This could be due to poor performance of science students in physics at the Senior Secondary School Certificate Examinations (SSSCE). For instance, in 2003 out of 15,667 candidates who sat for the physics paper in the SSSCE, only 3,154 (20.1%) obtained grade A-D; in 2004 out of 17,375 candidates presented, only 5,550 (31.9%) passed with grade A-D and also in 2005, out of 20,219 candidates presented, only 4,363 (21.6%) obtained grade A-D (Anamuah-Mensah, 2007).

The Chief Examiner's reports of the Senior Secondary School Certificate Examination (West Africa Examination Council (WAEC), 2000, 2001, 2002, 2003 & 2006) identified that one of the areas where students have difficulties and weaknesses is answering questions on electricity related concepts. They indicated that questions asked in both theory and practicals requiring the application of electricity related concepts were poorly managed by students. Few of the weaknesses identified are: most candidates were not able to draw electric circuits and interpret them (WAEC, 2002); the experiment on the determination of the resistivity of a wire was poorly done (WAEC, 2001 & 2002); majority of the candidates were not able to apply Kirchhoff's laws to the separate branches of the electrical network (WAEC, 2000); majority of the candidates failed to recognize the relationship between resistance and the balance lengths on the meter bridge wire (WAEC, 2003) and candidates wrongly stated the definition of certain concepts: an example is the definition of a junction as a point where two or more current meet instead of a junction is a point where three or more wires meet (WAEC, 2006). These weaknesses are evidence that students have difficulties in understanding concepts in direct current electricity.

Concepts in direct current electricity are complex, difficult and abstract for students to come to terms with because of the invisible nature of how electric charges move through electric wires (Carlton, 1991; Pfister, 2004). For example, Physicists use schematic diagrams to represent circuit elements and examine their behaviour. Students' recognition of what these diagrams represent is an important aspect of their understanding of circuits. However, research reveals that students view these diagrams as a system of pipes within which flows a fluid that they refer to as electricity (Joshua, as cited in Engelhardt & Beichner, 2004). Students have difficulty identifying series and parallel connections in such diagrams (McDermott & Shaffer, 1992).

Researches have shown that students amass considerable amount of knowledge about the natural and technological world prior to formal instruction which to a large extent influence their understanding of scientific concepts

(Joshua & Dupin, 1987; Osborne, Bell & Gilbert, 1983). Based on this realization, attempts need to be made to help students to understand scientific concepts through progression from students' preconceptions to the scientifically accepted concepts (Liew & Treagust, 1998). This attempt utilizes strategies to help students overcome their learning difficulties in physics. However, there is still lack of sufficient study to support any instructional approach that would adequately promote conceptual change and address adequately the numerous difficulties students' face in understanding scientific concepts (She, 2004). Several studies indicate that constructivist teaching strategies (in particular the learning cycle) has proven effective for helping students to construct concepts and conceptual systems as well as develop more effective reasoning skills about concepts in electricity (Ates, 2005; Yilmaz & Cavas, 2006). Despite the successful use of this strategy in fostering understanding of science concepts, there appears to be only a few research that have examined the effectiveness of the learning cycle approach for teaching several concepts in electricity (Wang & Andre, 1991). Research has also not been able to show how a particular strategy can be used to teach effectively all the interrelated concepts and a number of different aspects in direct current electricity.

Again, very few researches have been conducted which compares the learning cycle approach to the traditional teaching approach on students' understanding of concepts in direct current electricity. In Ghana no study has been done to this effect. Hence, the need for this current research study.

Purpose of the Study

This study was aimed at comparing the learning cycle approach which is based on the constructivist theory and the traditional approach on senior secondary school students' understanding of selected concepts in direct current electricity. It was also aimed at showing how effective the learning cycle teaching approach is in teaching the interrelated concepts and the different concepts or aspects involved in direct current electricity. Finally, it examined the effectiveness of the learning cycle activities in identifying students' preconceptions about specific concepts in direct current electricity.

Research Questions

The study sought answers to the following questions:

1. What are the differences in achievement between students instructed on selected concepts in direct current electricity using the learning cycle approach and those instructed using the traditional teaching approach?
2. How effective are the learning cycle approach and the traditional approach in teaching the interrelated concepts and a number of different concepts involved in direct current electricity?
3. How effective are the learning cycle activities in exploring students' preconceptions on selected concepts in direct current electricity?

Hypothesis

Based on research question one, the following null and alternative hypotheses were tested:

H_o: There is no significant difference in achievement between students instructed using the learning cycle approach and those instructed using the traditional teaching approach.

H_A: There is a significant difference in achievement between students instructed using the learning cycle approach and those instructed using the traditional teaching approach.

Significance of the Study

Firstly, the learning cycle teaching activities and the concept understanding test developed in this study could be useful to the researcher and other interested senior secondary school physics teachers to improve upon their teaching and testing students' knowledge on selected concepts in electricity.

Secondly, the findings of this study could form the bases for the organization of workshops, seminars and in-service training for physics teachers to be trained on how to use these materials to supplement the strategies they have been using in the classroom to bring about improved students' learning.

Thirdly, the outcome of this study could show physics teachers how the learning cycle teaching activities are carried out in the classrooms on specific concepts in direct current electricity. Finally, the outcome of this study could reveal students' preconceptions in direct current electricity which could help teachers, curriculum developers and course programme writers in developing lessons and syllabi.

Delimitations

The study focused on only selected electricity related concepts as dictated by the West African Senior School Certificate Examination (WASSCE) syllabus for physics from 2006-2010. Since direct current electricity is a very broad topic, all its content cannot be covered in a single study. The study therefore covered concepts such as electric current, voltage, electromotive force and electric resistance and their relationship. It also included parallel and series connections of resistors and dry cells.

Limitations

Generalization of the findings was limited to only the senior high schools selected since only two intact classes were used for the study out of a large number of classes. The study could not control extraneous variables such as age, ability, maturation, experience and previous learning which may influence students understanding of concepts in direct current electricity and so may lack internal validity. Again, not all students were present for all the lessons designed which could also affect the outcome of the study.

Organization of the Rest of the Thesis

The thesis has four additional chapters, which have been logically arranged to provide insights into the issues raised in this section and to provide answers to the research questions.

Chapter Two of the thesis is devoted to a general review of the relevant literature on issues relating to the study, namely, constructivist theory, constructivist teaching strategies, the learning cycle teaching approach, the learning cycle approach and the traditional teaching approach and studies on students' preconceptions about electricity.

Chapter Three discusses the research methodology for the study. It describes the type of study and design in detail, and the rationale for the design. The strengths and weaknesses of the design are also discussed. Issues relating to population and sampling, instruments, data collection procedure, and data analysis are also discussed in detail.

In Chapter Four, the results of the study are presented and discussed according to the research questions raised. In Chapter Five, an overview of the research problem and methodology are given. A summary of the key findings and their interpretations with reference to the literature are also provided. Implications and conclusions relating to the findings are also discussed. In addition, the issues unearthed for possible future research are presented.

Operational Definition of Terms

Conceptual change: Is a process where a student abandons or modifies previously held concepts to agree with the theory held by the scientific community.

Constructivist approach: Refers to the teaching strategy which recognizes and takes into account students' preconceptions on any given topic in instructing them and also allows students to actively construct knowledge through the use of hand-on activities, group and class discussion to arrive at science accepted concepts.

Learning cycle approach: Is a constructivist teaching strategy which is a three-phase inquiry approach consisting of exploration, term introduction and concept application phases.

Traditional teaching approach: Refers to the teaching strategy which involves the practice of feeding students with information whose interpretations are solely made by the teacher for students.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Overview

The chapter reviews relevant literature that provides support for the study under the following subheadings: Constructivist theory, constructivist teaching strategies, the learning cycle teaching approach, learning cycle approach verses traditional teaching approach, and studies on students' preconceptions about electricity.

Constructivist Theory

Constructivism is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in (Wheatley, 1991; Merriam, Caffarella, & Baumgartner, 2007). We generate our own rules and mental models, which we use to make sense of our experiences. The early development of constructivist theory can be attributed to the work of John Dewey, Lev Vygotsky, and Jean Piaget (Henson, 2003; Huang, 2002; Merriam *et al.*, 2007; Proulx, 2006). Constructivism is a theory of learning and not of teaching; and as a result, the constructivist learning environment is learner-centered rather than teacher-centered (Proulx, 2006). Learning, therefore, is simply the process of adjusting our mental models to accommodate new experiences. Some of the advantages of learner-centered education put forward by Dewey include students' increased intellectual curiosity, creativity, drive, and leadership skills (Henson, 2003). Teachers who are committed to learner-centered education seek to challenge students within their abilities while providing encouragement and recognition of student success.

Constructivist theory places the student at the center of the learning experience, and learner-centered education can be facilitated in a variety of ways (Henson, 2003; Spigner-Littles & Anderson, 1999). Students learn by doing; therefore, actively engaging students in experience-based learning is one key to the construction of new meaning (Merriam *et al.*, 2007). In developing learning experiences that will have maximum benefit to students, the teacher should also be cognizant of the needs of individual learners. When planning for curriculum delivery, viewing the curriculum from the learner's perspective and from its relevance to the learner can facilitate learning experiences that will have maximum impact on students (Garmston, 1996; Spigner-Littles & Anderson, 1999). Effective teaching will nurture the desire to learn and attempt to engage learners not only on an intellectual level, but also on an emotional level. To facilitate all of these conditions for maximum construction of meaning, teachers need to create a safe learning environment where individuals are free from fear and open to constructive learning, where learners feel welcomed, comfortable, and respected (Henson, 2003; Spigner-Littles & Anderson, 1999).

Proulx (2006) revealed that the constructivist theory has several implications for educators and they are discussed. It encourages teachers to be cognizant of the fact that learners bring with them prior knowledge about topics they teach. Learners' prior knowledge deserves recognition and may be utilized in constructing new meaning. Learning from mistakes can be a key element of constructivist learning activities, as they provide opportunities for further learning and are a natural part of the learning process. In a constructivist learning environment, teachers should be open to learning from their students as the students engage in creative construction of new concepts. As students verbalize their newly constructed knowledge, they provide learning opportunities for others who are in the same learning environment; and, they also engage in revising, analyzing, and improving their own construction as they verbalize it to others.

According to Hewson (1992), constructivist teaching strategies promote conceptual change in students by taking cognizant of their initial ideas before formal instruction. The term conceptual change which is widely used and often stands for constructivist ideas of learning in general denote that learning science usually involves fundamental restructuring of already existing or pre-instructional knowledge (Vosniadou, 1994). The first theory about conceptual change was proposed by Posner *et al.* (1982) and two kinds of conceptual change were explained in this theory by using Piaget's two terms: assimilation and accommodation. In the first one, new concept is assimilated by the pre-conceptual structure and in the second one, conceptual structure is accommodated if a students' existing concept contradicts with the newly learnt concepts. Posner *et al.* asserted that accommodation depends on some conditions such as dissatisfaction of students with the existing concept, plausibility of new concept (believing it to be true), intelligibility of new concept (knowing what it means) and fruitfulness of new concept (finding it useful). According to Hewson (1992), if the new conception follows all the four conditions, learning proceeds without difficulty. However, science educators face several difficulties when they attempt to put into practice the four proposed conditions in order to promote conceptual change. Based on the above, Strike and Posner (1992) criticized the theory of Posner *et al.* as being too linear and overly rational, based on the assumption that learners have well-articulated conceptions or misconceptions for most of science concepts. Hewson and Hewson (1992) suggest that conceptual change can be seen as a change of status attributed to a particular conception. They stressed that while the student's alternate conception was losing its status, the new concept learnt gain its status and therefore it was understood, accepted and seen as useful. They also emphasized that conceptual change should not be seen as a situation in which students' existing conceptions are completely deleted or exchanged for the new concept.

Constructivist Teaching Strategies

There are many constructivist teaching strategies suggested to change and improve students understanding during teaching of concepts in science (Clement, 1987; Nussbaum & Novick, 1982). Scott *et al.* (1992) identified two main groups of teaching approaches that promote conceptual change in students. The first group consists of strategies that are based on cognitive conflict and the resolution of the conflicting perspectives. Strategies which emphasize cognitive conflict and the resolution of such conflict by the learner may be seen to be derived from

Piagetian view of learning in which learners' active participation in reorganizing their knowledge is central. Students are made conscious about their own opinions and then an opposite event or some activities that challenge their own opinions are given. Examples of such strategies are the predict-observe-explain (POE) developed by White and Gunstone (1992) and learning cycle developed by Karplus and Thier in 1967.

The second group consists of strategies which build on students' existing ideas and opinions and spread them through for example analogy or metaphor to a new domain. According to Scott *et al.* (1992), the strategies which build on learners' existing knowledge schemes, extending them to new domains, may be seen to place less emphasis on the role of accommodation by the learner and instead focus on the design of appropriate interventions by the teachers to provide 'scaffolding' for new ways of thinking. Strategies belonging to this group are generally referred to as bridging strategy. Küçüközer and Kocakülah (2008) asserted that in order to promote immediate conceptual change in students, it is recommended to use cognitive conflict and analogy strategies together most of the time.

The Learning Cycle Teaching Approach

During the last few decades, there have been many efforts to increase students' learning abilities and to reform teaching and learning practices in science classrooms. The learning cycle introduced by Karplus and Thier in 1967 for the Science Curriculum Improvement Study (SCIS), has evolved into one of the most important teaching approaches in science education (Türkmen, 2006).

Marek, Eubanks, and Gallaher, (1990) described science as "a process of investigation through which an understanding of scientific, facts, laws, principles, and theories is gained" (p. 821). Poincaré cited "Science is built up with facts as a house is built with stones, but a collection of facts is no more a science than heap of stones is a house" (Marek *et al.*, 1990, p. 822). In the light of these descriptions, the learning cycle approach is an inquiry-based learning and its "goal is to enhance learning and provide students with more authentic science experiences that imitate those real scientists and are in accordance with the nature of science" (Türkmen, 2006, p.73)

Inquiry can be defined as a search for information, a quest for knowledge, or an exploration of certain phenomena to understand the world better (Marek & Cavallo, 1997). The critical element of inquiry is that students seek answers to questions and not teachers providing answers to questions. True learning comes from the investigation, resulting in summarizing, evaluating, and communication of findings and examination for known facts and theories; this is the essence of inquiry (Hogan & Berkowitz, 2000). The process of inquiring begins with gathering information and data through applying the human senses: seeing, hearing, touching, tasting, and smelling (Colburn, 2000; Martin-Hansen, 2002).

Marek *et al.* (2003) stated that "the learning cycle is a specific organization of phases dominated by the integrity of the whole and the relationships of the phases to each other for experiencing science by inquiry and for organizing science curricula" (p. 148). This approach is a student-centered teaching procedure and offers another way of teaching science concepts in which students learn from their experiences, rather than through other learning methods that rely on the textbook for classroom learning (Fleener & Marek, 1992). Researches indicate that correct use of the learning cycle accomplishes effective learning of science concepts (Lawson, Alkhoury, Benford, & Falconer, 2000; Lawson, 2001). Basically, learning cycle consists of three essential phases of Exploration, Term introduction and Concept Application. These terms are explained below.

Exploration: This phase typically consists of hands-on activities or field experience in which students gather and record data from their observations and measurements. The main purpose of this phase is that students are encouraged to learn through their own experience. When a teacher introduces a learner to the materials or experience, the learner begins to discover the science concept through his or her questions. Students should be encouraged to dialogue with classmates or teammates to formulate explanations, and to make predictions. This phase makes available to the groups the experience of each individual. This stage involves finding out what happened within the individual during the experiment (Beisenherz, Dantonio, & Richardson, 2001; Lawson, 2001).

Term introduction: The teacher takes an active role in leading the students to develop the concept. Students use their experience from exploration phase to develop an understanding of the science concept and explain the science concept with guidance from the teacher. During this phase, students make their own meaning out of their observations. The role of teacher is to be a mediator in assisting students to formulate these relationships and introduce the scientific term. This phase makes the experience practical, if it is omitted or glossed over the learning is likely to be superficial. The crucial aspect of this phase is to move reality from inside the experience to the reality of everyday (Türkmen, 2006; Lawson, 2001).

Concept application: It provides opportunities to directly apply the concept learned during the term introduction phase. Additional experiments, readings, films, and discussions can be done further. Students continue to expand the concepts by conducting more activities and using additional resources for investigation. Piaget described this phase as putting new thoughts in accordance with previous thoughts. During this time, the teacher should make an assessment of the students' abilities and thinking habits in investigating ideas. Students perform experiments that are explained by term introduction, and in this phase, new unexplained phenomena arise. The main purpose is to connect the newly learned concept to previously learned concept (Fleener & Marek, 1992).

There are other types of learning cycle approaches. These include the 4-E and 5-E learning cycles. The 4-E learning cycle approach is a four-phased teaching and planning model consisting of exploration, explanation (concept invention), expansion and evaluation (Yilmaz & Cavas, 2006). The 5-E learning cycle is a model consisting of: engage, explore, explain, elaborate and evaluate (Bybee & Sund, 1990). It incorporates the three original learning cycle phases while adding two more. The engage phase of the 5-E is designed to captivate students' attention and uncover their prior knowledge about the concept(s), while the evaluate phase is an opportunity for the teacher to assess students' progress, as well as for students to reflect on their new understandings (Hanuscin & Lee, 2007).

According to Türkmen (2006) the three phase learning cycle approach should be reinforced throughout the science curriculum and should be used in context at every grade level, in nearly every unit and that teachers should identify the potential hazards and/or precautions involved in scientific investigations and use simple key to classify objects and/or phenomena. Students must learn to evaluate conclusions based on scientific data. The teacher's main role in the learning cycle approach is to create social and intellectual climates, where collaborative, cooperative, constructivist and other learning methods are supported and also to provide contexts for students to think critically, explore phenomena in their everyday lives, and solve meaningful problems meaningfully.

The learning cycle approach can be derived from the work of Jean Piaget's theory. The main point is how we connect the Piaget's mental functions with the learning cycle approach (Türkmen & Usta, 2007). The three-phase learning cycle directly corresponds to the Piagetian principles of assimilation, accommodation, and organization.

According to Renner, Abraham, & Birnie (1986, p. 633) "Exploration phase of the learning cycle provides experiences leading to assimilation and disequilibrium", because, when information received from the outside world is different from the mental structure, the students do not make enough sense of it in their minds, and so the students reach a state of disequilibrium, or if the information fits the external reality to their existing cognitive structure, they can easily assimilate it in their mind (i.e. students are in the equilibrium phase). The exploration phase has the students interact with the laboratory environment while collecting data formally or informally. Marek *et al.* (1990) pointed out that here

> Students . . . have experienced or assimilated the essence of the concept. The experience is more directed than in the pure discovery approach, but care is taken not to tell the student what data is neither to be used in developing the desired concept nor to ask the student to interpret data prematurely (p.832).

Activities and materials are supplied by the teacher and the role of the teacher is just encouraging students and giving them some suggestions to maintain an appropriate level of disequilibrium.

Term introduction phase of the learning cycle approach is where students are expected to accommodate the new ideas (Türkmen & Usta, 2007). The teacher takes an active role in presenting the concept. Students redefine, change, or invent mental structures at this point. Students will be in the accommodation phase in this learning cycle stage, because students make their own meaning out of the observations. Either they succeed to make adjustments in each mental structure to make it fit their experience, or they do not construct the new mental structure and then fall in the disequilibrium phase again. Generally, accommodation phase will occur during the class discussion.

In the concept application stage, students continue to expand the concept by conducting more activities and using additional resources for investigation. The expansion of the idea may involve "additional laboratory experiences, demonstrations, readings, questions, and/or problem sets" (Marek *et al.*, 1990, p. 831). Concept application matches to the organization phase in the Piaget's mental functioning. This phase allows additional time for accommodation required by students needing more time for equilibrium. It also provides additional equilibrating experiences for students who have already accommodated the concepts, which were introduced. Its intent is to aid the organization and generalization of knowledge by adjustment of related mental structures and transfer from one context to another.

Learning Cycle Approach versus Traditional Teaching Approach

In the traditional teaching method, teachers present science concepts (informed) then give exercises related to the concept (verify) and then let their students do laboratory activity (practice). The laboratory activities are more peripheral to the main focus of instruction because they are used to confirm the concepts (Abraham & Renner, 1986; Renner *et al.*, 1986). The learning cycle approach is totally opposite of the traditional teaching method because teachers do not give any theoretical information before starting the laboratory activities. Students are instructed to collect data and then try to get concept by their own knowledge (Renner *et al.*, 1986). In other words, explanation and investigation of concept, which is the use of evidence to back up conclusions, and the designing of experiments, are emphasized in learning cycle approach. Whereas the development of skills and techniques that are receiving of information and knowing of the outcome of an experiment before doing it are emphasized in the traditional teaching method. According to Türkmen (2006, p. 5), the learning cycle approach is a better way to teach science than the traditional methods because "students feel more secured, and believe they have learned more since they experienced it" and that in the learning cycle teachers spend up to 90% of class time actively involved with their students, whereas in the traditional method, teachers spend approximately 7% of class time with their students.

Türkmen (2006) argued that the traditional teaching method utilized by many teachers in teaching only serves as information-giving to passive students and that only 20% of the students retain what the teacher discussed after the lecture. This means that students who have memorized facts, principles, or any specific kind of knowledge without experiencing and developing concepts for themselves have not been taught science. In this perspective, the learning cycle approach is the best solution, because teachers using the learning cycle approach in their science classrooms let their students try to experiment and develop concepts for themselves. According to Türkmen (2006) if we compare the learning cycle to other teaching strategies, we can see that it is easy for teachers to use. All stages of the learning cycle lend themselves to cooperative learning, especially exploration and concept application stages. However, the teacher will need to devote more time to the preparation of materials. Teachers should have a strong content background to provide suitable reinforcement during exploration and concept application stages. Again, the learning cycle approach is an effective tool for teaching science, which promotes the rational development of students while allowing them to understand science's inherent characteristics. In reality, many of the teachers who implement the learning cycle for the first time may have trouble and this is confirmed by some studies that have shown that "the learning cycle teaching approach is difficult, complex and an abstract structure to understand" (Marek *et al.*, 2003. p. 156). Many articles indicated that the learning cycle improves teachers behaviour and students outcomes, that is, the learning cycle is an effective teaching approach (Marek & Cavallo, 1995; Marek *et al.*, 1990) and in using the learning cycle approach students develop more positive attitudes toward science and science instruction than other approaches (Türkmen, 2006).

According to Mansfield and Happs (1996), the traditional teaching method though can also lead to conceptual change, it generally do not recognize the learner's conceptions and often fail to take into account the meaning of specific words as used and understood by classroom teachers and students. Sometimes, when teaching physics in the traditional fashion, students might 'accept' the scientifically correct theory only within a certain framework and often will memorize that theory only to pass tests and examinations.

Yilmaz and Cavas (2006) explored the effectiveness of the 4-E learning cycle method on the 6th grade students' understanding of flowing electricity and their attitude towards science. Seventy-nine (79) students of which 40 were in the experimental group and 39 were in the control group from Izmir Cavit Ozyegin primary school took part in the study. Results of the posttest revealed that students taught using the 4-E learning cycle method were more successful than the students taught with the traditional method. Again the 4-E learning cycle method produced statistically more positive attitude toward science after treatment. It was also found that almost all the students had misconceptions related to clashing current model. Students asserted that positive electricity moves from the positive terminal and negative electricity moves from the negative terminal of a power supply. The positive and negative electricity meet at a device and clash thereby powering the device and weakening current model that electrical current flows in one direction around a circuit, but that current gradually weakens because each device in the circuit uses up some of the current.

Ates (2005) investigated the effectiveness of the learning cycle method on university students' understanding of different aspects in resistive DC circuit. One hundred and fifty-two (152) freshmen from the Absnt Izzet Baysal University in Turkey participated in the study. The results of the study indicated that the implementation of the learning cycle method enhances students' understanding of key aspects and concepts involved in DC circuits than the traditional method. The study also revealed that the learning cycle group students over scored the traditional group students in understanding seven of the instructional objectives involved in electric circuits. However, the learning cycle could not teach concepts such as conservation of current and explaining the microscopic aspects of current flow in a circuit.

Studies on Students' Preconceptions about Electricity

For more than two decades, physics education research has revealed that students already have many ideas about how physical systems behave even before they start to study physics (Pfundt & Duit, 1991; Wandersee *et al.*, 1994). More importantly, some of these prior conceptions are found to differ from the accepted scientific views and were labeled in science education literature variously as misconception, preconceptions, alternative conception or children's science (Ates, 2005).

Why students hold preconceptions can be explained by several reasons: teaching method, student pre-existing knowledge, insufficient connection between concepts or between pre-existing knowledge and new one, textbook, procedural learning and so forth (Aubrecht & Raduta, 2005). Since students' pre-existing knowledge is central for further learning, physics studies, as in other disciplines, have made an attempt to elicit students' preconceptions of some perspectives such as heat and temperature, force and motion, mechanics, electricity and magnetism and so on (Choi & Chang, 2004).

Because electricity is one of the most difficult but important topics in the physics curricula (Ates, 2005; Borges & Gilbert, 1999), much research have been conducted to define students' understanding, their alternative conceptions and their mental models. Topics such as: 'electric circuits', 'electric charge flows within an electric circuit' and 'how the brightness of bulbs and the resistance change in series and parallel circuits' have been investigated well in many studies (Clement & Steinberg, 2002; Duit & Rhöneck, 1998; Periago & Bohigas, 2005; Psillos, 1998). The related studies have reported that students have alternative conceptions of the aforementioned concepts because of their prior academic knowledge about electric circuits (Clement & Steinberg, 2002), their learning difficulties (Duit & Rhöneck, 1998), their pre-existing knowledge (Duit & Rhöneck, 1998) and their misunderstandings or confusions (Psillos, 1998).

İpek and Çalık (2008) outlined the following prominent mental models students have regarding electric circuits: (a) 'Unipolar model (sink theory)': one wire between a bulb and a battery is enough to light the bulb; (b) 'Clashing Current theory (two-component model)': current leaves from the positive terminal and negative current leaves from the negative terminal of the battery and they meet and produce energy in the bulb; (c) 'Closed circuit model': the circuit elements have two connections. Current circulates around the circuit in a given direction and current flowing through a resistive circuit element liberates energy; (d) 'Current consumption model (Attenuation model)': current travels around the circuit in one direction and the devices in the circuit share the current equally; however less current returns to the power source than originally leaves (i.e. some portion of the current is used up as it goes through each component of the circuits; (e) 'Constant current source model': battery is seen as a source of constant current. The current supplied by the battery is always the same regardless of the circuit features; (f) 'Scientific view': current flows around the circuits transmitting energy. Current is conserved and well differentiated from energy. The circuit is seen in a whole as an interacting system, such that a change introduced at one point of the circuit affects the entire system.

Some of the studies on this issue revealed that the relative popularity of students' mental models changes with students' age and experience from simple intuitive mental models towards some scientific models (Shipstone, 1985; Osborne, 1983). Osborne (1983) stated that students' mental models about electric circuit improve with age and instruction, but elementary school students predominantly hold either a clashing current or non-recursive model.

There is also some evidence to indicate that students change their reasoning pattern to suit the question at hand (Heller & Finley, 1992). Thus, they do not appear to use a single model to analyze circuit phenomena. In analyzing circuits, students use one of three ways of reasoning: sequential, local or superposition (Ates, 2005). Students using sequential reasoning believe that current is influenced by each circuit element as it is encountered and a change made at a particular point does not affect the current until it reaches that point (Closset, 1984). Local reasoning means that current divides into two equal parts at every junction regardless of what is happening elsewhere (Rhöneck & Grob, 1987). Students using superposition reasoning would conclude that if one battery makes a bulb shine with a certain brightness, then two batteries would make the bulb shine twice as bright regardless of the configuration (Sebastia, 1993).

Some aspects of circuits seem to occupy a more central place in students' mental models so that instruction may affect them to different degrees. For example, a student who does not have a proper understanding about the difference between current and energy is unlikely to adopt a view in which current is conserved (Ates, 2005). Research findings suggest that students can easily change their views about some of the above-mentioned aspects than about others after instruction (Shipstone, 1985). After students are provided a battery, a bulb and some wires and then asked to light the bulb, they recognize that circuit elements are bipolar devices and circuits should be closed if current is to circulate in it

(Cosgrove, 1995). However, some aspects of students' mental models of electricity are more resistant to change, such as those involving the concept of current and energy (Osborne, 1983; McDermott, 1991; Wandersee *et al.*, 1994). This becomes a critical difficulty when students study more complex circuits involving combination of resistors in series and parallel (McDermott & van Zee, 1985) and when they start to learn microscopic process going on in a circuit (Eylon & Ganiel, 1990). Some researchers point out that the problem is with the lack of differentiation between current and energy (Arnold & Millar, 1987), while others mentioned that problem is with the lack of robust models of understanding microscopic process leading to the macroscopic phenomena observed (Eylon & Ganiel, 1990).

Mcdermott and Shaffer (1992) investigated how students' understanding of electric circuit has contributed to the building of a research base that can be used to guide the development of curriculum that matches the needs and abilities of students. The subject matter in the research is an electric circuit that consists only of batteries and resistive elements. They found that some serious conceptual and reasoning difficulties were not solved after using standard lecture and laboratory instruction. The difficulties identified were divided into three general categories: inability to apply formal concepts to electric circuits, inability to use and interpret formal representation s of electric circuits, and an inability to reason qualitatively about the behaviour of electric circuits.

Engelhardt and Beichner (2004) have studied students' understanding of direct current resistive electrical circuits. They found that both high school and university students' reasoning patterns regarding direct current resistive electric circuits often differ from the currently accepted explanations. The information provided by the exam provides classroom instructors a means with which to evaluate the progress and conceptual difficulties of their students and their instructional methods. It can be used to evaluate curricular packages or other supplemental materials for their effectiveness in overcoming students' conceptual difficulties. They indicated that students, especially females, tend to hold multiple misconceptions, even after instruction. During interviews, the idea that the battery is a constant source of current was used most often in answering the questions. Students tended to focus on current in solving the problems and to confuse terms, often assigning the properties of current to voltage and/or resistance. Students do not have a clear understanding of the underlying mechanisms of electric circuit phenomena. On the other hand, students were able to translate easily from a "realistic" representation of a circuit to the corresponding schematic diagram.

Küçüközer and Kocakülah (2007) aimed at revealing secondary school students' misconceptions about simple electric circuits. Seventy-six (76) students in the three grade 9 classes in the city of Balikesir in Turkey participated in the study. The results revealed the following misconceptions specific to Turkish students: none of the bulbs will light when the circuit is closed, bulbs in parallel are always brighter than those in series, batteries are constant current sources and current is consumed by circuit components. The sources of such misconceptions were found to emerge from everyday use of language and misconceptions acquired during teaching.

Summary of Major Findings in Review of Related Literature

1. Constructivism is a philosophy of learning which is learner-centered and it is founded on four main characteristics: (a) learning is an active process, (b) students construct their knowledge by means of their pre-existing knowledge, (c) learners are responsible for their own learning and (d) learning may involve conceptual change (Henson, 2003; Spigner-Littles & Anderson, 1999; Proulx, 2006; Hewson, 1992).
2. The first theory about conceptual change was proposed by Posner et al. (1982) and two kinds of conceptual change were explained in this theory by using Piaget's two terms: assimilation and accommodation. They asserted that accommodation depends on some conditions which are: dissatisfaction, plausibility, intelligibility and fruitfulness. Hewson and Hewson (1992) suggest that conceptual change can be seen as a change of status attributed to a particular conception.
3. There are two main groups of teaching approaches that promote conceptual change in students. The first group consists of strategies that are based on cognitive conflict and the resolution of conflicting perspectives (e.g. POE and learning cycle) while the second group consists of strategies which build on students' existing ideas and opinions for example analogy or metaphor (Scott *et al.*, 1992).
4. The learning cycle is an inquiry-based student-centered learning approach developed by Karplus and Thier in 1967 for the Science Curriculum Improvement Study (SCIS). It has evolved into one of the most important

teaching approaches in science education (Türkmen, 2006). Basically, the learning cycle consists of three essential phases: Exploration, Term introduction and Concept application. Other learning cycles such as the 4-E and 5-E were developed from the three-phased one. The three-phase learning cycle directly corresponds to the Piagetian principles of assimilation, accommodation, and organization (Türkmen & Usta, 2007).

5. The learning cycle approach of teaching is student-centered while the traditional approach is teacher-centered and information-giving (Renner *et al.*, 1985). The learning cycle approach enhances students' understanding of key aspects and concepts involved in direct current electricity than the traditional approach because students feel more secured, and believe they have learned more since they experienced it (Türkmen, 2006; Yilmaz & Cavas, 2006; Ates, 2005). The learning cycle is an effective teaching approach and using it in the classroom makes students develop more positive attitudes toward science and science instruction than other approaches (Türkmen, 2006).
6. The learning cycle approach is more effective for teaching most of the interrelated concepts and a number of different aspects in electricity than the traditional approach. However, the learning cycle is not very effective for teaching concepts such as conservation of current and explaining the microscopic aspects of current flow in a circuit (Ates, 2005).
7. Students at different stages have one of the following mental models about simple electric circuit prior to formal instruction of which some contradict

the right scientific concepts (İpek & Çalık, 2008): (a) Unipolar model/sink theory; (b) Clashing Current theory/two-component model (c) Closed circuit model; (d) "Current consumption model/Attenuation model; (e) Constant current source model; (f) Scientific view. Other preconceptions include the use of the concepts current and voltage interchangeably (Engelhardt & Beichner, 2004). If one battery makes a bulb shine with a certain brightness, then two batteries would make the bulb shine twice as bright regardless of the configuration (Sebastia, 1993). Current divides into two equal parts at every junction regardless of what is happening elsewhere (Rhöneck & Grob, 1987).

8. Students face some difficulties when learning concepts in electricity. They have a critical difficulty when studying more complex circuits involving combination of resistors in series and parallel (McDermott & van Zee, 1985). Also they face difficulties when they start to learn microscopic processes going on in a circuit (Eylon & Ganiel, 1990).

CHAPTER THREE

METHODOLOGY

Overview

This chapter describes and explains how the study was conducted. It discusses the research design, population, sample and sampling procedure, research instrument, data collection procedure and data analysis.

Research Design

A pretest-posttest two group nonequivalent quasi-experimental design was used in the study. In this design, the subjects in the experimental group and the control group are selected without random assignment (Creswell, 1994). It is a design used for comparing the achievements of two groups in the pretest and posttest and also to determine how effective a treatment is. The experimental group received treatment using the learning cycle teaching approach while the control group received the traditional approach of teaching. Both groups however, covered the same content of the selected concepts in direct current electricity. Students in both groups took a pretest to measure their prior knowledge of the selected concepts in direct current electricity before instruction and a posttest after instruction respectively to determine students' academic achievements regarding the strategies used. The design can be depicted in the visual mode as:

Experimental group	N	O_1	X+	O_2
Control group	N	O_1	X-	O_2

Where:

N = Nonequivalent

O_1 = Pretest measure

O_2 = Posttest measure

X+ = Learning cycle approach.

X- = Traditional teaching approach.

It is a design used most often in educational research where random assignment of subjects in a school or classroom is impracticable (Cohen & Manion, 1994). In a typical school situation, schedules cannot be disrupted nor classes reorganized in order to accommodate the researcher's study and in such a case it is necessary to use groups that are already organized into classes or intact groups (Ary, Jacobs & Razavieh, 1990). The main weakness of this design is that it is inferior to randomized experiments in terms of internal validity (Trochim, 2000). This study was affected by this weakness since extraneous variables such as age, ability, maturation and previous learning experiences were not controlled. Another weakness of the design which is also a threat to internal validity is the interaction between the control and experimental groups especially when both groups are in the same school. However, this weakness was minimized in the study since both groups were in different schools which are about 25km apart. Both quantitative and qualitative data were used in the study. Scores of students from the achievement test for both pretest and posttest constituted the quantitative data whiles responses made by students on the learning cycle activity sheets make up the qualitative data.

Population

According to Best and Kahn (1993) a population is any group of individuals that have one or more characteristics in common that are of interest to the researcher. It is the larger group about which generalization is made. The target population was form three (3) students from the six senior secondary schools offering the General Science programme in the New Juaben Municipality. Form three students in one of the schools were used for a pilot study of the instrument for data collection and so did not take part in the main study. This school is about 15km from the other two schools which were used for the study.

Sample and Sampling Procedure

Two intact science classes from two of the five remaining senior secondary schools offering physics as elective were randomly sampled using the computer generated random numbers to participate in the study. The choice of experimental and control groups were also determined by random sampling. All the students in the two intact classes took part in the study. In all 101 students participated in the study. The experimental group consisted of 59 students and the control group had 42 students. The form three students were chosen for the study because by the time the study was undertaken they had not yet been taught direct current electricity concepts as specified in their syllabus. Students gave the researcher the fullest cooperation since they were preparing for their final external examinations and also because the topic will not be repeated by their teacher after the study.

Instruments

The main instruments for data collection were a concept understanding test for pretest and posttest and students' learning cycle activity sheets [see Appendices A and C for the test and activity sheets respectively]

Pretest and Posttest

The study used a concept understanding test called Current Electricity Concept Achievement Test (CECAT) developed by the Researcher. CECAT consisted of thirty (30) multiple choice test items with three to five answer options for all the questions. The choice of any option required a brief explanation from the respondents in order to determine the extent of understanding. In developing CECAT, a set of instructional objectives were constructed from subtopics treated under direct current electricity in the senior secondary school syllabus and textbooks. This helped the Researcher in developing the various test items. The Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) version 1.0 developed by Engelhardt and Beichner (2004) to evaluate high school and university students' understanding of a variety of resistive direct current circuit concepts also helped the researcher in the development of CECAT. For a test to be useful, it must be both reliable and valid.

Reliability

The KR-20 formula was used to evaluate the reliability of the test because the items in the test were scored dichotomously (right or wrong) and also the items were not of equal difficulty (Creswell, 1994).

Validity

Content validity of the instrument was established by presenting the test and its instructional objectives (IOs) to two physics lecturers in the Department of Science and Mathematics Education for inspection to ensure that the domains were adequately covered. The instructional objectives (IOs) are shown in Table 1.

The discrimination and difficulty indices of the items were also determined.

Table 1: Instructional Objectives for Current Electricity Concepts Achievement Test (CECAT) and Question Numbers

Instructional Objectives	Question Numbers
Physical aspects of electric circuits	
1. Identify and explain a short circuit (i.e. more current flows through the path of lesser resistance).	13, 24
2. Explain the functional two-endedness of circuit elements (i.e. circuit elements have two possible points with which to make a connection).	18
3. Identify a complete circuit and acknowledge the necessity	28

Table 1 continued

Instructional Objectives	Question Numbers
of a complete circuit for charges to flow in a steady state.	
4. Apply the concept of resistance to a variety of circuits.	5, 9, 10
5. Interpret diagrams for a variety of circuits including series, parallel and combination of the two.	6,17, 19
6. Apply the conceptual understanding that the battery is a source of electrical energy.	7
Current	
7. Apply the conservation of current to a variety of circuits.	3, 12
8. Explain the microscopic aspects of charge flow in a circuit.	1, 2, 22, 30
Potential difference	
9. Apply the knowledge that the amount of current is influenced by the potential difference maintained by the battery and resistance in a circuit.	4, 8, 11
10. Apply the concept of potential difference to a variety of circuits including the knowledge that total potential difference in a series circuit is the sum of all the individual potential differences whiles in a parallel circuit the total potential difference is equal everywhere in the circuit.	14, 15, 16 20, 21, 23, 25
Current and Voltage	
11. Combine the concepts of current and potential difference to a variety of circuits.	26, 27, 29

Pilot Testing

After the Current Electricity Concept Achievement Test (CECAT) was modified from expert advice, it was field tested. The test was administered to students in one of the senior secondary schools in the New Juaben Municipality to determine its reliability. This school was part of the target population but did not take part in the main study. Seventy (70) form three students took part in the test and it took them approximately one and half hours to complete. Both the question papers and the answer sheets were collected from the students just after the test. Students' total scores for the items ranged from 0 to 30. The reliability of the test was calculated using the KR-20 formula and found to be 0.76. The discrimination and difficulty indices of the items were also determined (see Appendix B for the answers, discrimination and difficulty indices of the items).

The learning cycle activities and the traditional teaching method lesson plans that were developed for teaching the selected concepts in direct current electricity were shown to two science education physics lecturers for their appraisal. The learning cycle activities were then tried by the researcher in collaboration with two other physics teachers on the field. These enabled modifications to be made to obtain the final form for the study. In all twelve (12) lessons were designed, six each for both the learning cycle approach and traditional teaching approach.

Data Collection Procedure

Permission was sought from the headmasters of the two sêlected senior high schools to undertake the study. The Researcher administered the test instrument as pretest to the groups to assess students' knowledge prior to the treatment. This was followed by teaching the instructional materials to both groups by the researcher. The experimental group was instructed using the learning cycle approach whiles the control group was instructed using the traditional teaching approach. The two groups however covered the same content area regarding the selected concepts in direct current electricity. Two days after the intervention, a posttest was administered to the groups in order to determine students' achievement after the interventions. The study, including testing lasted for about three weeks.

Description of Teaching Interventions

The Traditional Teaching Approach

It involves the teaching of topics in a regular physics course where teaching-learning activities are teacher centered. The Researcher prepared his notes and did most of the talking during the teaching process. He presented the scientifically correct concepts to students, then asked students to do laboratory activities to confirm the concepts and then gave exercises related to the concepts learnt. The Researcher answered students' questions and occasionally asked students some questions. After marking students' assignments or class exercise, he distributed the marked scripts to students to effect the necessary corrections. Students were put into groups during practical sections but individual students developed their experimental reports where necessary. Students were encouraged to discuss among themselves when performing the activities. The above approach was used to teach all the selected concepts in direct current electricity to students in the control group.

The Learning Cycle Teaching Approach

This approach is a student-centered teaching procedure and offers another way of teaching science concepts in which students learn from their experiences, rather than through other learning methods which rely solely on textbooks for classroom learning. The learning cycle teaching approach used went through three essential phases as follows:

1. Exploration: This phase typically consists of hands-on activities or field experience in which students gather and record data from their observations and measurements. The purpose of this phase is that students are encouraged to learn through their own experience. Students were informed about an experiment or demonstration which will be performed. Students were put into groups to perform activities. During each practical activity lesson, a set of materials were given to students to perform the experiment. Every student was given an activity sheet containing instructions to be followed. On this sheet, spaces were provided for students to write their predictions before performing a specific task, then make observation and draw conclusions after each activity. When their predictions and observations are inconsistent with each other, the students' explanations are explored. This helped students to reconcile their prior ideas with their current observations.
2. Term introduction: The Researcher toke an active role in leading the students to develop the concept. Students used their experience from exploration phase to develop an understanding of the science concept and explain the science concept with guidance from the teacher.

3. Concept application: Students were given the opportunity to directly apply the concept learned during the term introduction phase. Exercises and assignments were given to students to do.

This approach was used to teach all the selected concepts in direct current electricity to students in the experimental group. Specimen lesson plans for teaching the selected concepts in direct current electricity using the learning cycle approach and the traditional teaching approach are found below.

Specimen Lesson Plans for Teaching the Selected Concepts in Direct Current Electricity Using the Learning Cycle Approach.

Lesson One

Topic: Elements of simple electric circuit.

Duration: 80 minutes

Previous Knowledge: Students have been using a torchlight bulb, dry cell(s) and connecting wires to light up the bulb.

Specific Objectives

By the end of the lesson the student should be able to:

1. state the physical elements of a simple electric circuit.
2. define 'electromotive force', 'potential difference', 'electric current' and 'electric resistance' in his/her own words.

Teaching/Learning materials: A dry cell, a torchlight bulb, key and two connecting wires.

Exploration Stage

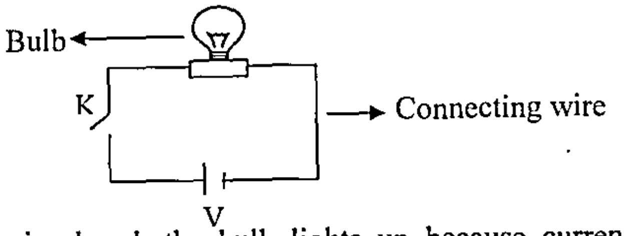
Students in groups of three (3) are given a dry cell, a bulb, a key and two connecting wires and asked to find out different ways to light the bulb; and to describe how they got the bulb to light up.

Term Introduction Stage

Teacher explains to students the symbols used in electric circuits and also defines what constitutes a "simple electric circuit".

Key ideas:

i. A simple electric circuit consists of a dry cell or series of dry cells connected by copper wires to one or more resistors (bulbs) or other components as shown below:



ii. When the key is closed, the bulb lights up because current flows through the circuit.

iii. When the key is opened the bulb does not light up because no current flows through the circuit.

Teacher helps students to identify the various functions of a dry cell, the bulb, and the connecting wires.

Key ideas:

<u>The Dry Cell</u>

A dry cell, either primary or secondary, supplies electrical energy; it has an electromotive force (e.m.f.) which drives electric charges (current) around a closed circuit which sets up a potential difference across the various components.

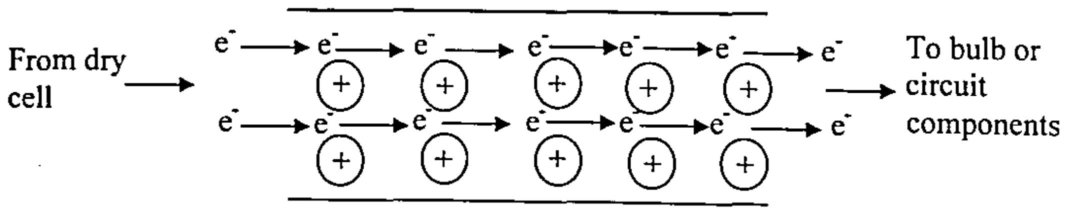
The e.m.f. may be defined as the total work done when the cell transfers a unit charge around a circuit. For any given circuit, the greater the e.m.f. the greater the current in the circuit. The unit of e.m.f. is volt (V).

The e.m.f. creates an electric potential energy (potential) around a circuit. Conventionally, the direction of current is from the positive terminal to the negative terminal of a cell. Hence the potential is considered to fall from the positive terminal to the negative terminal (i.e. the positive terminal of a cell has a greater potential than the negative terminal).

At any two points in the circuit, there exist a potential difference (pd) arising from the fall in potential. Electrical potential energy is analogous to gravitational potential energy (i.e. the higher a body is from the ground the greater the potential energy). Electric potential energy may be defined as the work done in moving a unit charge from one point to another in a circuit.

The Connecting Wires

Teacher describes how current is conducted through a wire to students as follows: The conducting wire is made up of positive centers arranged at regular distances from each other and surrounded by free (delocalized) electrons as shown below:



The e.m.f. drives electrons for the cell which enter the wire and push nearby electrons. Nearby electrons are pushed at the same time towards the other end of the wire. The entry of one electron pushes out one electron at the opposite end of the wire. This is because electrons are free to move between points of different electric potential. Electricity is conducted by the quick movement of electrons through metals (wires).

The amount of electric charge that passes a point in a circuit in one second determines the current. Electric current (I) may be defined as the rate of flow of electric charges around a circuit. Its unit is ampere (A). Mathematically,

$$current = \frac{Electric\,charge}{Time} = \frac{Q}{t}$$

As the electrons move through a wire their movements get restricted by the positive centers which are continuously vibrating about their fixed positions. This offers resistance to the flow of electric charges compared to the connecting wires in a circuit. Electrical resistance (R) may be defined as the force which opposes the flow of electric charges (current) in a conductor. Its unit is ohm (Ω). [Teacher arranges the scene and asks students to dramatize the analogy of how electricity is conducted through a wire].

The Bulb

The filament of the torchlight bulb is made of a thin wire which offers more resistance to the flow of charges. Through collision, charges in the filament produce friction which generates heat energy and is converted to light energy to light the bulb.

Concept Application Stage

Students are asked to do the following exercises:

1. Draw a simple electric circuit and label it.

2. In your own words define the terms "electromotive force", "electric current", "electric resistance" and "potential difference".
3. Calculate the current if 24 coulombs of charge pass through a wire at a steady rate for 4 seconds.

Lesson Two

Topic: Ohm's law.

Duration: 40 minutes.

Previous Knowledge: Students can set up simple electric circuits and also define the terms 'electromotive force', 'current', 'potential difference' and 'resistance'.

Specific Objectives

By the end of the lesson the student should be able to:

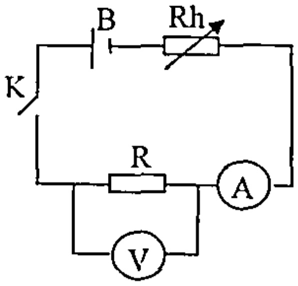
1. state Ohm's law correctly.
2. perform experiments to verify Ohm's law.

Teaching/Learning materials: A power supply, rheostat, key, ammeter, voltmeter, a standard resistor and connecting wires.

Exploration Stage

Teacher gives students the instructional sheets containing the steps to be followed and explains to students that the experiment is about finding the relationship between" current" and the "potential difference".

Teacher guides students to follow the instructions below to perform the experiment.



1. The circuit above consists of a battery B, a key K, a resistor R, a rheostat Rh, an ammeter A, a voltmeter V and connecting wires.
2. Connect the circuit as shown.
3. Set the rheostat Rh, so that it is as large as possible.
4. Close the key K, and record the readings on the voltmeter and ammeter as V_0 and I_0 respectively.
5. Adjust the rheostat to a voltmeter reading of 0.2V and record the corresponding ammeter reading.
6. Repeat the procedure for values of 0.4V, 0.6V, 0.8V and 1V.
7. Tabulate the results as shown on the table below:

V_0=

I_0=

V (V)	I (A)	V/I (Ω)
0.2		
0.4		
0.6		
0.8		
1.0		

8. Evaluate the ratio of V and I.

   What can be said about the results for the ratio of V and I from the table?
9. Plot a graph of V on the vertical axis against I on the horizontal axis.
10. Determine the slope of the graph.

11. Compare the value of the slope to the results for the ratio of V and I from the table.
12. What conclusions can you draw from the experiment?

[Teacher through discussion with students derives Ohm's law from the experiments performed.]

Key ideas:

1. Ohm's law states that at constant temperature the current passing through a wire is directly proportional to the potential difference between the ends of the wire.
2. Mathematically, the law is given as $V \propto I$

$$\Rightarrow V = IR$$

where R is the constant of proportionality and called 'electrical resistance'.

Concept Application Stage

Students are asked to undertake the following exercises:

1. State Ohm's law correctly.
2. With the aid of a diagram, describe an experiment to verify Ohm's law.
3. For a cell with a voltage of 1.5V producing a current of 0.5A, what is the resistance of the connecting wire?

Lesson Three

Topic: Cells Connected in series.

Duration: 80 minutes

Previous knowledge

Students can connect up simple electric circuits.

Specific Objectives

By the end of the lesson the student should be able to:

1. explain that the more the number of cells connected in series, the brighter the lighted bulb in the circuit.
2. show that the total voltage of a number of cells connected in series equals the algebraic sum of the voltages of the individual cells.

Learning Cycle Activity 1

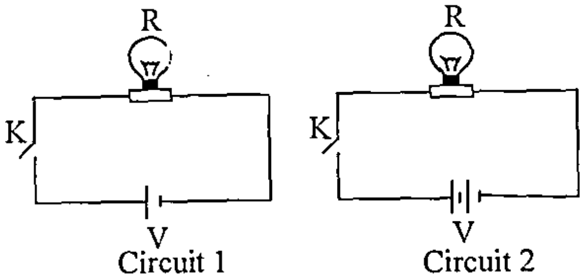
Teaching/Learning materials: 3 dry cells, a bulb of voltage 2.5V, key and 3 connecting wires.

Exploration Stage

Teacher gives the activity sheet to students and guides students in groups of three to perform the activities on the sheet.

Students' Activity

1. Using the materials provided, set up Circuit 1.



Circuit 1 Circuit 2

2. Predict what you expect about the brightness of bulb R if one more identical dry cell is added to the circuit (like as in Circuit 2). Explain your response.
3. Discuss your predictions and reasons among yourselves.
4. Using your materials, set up Circuit 2.

5. What did you observe in the brightness of the bulb in Circuit 2?
6. Had your observation confirmed your prediction? Yes/No
7. Which circuit had the brightest bulb, Circuit 1 or Circuit 2?
8. Why did it turn up so?
9. What conclusion can you give for this observation?
10. What do you predict will happen to the brightness of the bulb if more identical dry cell were added to Circuit 2?
11. Try this out. What did you observe?
12. How do we term a circuit that contains dry cells arranged like as in Circuit 2?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key ideas:

1. A group of dry cells connected together is called a battery.
2. Dry cells connected end to end consecutively to each other (as shown) constitute a series connection of cells. 
3. The more the number of cells connected in series, the brighter the bulb connected in the circuit will light up.

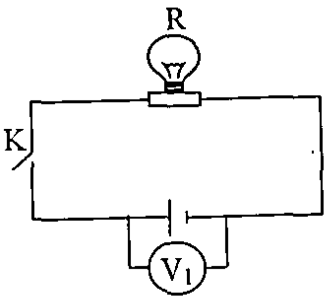
Learning Cycle Activity 2

Teaching/Learning materials: 2 dry cells, a bulb of voltage 2.5V and connecting wires.

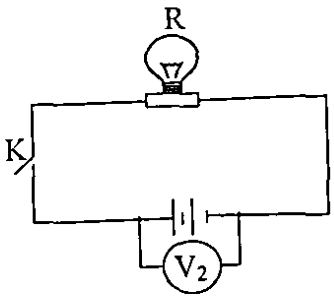
Exploration Stage

Teacher guides students to follow instructions on the activity sheet to perform the activities.

Students' Activity



Circuit 1



Circuit 2

1. Suppose voltmeter V_1 in Circuit 1 shows a reading of 1.5V, what will be the reading on voltmeter V_2 in Circuit 2 if the dry cells are identical? V = ...V. Explain your response.
2. Discuss your predictions and reasons among yourselves.
3. Using the materials provided, set up Circuits 1 and 2 as shown one after the other and note the readings on each voltmeter.

   V_1 = ...V

   V_2 = ...V
4. Are there any differences between your response (in Step 1) and experimental results (in Step 3)? Yes/No. Explain your response.
5. What will be the reading on the voltmeter if three identical dry cells are connected in series in a circuit? V_3 =...........V.
6. What conclusions can you draw about the voltage of dry cells connected in series in a circuit?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key ideas:

1. The effective voltage of a number of dry cells in series equals the algebraic sum of the voltages. $V_T = V_1 + V_2 + V_3 + \ldots\ldots\ldots\ldots + V_n$

V_T = effective voltage

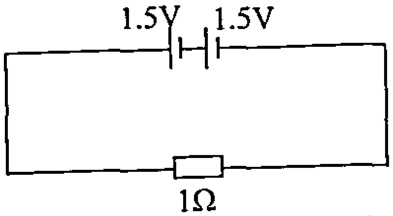
Concept Application Stage

Students are asked the do the following exercises in class:

1. Two dry cells, each having an e.m.f. of 1.5V, are connected in series as shown below. Find

   (a). the effective e.m.f. of the cells.

   (b). the current when the cells are connected to a 1Ω resistor.



2. Six cells, each having an e.m.f. of 2V are connected in series with an ammeter of negligible resistance and a 1.4Ω resistor.

   (a). Draw the corresponding circuit diagram.

   (b). Calculate the combined e.m.f. of the dry cells.

Lesson Four

Topic: Cells Connected in parallel

Duration: 80 minutes

Previous knowledge: Students are familiar with circuit diagrams and circuit connections.

Specific Objectives

By the end of the lesson the student should be able to:

1. explain that a number of identical dry cells connected in parallel does not increase the brightness of a bulb connected in series to it in a circuit.

2. show that the effective voltage of a number of similar cells connected in parallel equals the voltage of one cell.

Learning Cycle Activity 1

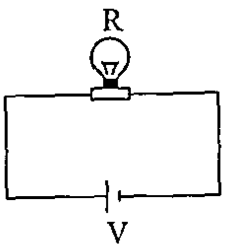
Teaching/Learning materials: 3 dry cells, a bulb of voltage 2.5V and 5 connecting wires.

Exploration Stage

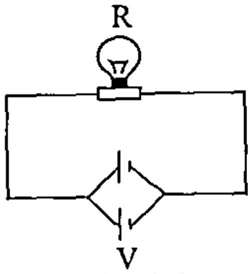
Teacher gives the activity sheet to students and guides students in groups of three to perform the activities on the sheet.

Students' Activity

1. Using your materials, set up Circuit 1.



Circuit 1



Circuit 2

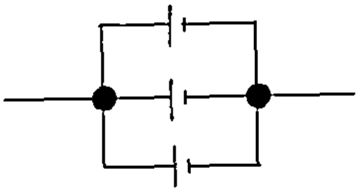
2. Predict what you expect about the brightness of bulb R should one more identical dry cell be added to the circuit (as in Circuit 2). Explain your response.
3. Discuss your predictions and reasons among yourselves.
4. Using your materials, set up Circuit 2.
5. What did you observe in the brightness of the bulb in Circuit 2?
6. Had your observation confirmed your prediction? Yes/No.
7. Which circuit had the brightest bulb, Circuit 1 or Circuit 2?
8. Why is this so?

9. What conclusion can you give for this observation?
10. What do you predict will happen to the brightness of the bulb if more identical dry cells are added to Circuit 2?
11. Try this out. What did you observe?
12. How do we call a circuit that contains dry cells arranged like in Circuit 2?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key ideas:

1. Dry cells connected side by side with their corresponding ends joined together at their respective common points are said to form a parallel connection of cells.



2. The meeting point of three or more wires in an electrical network is called a junction.
3. A number of identical dry cells connected in parallel in a circuit does not increase the brightness of the bulb connected to them (i.e. the brightness remains the same).

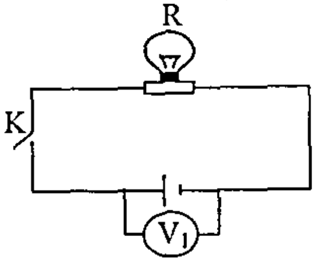
Learning Cycle Activity 2

Teaching/Learning materials: 2 dry cells, a bulb of voltage 2.5V and connecting wires.

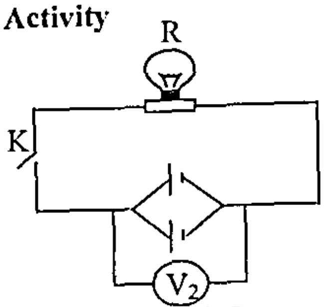
Exploration Stage

Teacher gives the activity sheet to students and guides students in groups of three to perform the activities.

Students' Activity



Circuit 1



Circuit 2

1. Suppose voltmeter V_1 in circuit 1 shows a reading of 1.5V, what will be the reading on voltmeter V_2 in Circuit 2? V_2 = ...V. Explain your response.
2. Discuss your predictions and reasons among yourselves.
3. Using the materials provided, set up Circuit 1 and 2 as shown, one after the other. Close the key and note the readings on each voltmeter.

   V_1 = ...V

   V_2 = ...V
4. Are there any differences between your response (in Step. 1) and the experimental results (in Step 3)? Yes/No? Explain your response.
5. What will be the reading on the voltmeter if three identical dry cells are connected in parallel? V_3 =...........V.
6. What conclusion can you draw about the voltage of the identical dry cells connected in parallel?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key idea:

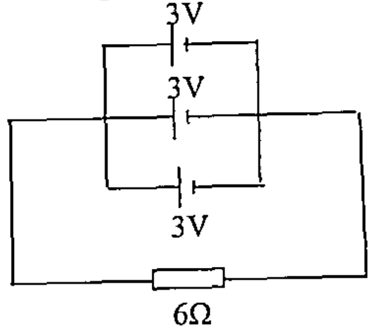
1. The effective voltage of a number of similar cells connected in parallel equals the voltage of one of the cells. $V_T = V_1 = V_2 = V_3 = \ldots V_n$

V_T = effective voltage.

Concept Application Stage

Students are asked the do the following exercises in class:

1. Calculate the effective voltage and the current flowing in the circuit diagram shown.



2. Two dry cells each having an e.m.f. of 1.5V are connected in parallel in a circuit. Find

   (a). the effective e.m.f. of the cells.

   (b). the current when the cells are connected to a 1Ω resistor.

Lesson Five

Topic: Resistors Connected in Series.

Duration: 120 minutes

Previous knowledge: Students are familiar with series and parallel connections of dry cells.

Specific Objectives

By the end of the lesson the student should be able to:

1. explain that two or more identical bulbs connected in series to a dry cell produce a dimmer light than one of them connected to the same.
2. explain correctly the following:

a. the source voltage is shared equally between resistors of similar resistances.

b. the source voltage is shared proportionally by unequal resistors.

3. deduce the general relation for resistors connected in series.

Learning Cycle Activity 1

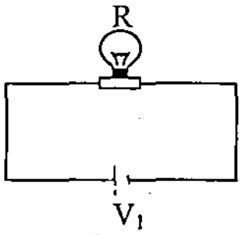
Teaching/Learning materials: A power supply, 3 bulbs of voltage 2.5V and connecting wires.

Exploration Stage

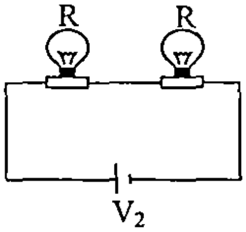
Teacher gives the activity sheet to students and guides students in groups of three to perform the activities.

Students' Activity

1. Using your materials, set up Circuit 1.



Circuit 1



Circuit 2

2. Predict what you expect about the brightness of bulb R if one more identical bulb is added to the circuit (as in Circuit 2). Explain your response
3. Discuss your predictions and reasons among yourselves.
4. Using your materials, set up Circuit 2.
5. What did you observe in the brightness of the bulbs in Circuit 2?
6. Had your observation confirmed your prediction? Yes/No.

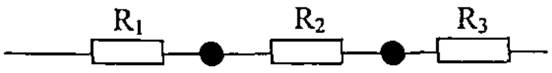
7. Which circuit had the brightest bulb, Circuit 1 or Circuit 2?
8. Why is this so?
9. What conclusion can you give for this observation?
10. What will happen should you unscrew one bulb in Circuit 2?
11. Try this out.
12. What did you see and why was this so?
13. What will happen to the brightness of the bulbs if one more identical bulb should be added to those in Circuit 2?
14. Try the set up. What did you observe?
15. Suppose you had a string of Christmas tree lights connected like in circuit 2, what would happen to the bulbs when one of the bulbs is unscrewed off?
16. How do we call a circuit that contains dry cells arranged like in Circuit 2?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key ideas:

1. Two or more identical bulbs connected in series to a dry cell produce a dimmer light than one of them connected to the same source because the source voltage will be shared among the bulbs.
2. When one of the bulbs is unscrewed, all other bulbs will go off because the circuit will be opened.

3. The arrangement whereby resistors or bulbs are connected end to end consecutively so that the same current flows through each is called <u>series connection of resistors</u> as shown below:



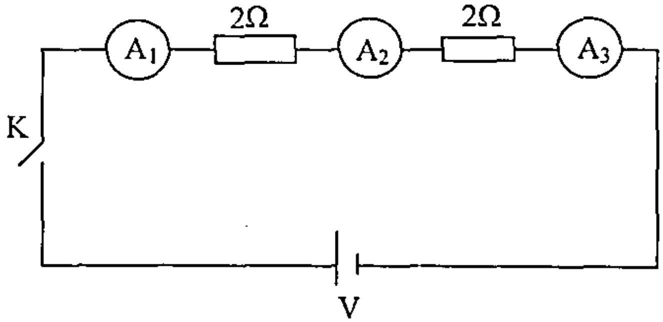
Learning Cycle Activity 2

Teaching/Learning materials: A power supply, three ammeters, two 2Ω resistors, a 3Ω resistor and conducting wires.

Exploration Stage

Teacher gives the activity sheet to students and guides students in groups of three to perform the activities.

Students' Activity



1. In the circuit above, suppose ammeter A_1 shows a reading of 0.06A. Choose from the alternatives below the correct answer for the current measurement of ammeter A_2 and ammeter A_3.

   A. $A_2 = 0.05A$; $A_3 = 0.04A$.

   B. $A_2 = 0.06A$; $A_3 = 0.05A$.

   C. $A_2 = 0.06A$; $A_3 = 0.06A$.

   D. $A_2 = 0.07A$; $A_3 = 0.08A$

Explain your response.

2. Discuss your predictions and reasons among yourselves.
3. Using the materials, set up the circuit as shown in the figure above.
4. Close the key and note down the value of the current passing through each ammeter in turns.

   A_1 = ……A A_2 = ……A A_3 = ……A

5. Are there any differences between your response (in step 1) and experimental results (in step 4)? Yes/No?
6. Replace the second 2Ω resistor with a 3Ω resistor, and note the ammeter readings in turns.

   A_1= ……A A_2 = ……A A_3 = ……A

7. Are there any differences between the results in Step 4 and results in Step 6? Yes/No.
8. What conclusions can you draw from the experiment?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key idea:

1. The same current flow through resistors connected in series in a given circuit.

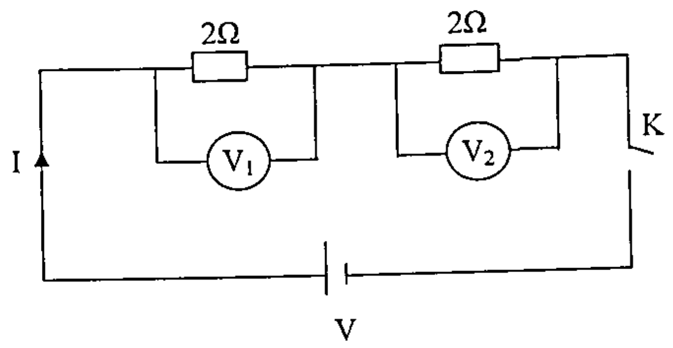
Learning Cycle Activity 3

Materials: A power supply, two voltmeters, two 2Ω resistors, a 3Ω and seven conducting wires.

Exploration Stage

Teacher gives the activity sheet to students and guides students in groups of three to perform the activities.

Students' Activity



1. In the circuit, will the reading on voltmeter V_1 be the same or different from the reading on voltmeter V_2? Explain your response.
2. Discuss your predictions and reasons among yourselves.
3. Using the materials, set up the circuit as shown in the figure above.
4. Close the key and note down the readings on each voltmeter in turns.

   V_1 = ……V V_2 = ……V

5. Are there any differences between your response (in Step 1) and experimental results (in Step 4)? Yes/No
6. Replace the second 2Ω resistor with a 3Ω resistor, and note the voltmeter readings in turns.

   V_1 = ……V V_2 = ……V

7. Are there any differences between the results in step 4 and the results in step 6? Yes/No
8. What conclusions can you draw about the voltage across the resistors?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key ideas:

1. The algebraic sum of the potential differences (or voltages) across resistors connected in series in a circuit is equal to the effective voltage or source voltage.
2. The effective voltage in a series circuit is shared equally across resistors of similar resistances.
3. The effective voltage in a series circuit is shared proportionally across unequal resistors.
4. The effective voltage across a single resistor in a circuit is that of the source voltage.
5. From activity 2 and 3, it can be seen that for any series connection, the current flowing through the resistors is the same whiles the voltages through each resistor is different. From Ohm's law, we get

$$V_1 = IR_1 \qquad\text{———} \qquad 1$$

and $V_2 = IR_2$ ——— 2

But the total voltage in the circuit is given by $V = V_1 + V_2$ ——— 3

Substituting equation 1 and 2 into 3, we get

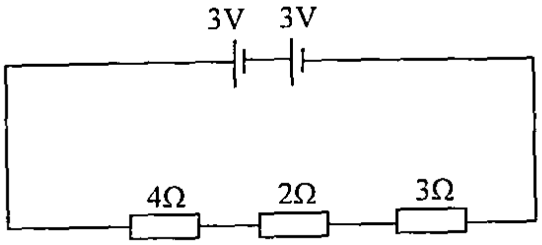
$$IR = IR_1 + IR_2$$
$$IR = I(R_1 + R_2)$$
$$\therefore R = R_1 + R_2 \qquad\text{———}\qquad 4$$

Generally, if there are two or more resistors in series, the effective or combined resistance (R$_T$) can be given as $R_T = R_1 + R_2 + R_3 + \ldots\ldots. R_N$

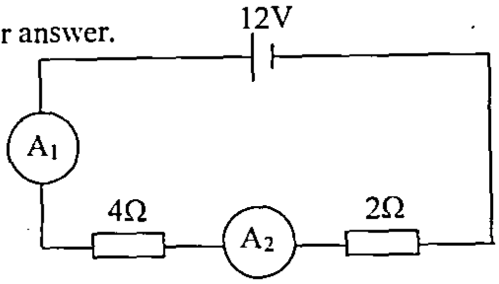
Concept Application Stage

Students are asked to do the following exercises in class:

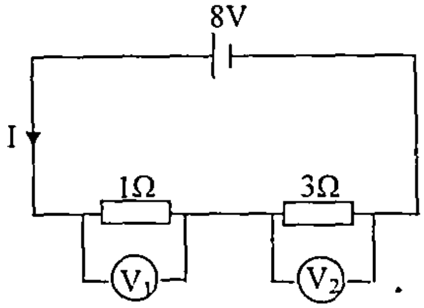
1. In the circuit diagram below, what is:
   a. The effective voltage of the cells?
   b. The effective resistance of the circuit?
   c. The current in the circuit?
   d. The direction of current in the circuit?



2. In the circuit diagram below, ammeter A_1 reads 2A. What is the reading of ammeter A_2? Explain your answer.



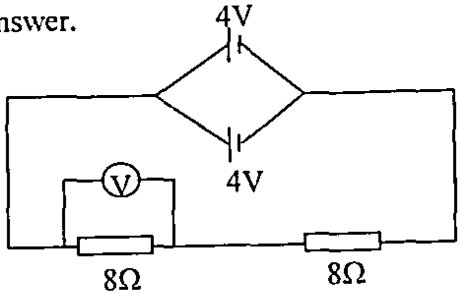
3. In the circuit diagram below, what are the readings of voltmeter V_1 and V_2? Explain your answers.



4. In the circuit below
   a. What is the effective voltage?

b. What will be the reading of the voltmeter V shown in the diagram?

Explain your answer.



Lesson Six

Topic: Resistors Connected in Parallel.

Duration: 120 minutes

Previous knowledge: Students are familiar with series connection of resistors in a circuit.

Specific Objectives

By the end of the lesson the student should be able to:

1. describe the brightness of bulbs connected in parallel in a circuit.
2. measure, and identify through experimentation, that the current in the main circuit is the sum of currents in the sub-circuits.
3. measure, and identify through experimentation, that the voltage across each of the resistors in parallel is equal to that of the source voltage.
4. deduce the general relation for resistors connected in parallel in a circuit.

Learning Cycle Activity 1

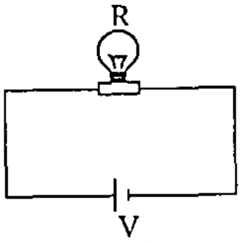
Teaching/Learning materials: A power supply, 3 bulbs and connecting wires.

Exploration Stage

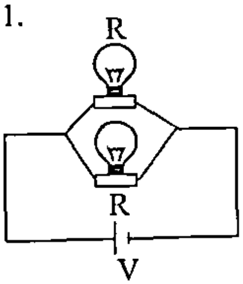
Teacher gives the activity sheet to students and guides students in groups of three to perform the activities.

Students' Activity

1. Using your materials, set up Circuit 1.



Circuit 1



Circuit 2

2. Predict what you expect about the brightness of bulb R if one more identical bulb is added to the circuit (as shown in Circuit 2). Explain your response.
3. Discuss your predictions and reasons among yourselves.
4. Using your materials, set up Circuit 2.
5. What did you observe in the brightness of the bulbs in Circuit 2?
6. Had your observation confirmed your prediction? Yes/No.
7. Which circuit had the brightest bulb(s), Circuit 1 or Circuit 2?
8. Why is this so?
9. What conclusion can you give for this observation?
10. What would happen should you unscrew one bulb in Circuit 2?
11. Try this out.
12. Did you observation match up with your prediction?
13. What will happen to the brightness of the bulbs if one more identical bulb is added to those in Circuit 2?
14. Try this out. What did you observe?

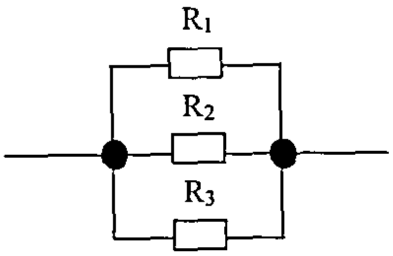
15. Suppose you had a string of Christmas tree lights connected like in Circuit 2, what would happen to the bulbs when one of the bulbs is unscrewed off?

16. What is the name given to a circuit that contains bulbs arranged like in Circuit 2?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key ideas:

1. Similar bulbs connected in parallel to a cell produce the same brightness but dissimilar bulbs produce varying brightness depending on their resistances.
2. When one of the bulbs is disconnected in a sub-circuit, others in the other sub-circuits continue to glow.
3. The arrangement whereby two or more resistors (or bulbs) are connected side by side and so that their corresponding ends are joined together at their respective points (as shown below) is called <u>parallel connection of resistors</u>.

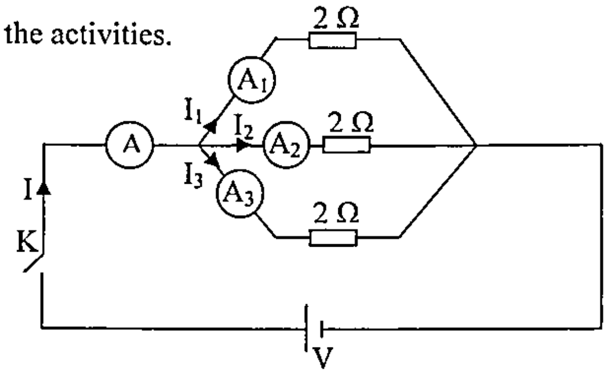


Learning Cycle Activity 2

Teaching/Learning materials: A power supply, 4 ammeters, three 2Ω resistors, a 3Ω resistor, 4Ω resistor and connecting wires.

Exploration Stage

Teacher gives the activity sheet to students and guides students in groups of three to perform the activities.



1. In the circuit diagram, will the reading on ammeters A_1, A_2, A_3 and A_4 be the same or different? Explain your response.
2. Discuss your predictions and reasons among yourselves.
3. Using the materials, set up the circuit as shown in the circuit diagram shown.
4. Close the key and note down the value of the current passing through each ammeter in turns.

   A = ……A A_1 = ……A A_2 = ……A A_3 = ……..A

5. Are there any differences between your response (in Step1) and experimental results (in Step 4)? Yes/No.
6. Replace two of the 2Ω resistors with the 3Ω and 4Ω resistors respectively and note down the ammeter readings in turns.

   A = ……A A_1 = ……A A_2 = ……A A_3 = ……..A

7. Are there any differences between the results (in step 4) and the results (in step 6)? Yes/No.
8. What conclusions can you draw about the experiment?

[Teacher summaries all that has been done in the activity through discussion with students.]

Key ideas:

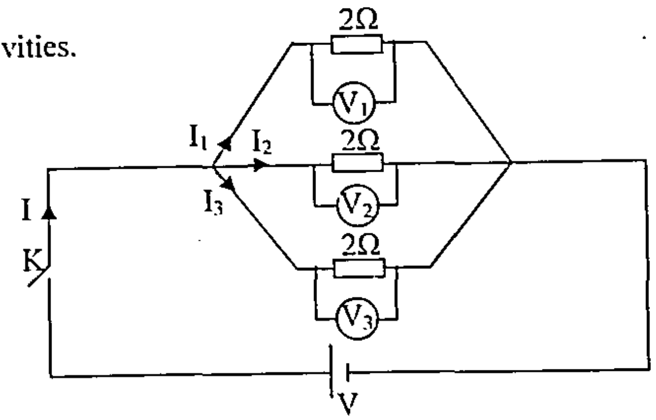
1. The current in the main circuit is the algebraic sum of all the currents in the sub-circuits. $I = I_1 + I_2 + I_3 + \ldots + I_n$
2. The current in the main circuit is shared equally among similar resistors in the sub-circuits and proportionally among unequal resistors.

Learning Cycle Activity 3

Teaching/Learning materials: A power supply, three voltmeters, three 2Ω resistors, a 3Ω resistor, 4Ω resistor and conducting wires.

Exploration Stage

Teacher gives the activity sheet to students and guides students in groups of three to perform the activities.



Students' Activity

1. In the circuit diagram, will the reading on voltmeter V_1, V_2, and V_3 be the same or different? Explain your response.
2. Discuss your predictions and reasons among yourselves.
3. Using the materials, set up the circuit as shown in the circuit diagram.

4. Close the key and note down the voltage across each of the resistors in turns. $V_1 = \ldots\ldots V$ $V_2 = \ldots\ldots V$ $V_3 = \ldots\ldots V$
5. Are there any differences between your response (in Step 1) and experimental results (in Step 4)? Yes/No
6. Replace two of the 2Ω resistors with the 3Ω and 4Ω resistors respectively and note down the voltmeter readings in turns.

   $V_1 = \ldots\ldots V$ $V_2 = \ldots\ldots V$ $V_3 = \ldots\ldots V$
7. Are there any differences between the results in Step 4 and the results in Step 6? Yes/No.
8. What conclusions can you draw about the experiment?

[Teacher summaries all that has been done in the activity through discussion with students]

Key ideas:

1. The voltage across each of the resistors connected in parallel in a circuit is equal to that of the source voltage.
2. For any parallel connection of resistor in a circuit, the voltage across each of the resistors is the same whiles the current passing through each of the resistors is different. From Ohm's law $V = IR$ ——— 1

$$\text{i.e. } I = \frac{V}{R} \qquad \text{———} \qquad 2$$

Hence, the currents across each of the resistors are given by

$$I_1 = \frac{V}{R_1},\ I_2 = \frac{V}{R_2} \text{ and } I_3 = \frac{V}{R_3} \qquad \text{———} \qquad 3$$

But the total current in the circuit is given by $I = I_1 + I_2 + I_3$ ——— 4

$\therefore$ Substituting equation 2 and 3 into 4, we get

$$\frac{V}{R}=\frac{V}{R_1}+\frac{V}{R_2}+\frac{V}{R_3}$$

$$\frac{V}{R}=V\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)$$

$$\therefore\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

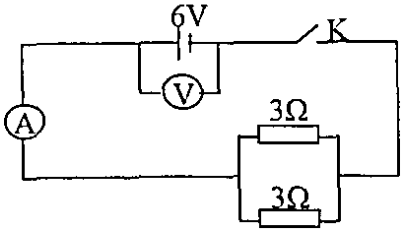
Generally, if there are two or more resistors connected in parallel in a circuit, the effective resistance R can be given as $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\ldots+\frac{1}{R_N}$

3. Currents in the sub-circuits are inversely proportional to the resistance in their respective circuits in a parallel connection of resistors in a circuit.

Concept Application Stage

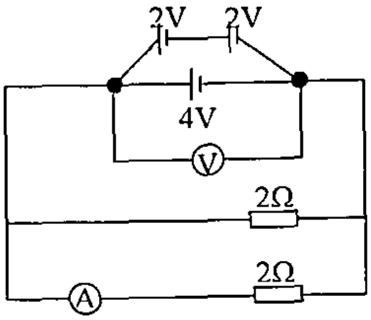
Students are asked to do the following exercises in class:

1. In the circuit diagram, the key (K) is open.
   a. What is the effective resistance in the circuit?
   b. What will be the reading on ammeter A? Explain your answer.
   c. What will be the reading on voltmeter V? Explain your answer.

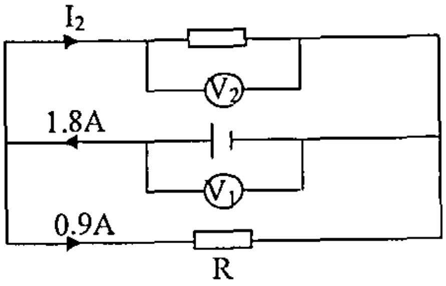


2. In the circuit diagram below,
   a. What is the effective resistance in the circuit?
   b. What is the reading on the voltmeter?

c. What is the reading on the ammeter?



3.



In the circuit diagram above,

a. What will be the reading of voltmeter V_1 if V_2 reads 4V?

b. What is the value of the current I_2?

Specimen Lesson Plans for Teaching the Selected Concepts in Current Electricity using the Traditional Teaching Approach.

Lesson One

Topic: Elements of a simple electric circuit.

Duration: 80 minutes

Previous Knowledge: Students have been using a torchlight bulb, dry cell(s) and connecting wires to produce light.

Specific Objectives

By the end of the lesson, the student should be able to

1. state the physical components of a simple electric circuit.

2. define 'electromotive force', 'potential difference', 'and electric current' and 'electric resistance' in his/her own words.

Teaching/Learning materials: A dry cell, a torchlight bulb and two connecting wires.

Introduction

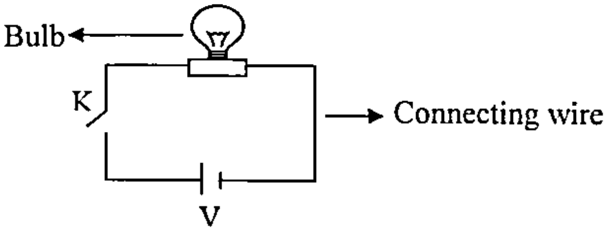
Teacher uses questions to review students' previous knowledge.

Content Development

1. Teacher explains the symbols used in electrical circuits to students. He explains to students the uses of the various materials supplied to them.
2. Teacher provides the material to students in groups of three.
3. Teacher demonstrates to students the different way to light up the bulb using the materials provided.
4. Students are asked to also connect up the materials to let the bulb light up.
5. Teacher explains the functions of the dry cell, connecting wires and bulb to students and asks them to copy the following into their notebooks.

Key ideas:

A simple electric circuit consists of at least a bulb (resistor), a dry cell and connecting wires as shown below:



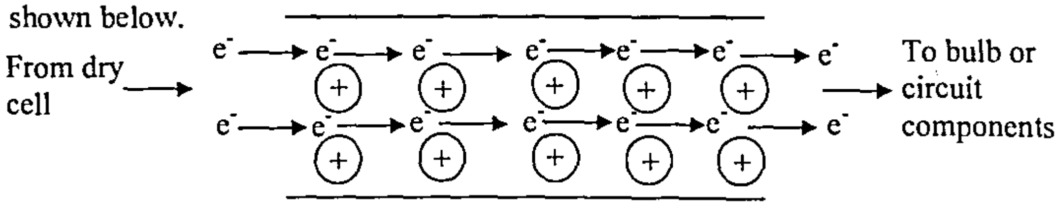
When the key is closed, the bulb lights up because current flows through the circuit. When the key is opened or removed the bulb does not light up because no current flows.

A dry cell, either primary or secondary, supplies electrical energy; it has an electromotive force (e.m.f.) which drives electric charges (current) around a closed circuit which sets up a potential difference across the various components. The e.m.f. may be defined as the total work done when the cell transfers a unit charge around a circuit. For any given circuit, the greater the e.m.f. the greater the current in the circuit. The unit of e.m.f. is volt (V).

The e.m.f. creates an electric potential energy (potential) around a circuit. Conventionally, the direction of current is from the positive terminal to the negative terminal of a cell. Hence, the potential is considered to fall from the positive terminal to the negative terminal (i.e. the positive terminal of a cell has a greater potential than the negative terminal).

At any two points in the circuit, there exist a potential difference (pd) arising from the fall in potential. Electrical potential energy is analogous to gravitational potential energy (i.e. the higher a body is from the ground the greater the potential energy). Electric potential energy may be defined as the work done in moving a unit charge from one point to another in a circuit.

The conducting wire is made up of positive centers arranged at regular distances from each other and surrounded by free (delocalized) electrons as shown below.



The e.m.f. drives electrons for the cell which enter the wire and push nearby electrons. Nearby electrons are pushed at the same time towards the other end of the wire. The entry of one electron pushes out one electron at the opposite end of the wire. This is because electrons are free to move between points of different electric potential. Electricity is conducted by the quick movement of electrons through metals (wires).

The amount of electric charge that passes a point in a circuit in one second determines the current. Electric current (I) may be defined as the rate of flow of electric charges around a circuit. Its unit is ampere (A). Mathematically

$$current = \frac{Electric\,charge}{Time} = \frac{Q}{t}$$

As the electrons move through a wire their movements get restricted by the positive centers which are continuously vibrating about their fixed positions. This offers resistance to the flow of electric charges. Electrical resistance may be defined as the force which opposes the flow of electric charges (current) in a conductor. Its unit is ohm (Ω).

The filament of the torchlight bulb is made of a thin wire which offers more resistance to the flow of charges compared to the connecting wires in a circuit. Through collision, charges in the filament produce friction which generates heat energy and is converted to light energy to light the bulb.

Closure

Teacher summarizes all that has been taught in the lesson for students.

Assignment

Students are asked to do the following exercises:

1. Draw a simple electric circuit and label it.

2. In your own words define the terms "electromotive force", "electric current", "electric resistance" and "potential difference".
3. Calculate the current if 24 coulombs of charge pass through a wire at a steady rate for 4 seconds.

Lesson Two

Topic: Ohm's law.

Duration: 40 minutes.

Previous Knowledge: Students can set up simple electric circuits and also define the following terms 'electromotive force', 'current', 'potential difference' and 'resistance'.

Specific Objectives

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

1. state Ohm's law correctly.
2. perform experiments to verify Ohm's law.

Teaching/Learning materials: A power supply, rheostat, key, ammeter, voltmeter, a standard resistor and connecting wires.

Introduction

Teacher revises the concept of simple circuit with students and asks them to define the terms "electromotive force", "current", "potential difference" and "resistance".

Content Development

Teacher explains to students the relationship between the "voltage" and "current" using a simple circuit. Teacher states Ohm's law for students to copy into their notebooks.

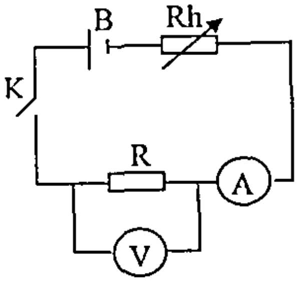
Key ideas:

1. Ohm's law states that at constant temperature the current passing through a wire is directly proportional to the potential difference between the ends of the wire.
2. Mathematically the law is given as $V \propto I$

$$\Rightarrow V = IR$$

where R is the constant of proportionality and called 'electrical resistance'.

Teacher gives students in groups of three an instructional sheet to follow to verify Ohm's law. Teacher connects up the circuit and demonstrates how readings are recorded for students to observe and asks them to also set up the circuit on their own and continue with the experiment using instructions on the instructional sheet.



1. The circuit consists of a battery B, a key K, a resistor R, a rheostat Rh, an ammeter A, a voltmeter V and connecting wires.
2. Connect the circuit as shown in the circuit above.
3. Set the rheostat Rh, so that it is large as possible.
4. Close the key K, and record the readings on the voltmeter and ammeter as V_0 and I_0 respectively.
5. Adjust the rheostat to a voltmeter reading of 0.2V and take its corresponding ammeter reading.

6. Repeated the procedure for values of 0.4V, 0.6V, 0.8V and 1V.
7. Tabulate the results as shown in the table below:

$V_0 =$ $I_0 =$

V (V)	I (A)	V/I (Ω)
0.2		
0.4		
0.6		
0.8		
1.0		

8. Evaluate the ratio of V and I.
9. Plot a graph of V on the vertical axis against I on the horizontal axis.
10. Determine the slope of the graph.

Teacher asks students to compare the value of the slope to the results for the ratio of V and I from the table. He then asks students what conclusions they can draw from the results of the experiment.

Closure

Teacher gives a brief summary of all that has been taught in the lesson for students.

Assignment

Students are asked to undertake the following exercises:

1. State Ohm's law correctly.
2. With the aid of a diagram, describe an experiment to verify Ohm's law.

3. When a cell, having a voltage of 1.5V produces a current of 0.5A, what is the resistance in the wire?

Lesson Three

Topic: Cells Connected in series.

Duration: 80 minutes

Previous knowledge

Students can connect up simple electric circuits.

Specific Objectives

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

1. explain that the more the number of cells connected in series, the brighter the lighted bulb.
2. show that the effective voltage of a number of cells connected in series equals the algebraic sum of the voltages of the individual cells.

Teaching/Learning materials: 3 dry cells, a bulb of voltage 2.5V, key and connecting wires.

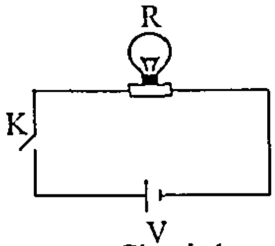
Introduction

Teacher through questions revises with students the previous lesson on the experimental verification of the Ohm's law.

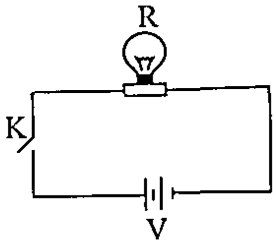
Content Development

1. Teacher explains to students what is meant by a series connection of dry cells in a circuit.
2. Teacher gives students in groups of three materials for the activities.

3. Teacher draws the circuits below on the chalkboard and connects them for students to observe.

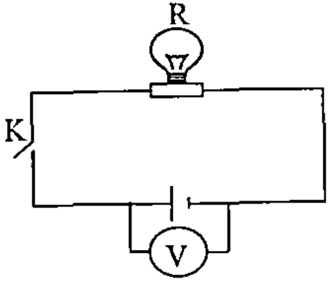


Circuit 1

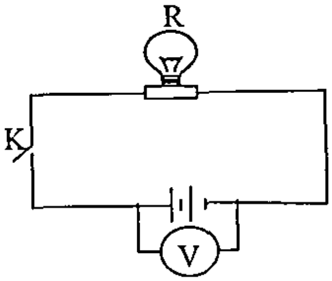


Circuit 2

4. Teacher asks students in the groups to repeat what he demonstrated and note down their observations of the brightness of the bulbs in Circuits 1 and 2.
5. Teacher measures the e.m.fs of both circuits for students to observe and asks students to do likewise and write down their observation.



Circuit 1



Circuit 2

6. Teacher through discussion with students summarizes all that has been done in the activities.

Key ideas:

1. A group of dry cells connected together is called a battery.
2. Dry cells connected end to end consecutively to each other as shown below is called series connection of cells. 
3. The more the number of cells connected in series, the brighter the bulb connected will light up.

4. The effective voltage of a number of cells connected in series in a circuit equals the algebraic sum of the voltages in a circuit.

$$V_T = V_1 + V_2 + V_3 + \ldots\ldots\ldots\ldots + V_n$$

V_T = effective voltage.

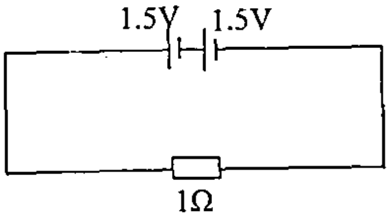
Closure

Teacher gives a brief summary of all that has been taught in the lesson for students.

Assignment

Students are asked to do the following exercises in class:

1. Two dry cells, each having an e.m.f. of 1.5V, are connected in series as shown. Find
   (a). the effective e.m.f. of the cells.
   (b). the current flowing through the circuit when the cells are connected to a 1Ω resistor.



2. Six cells, each having an e.m.f. of 2V are connected in series, with an ammeter of negligible resistance and a 1.4Ω resistor.
   (a). Draw the corresponding circuit diagram.
   (b). Calculate the combined e.m.f. of the dry cells.

Lesson Four

Topic: Cells Connected in parallel

Duration: 80 minutes

Previous knowledge

Students are familiar with circuit diagrams and circuit connections.

Specific Objectives

By the end of the lesson the student should be able to:

1. explain that a number of identical dry cells connected in parallel does not increase the brightness of a bulb connected in series to it in a circuit.
2. show that the effective voltage of a number of similar cells connected in parallel equals the voltage of one cell.

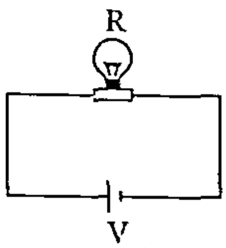
Teaching/Learning materials: 3 dry cells, a bulb of voltage 2.5V, and connecting wires.

Introduction

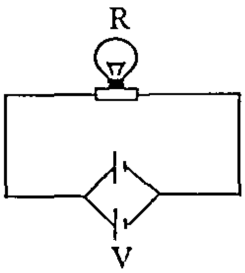
Teacher reviews the previous lesson on the series connection of cells with students through questioning.

Content Development

1. Teacher explains to students what is meant by the parallel connection of dry cells.
2. Teacher gives students in groups of three materials for the activities.
3. Teacher draws the circuits below on the chalkboard and connects up the circuits for students to observe.



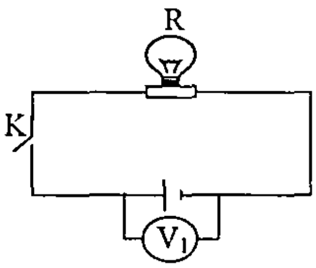
Circuit 1



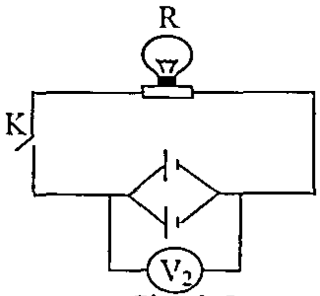
Circuit 2

4. Teacher asks students in the groups to repeat what he demonstrated and write down their observations of the brightness of the bulbs in Circuits 1 and 2.

5. Teacher measures the e.m.f. of the single and combined cells in turns by connecting voltmeter across the cells for students to observe and asks students to do likewise and write down their observations.



Circuit 1

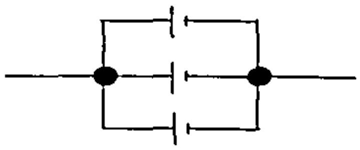


Circuit 2

6. Teacher through discussion with students summarizes all that has been done in the activities.

Key ideas:

1. Dry cells connected side by side with their corresponding ends joined together at their respective common points are said to form parallel connection of cells.



2. The meeting point of three or more wires in an electrical network is called a junction.

3. A number of dry cells connected in parallel in a circuit does not increase the brightness of bulb connected to them (i.e. the brightness remains the same).
4. The effective voltage of a number of similar connected in parallel equals the voltage of one of the cells.

$$V_T = V_1 = V_2 = V_3$$

V_T = effective voltage.

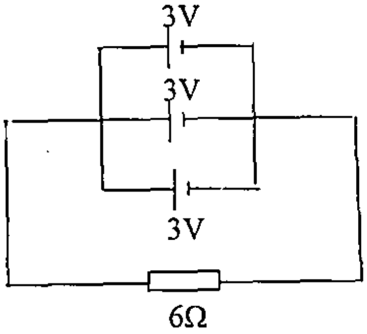
Closure

Teacher gives a brief summary of all that has been taught in the lesson for students.

Assignment

Students are asked the do the following exercises in class:

1. Calculate the effective voltage and the current flowing in the circuit diagram shown.



2. Two dry cells each having an e.m.f. of 1.5V are connected in parallel. Find
   (a). the effective e.m.f. of the cells.
   (b). the current when the cells are connected to a 1Ω resistor

Lesson Five

Topic: Resistors Connected in Series.

Duration: 120 minutes

Previous knowledge: Students are familiar with series and parallel connection of dry cells.

Specific Objectives

By the end of the lesson the student should be able to:

1. explain that two or more identical bulbs connected in series to a dry cell produce a dimmer light than one of them connected to the same.
2. explain correctly the following:
    a. the source voltage is shared equally between resistors of similar resistances.
    b. the source voltage is shared proportionally by unequal resistors.
3. Deduce the general relation for resistors connected in series.

Teaching/Learning materials: A power supply, 3 bulbs of voltage 2.5V, three ammeters, two voltmeters two 2Ω resistors, a 3Ω resistor and connecting wires.

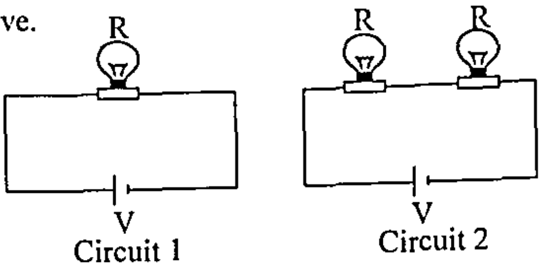
Introduction

Teacher reviews the previous lesson on the parallel connection of cells with students through questioning.

Content Development

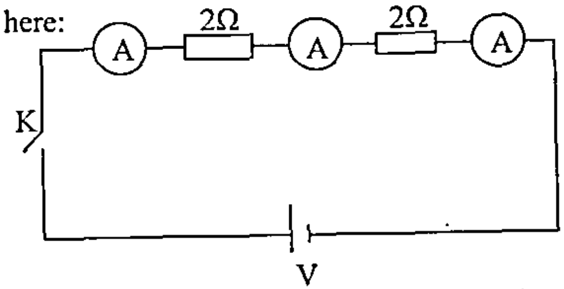
1. Teacher explains to students what is meant by a series connection of resistors.
2. Teacher gives students in groups of three materials for the activities.

3. Teacher draws the circuits below on the chalkboard and connects up the circuits for students to observe.



4. Teacher asks students in the groups to repeat what he demonstrated and write down their observations of the brightness of the bulbs in Circuit 1 and 2.

5. Teacher draws a circuit diagram on the chalkboard with two similar resistors in series as shown here:

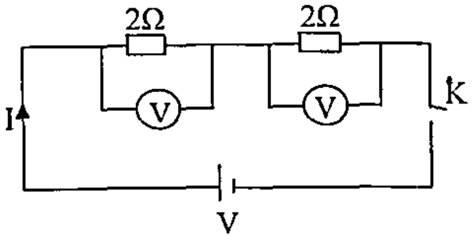


6. Teacher connects up the circuit and asks students to observe and write down their observations.

7. Teacher asks students to connect up their circuits as he has done and note down the current readings of the ammeters when the key is closed.

8. Teacher asks students to replace one of the 2Ω resistors with the 3Ω and note down the ammeter readings.

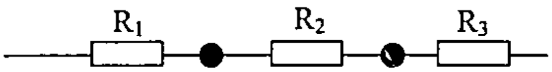
9. Teacher connects up voltmeters across all the 2Ω resistors as shown below for students to observe.



10. Teacher asks students to connect up their circuits as he has done and note down the voltage of the voltmeters when the key is closed.
11. Teacher asks students to replace one of the 2Ω resistors with the 3Ω and note down the voltmeter readings.
12. Teacher through discussion with students summarizes all that has been done in the activities.

Key ideas:

1. Two or more identical bulbs connected in series to a dry cell produce a dimmer light than one of the connected to the same.
2. When one of the bulbs is unscrewed, all other bulbs will go off because the circuit will be opened.
3. The arrangement whereby resistors or bulbs are connected end to end consecutively so that the same current flows through each are called a <u>series connection of resistors</u> as shown below:



4. The same current flow through resistors connected in series in a given circuit.
5. The algebraic sum of the potential differences or voltages across resistors connected in series in a circuit is equal to the effective voltage or source voltage.
6. The effective voltage in a series circuit is shared equally between resistors of similar resistances.

7. The effective voltage in a series circuit is shared proportionally by unequal resistors.
8. The effective voltage across a fixed resistor is that of the cell.
9. From the activities, it can be seen that for any series connection, the current flowing through the resistors are the same whiles the voltage through each resistor is different. From Ohm's law, we get

$$V_1 = IR \quad \text{———————} \quad 1$$

$$\text{and } V_2 = IR_2 \quad \text{———————} \quad 2$$

But the total voltage in the circuit is given by $V = V_1 + V_2$ ——— 3

Substituting equation 1 and 2 into 3, we get

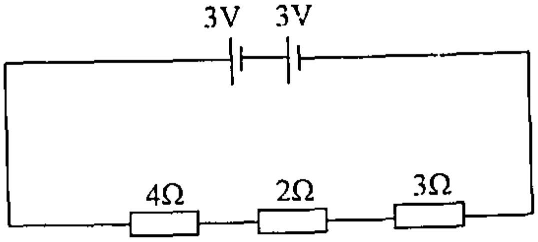
$$IR = IR_1 + IR_2$$
$$IR = I(R_1 + R_2)$$
$$\therefore R = R_1 + R_2 \quad \text{———————} \quad 4$$

Generally, if there are two or more resistors in series the effective or combined resistance (R_T) can be given as $R_T = R_1 + R_2 + R_3 + \dots\dots R_N$

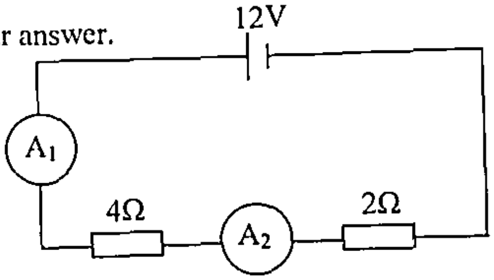
Concept Application Stage

Students are asked to do the following exercises in class:

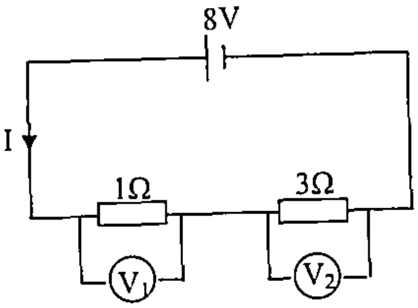
1. In the circuit diagram below, what is:
   a. The effective voltage of the cells?
   b. The effective resistance of the circuit?
   c. The current in the circuit?
   d. The direction of current in the circuit?



2. In the circuit diagram below, ammeter A_1 reads 2A. What is the reading of ammeter A_2? Explain your answer.



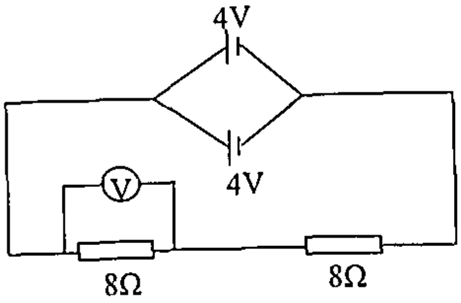
3. In the circuit diagram below, what are the readings of voltmeter V_1 and V_2? Explain your answers.



4. In the circuit below

a. What is the effective voltage?

b. What will be the reading of the voltmeter V shown in the diagram? Explain your answer.



Lesson Six

Topic: Resistors Connected in Parallel.

Duration: 120 minutes

Previous knowledge: Students are familiar with series connection of resistors and can use ammeters and voltmeters.

Specific Objectives

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

1. describe the brightness of bulbs connected in parallel in a circuit.
2. measure, and identify through experimentation, that the current in the main circuit is the sum of currents in the sub-circuits.
3. measure, and identify through experimentation, that the voltage across each of the resistors in parallel is equal to that of the source voltage.
4. deduce the general relation for resistors connected in parallel in a circuit.

Teaching/Learning materials: A power supply, 3 bulbs of voltage 4.5V, three ammeters, two voltmeters two 2Ω resistors, a 3Ω resistor and connecting wires.

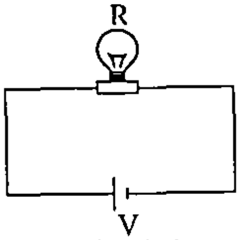
Introduction

Teacher reviews the previous lesson on series connection of resistors with students through questioning.

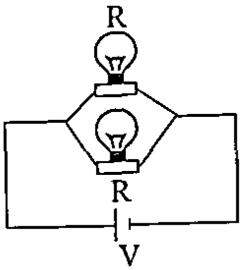
Content Development

1. Teacher explains to students what is meant by the parallel connection of resistors.
2. Teacher gives students in groups of three materials for the activities.

3. Teacher draws the circuits below on the chalkboard and connects up the circuits for students to observe.



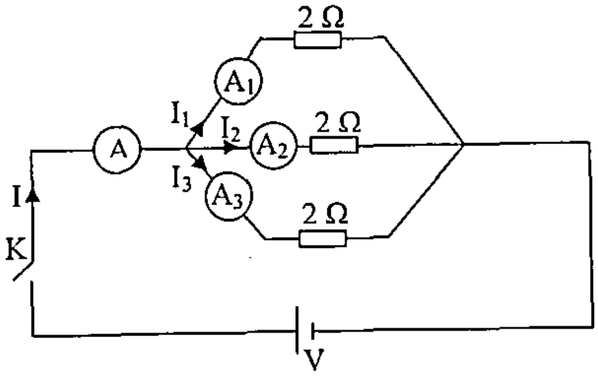
Circuit 1



Circuit 2

4. Teacher asks students in the groups to repeat what he demonstrated and write down their observations of the brightness of the bulbs in Circuit 1 and 2.

5. Teacher draws a circuit diagram on the chalkboard with three similar resistors in parallel as shown below:

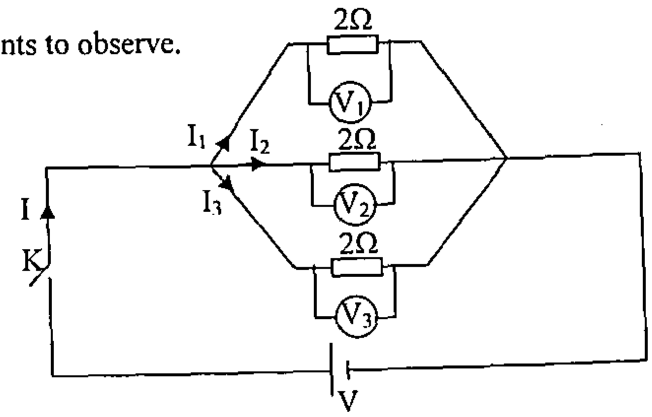


6. Teacher connects up the circuit and asks students to observe and write down their observations.

7. Teacher asks students to connect up their circuits as he has done and note down the current readings of the ammeters when the key is closed.

8. Teacher asks students to replace two of the 2Ω resistors with the 3Ω and 4Ω respectively and note down the ammeter readings.

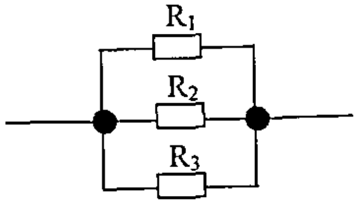
9. Teacher connects up voltmeters across the 2Ω resistors as shown below for students to observe.



10. Teacher asks students to connect up their circuits as he has done and note down the voltage of the voltmeters when the key is closed.
11. Teacher asks students to replace two of the 2Ω resistors with the 3Ω and 4Ω respectively and note down the voltmeter readings.
12. Teacher through discussion with students summarizes all that has been done in the activities.

Key ideas:

1. Similar bulbs connected in parallel to a cell in a circuit produce the same brightness but dissimilar bulbs produce varying brightness depending on their resistances.
2. When one of the bulbs is disconnected in a sub-circuit, others in the other sub-circuits continue to glow.
3. The arrangement whereby two or more resistors (or bulbs) connected side by side and so that their corresponding ends are joined together at their respective points (as shown below) is called a <u>parallel connection of resistors</u>:



4. The current in the main circuit is the algebraic sum of all the currents in the sub-circuits. $I = I_1 + I_2 + I_3 + \ldots + I_n$
5. The current in the main circuit is shared equally among similar resistors in the sub-circuits and proportionally among unequal resistors.
6. The voltage across each of the resistors in parallel is equal to that of the source voltage.
7. For any parallel connection of resistor in a circuit, the voltage across each of the resistors is the same whiles the current passing through each of the resistors is different. From Ohm's law $V = IR$ ——— 1

i.e. $I = \frac{V}{R}$ ——— 2

Hence, the currents across each of the resistors are given by

$$I_1 = \frac{V}{R_1},\ I_2 = \frac{V}{R_2}\ and\ I_3 = \frac{V}{R_3} \qquad \text{———} \quad 3$$

But the total current in the circuit is given by $I = I_1 + I_2 + I_3$ ——— 4

$\therefore$ Substituting equation 2 and 3 into 4, we get

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\therefore \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

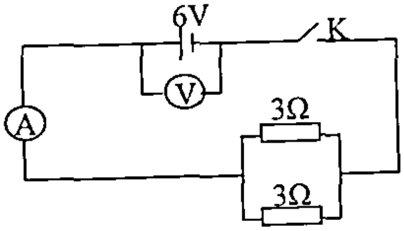
Generally, if there are two or more resistors connected in parallel in a circuit, the effective resistance R can be given as $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+...+\frac{1}{R_N}$

8. Currents in the sub-circuits are inversely proportional to the resistance in their respective circuits in a parallel connection of resistors in a circuit.

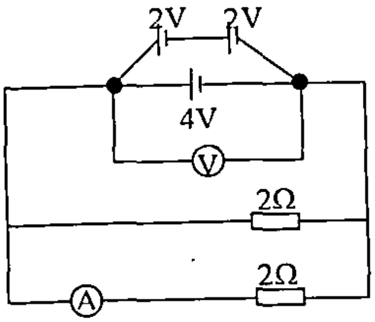
Concept Application Stage

Students are asked to do the following exercises in class:

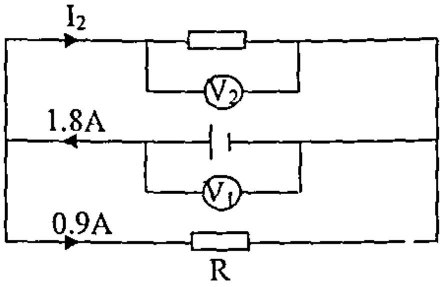
1. In the circuit diagram, the key (K) is open.
   a. What is the effective resistance in the circuit?
   b. What will be the reading on ammeter A? Explain your answer.
   c. What will be the reading on voltmeter V? Explain your answer.



2. In the circuit diagram below,
   a. What is the effective resistance in the circuit?
   b. What is the reading on the voltmeter?
   c. What is the reading on the ammeter?



3.



In the circuit diagram above,

a. What will be the reading of voltmeter V_1 if V_2 reads 4V?

b. What is the value of the current I_2?

Data Analysis

The experimental and control groups' mean scores from pretest and posttests were analyzed using the t-test for independent and dependent samples. The t-test is more effective since it evaluates the difference between the mean scores of the two groups. A linear regression analysis was done to determine to what extent the scores obtained could be accounted for by the intervention. The two groups' posttest mean scores for the instructional objectives (IOs) were also analyzed using the t-test for independent samples to determine how effective the interrelated concepts and the different concepts in direct current electricity were taught in both the experimental and control groups. Thematic content analysis technique was used to analyze students' responses on the learning cycle activity sheets to identify students' preconceptions on specific concepts in direct current electricity. Frequencies and percentages of the various responses given by students were analyzed.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

In this chapter, the findings from the study are presented and discussed in relation to the three research questions and the hypothesis.

Research Question One

What are the differences in achievement between students instructed on selected concepts in direct current electricity using the learning cycle approach and those instructed using the traditional teaching approach?

Hypothesis

H_o: There is no significant difference in achievement between students instructed using the learning cycle approach and those instructed using the traditional teaching approach.

H_A: There is a significant difference in achievement between students instructed using the learning cycle approach and those instructed using the traditional teaching approach.

Preliminary analysis was done by comparing the two groups' scores from the pretest using t-test for independent samples. As shown in Table 2, there was no statistically significant difference between the mean scores of students in the experimental and control groups with respect to CECAT before instruction (t (99)= 0.035, p = .972). The results indicate that on the average, students in both groups had similar preconception of the selected concepts in direct current electricity and they had started the treatments with nearly the same level of learning.

Table 2: Results of Independent Samples t-test for Pretest Scores of Experimental and Control Groups

Variable	Group	N	Mean	SD	t	df	p
	Experimental	59	10.54	2.575			
Pretest					.035	99	.972*
	Control	42	10.52	2.616			

*Not significant, since p > 0.05

Since there were no significant differences between the experimental and control groups' mean scores in terms of pretest, the pretest and posttest scores of each group were compared using the t-test for dependent samples. Table 3 indicates a statistically significant difference between the two groups' pretest and posttest scores. The experimental group's mean score from posttest (M = 21.14, SD = 2.240) was significantly higher than the mean score from the pretest (M = 10.54, SD = 2.575, t (59) = -21.177, p = .001). The magnitude of the difference in mean scores for the experimental group was very large with a standardized effect size index of 2.76 [see Appendix E for calculation of effect size statistics]. Also, the control group's mean score from posttest (M = 16.07, SD = 2.722) was significantly higher than that of the pretest (M = 10.52, SD = 2.616, t (42) = -8.918, p = .001). The difference in mean scores for the control group was very large with a standardized effect size index of 1.38 [see Appendix E for calculation of effect size statistics].

This means that both the traditional and the learning cycle approaches had a significant effect on students' understanding of the selected concepts in direct current electricity.

Table 3: Results of Dependent Samples t-test for the Pretest and Posttest Scores of Experimental and Control Groups

Group	Variable	N	Mean	SD	t	df	p
	Pretest	59	10.54	2.575			
Experimental					-21.177	58	.001*
	Posttest	59	21.14	2.240			
	Pretest	42	10.52	2.616			
Control					-8.918	41	.001*
	Posttest	42	16.07	2.722			

*Significant, since $p < 0.05$

To investigate possible significant difference in achievement between the experimental and control groups in the posttest, the groups' mean scores were compared using the t-test for independent samples. As shown in Table 4, there is a statistically significant difference between the two groups' posttest scores with respect to CECAT ($\underline{t}$ (99) = 10.192, $\underline{p}$ = .001). Therefore, the null hypothesis should be rejected whiles we fail to reject the alternative hypothesis. The difference in posttest mean scores for the experimental and control groups was very large with a standardized effect size index of 2.06 [see Appendix E for calculation]. The boxplot of the posttest mean scores for the experimental and control groups are shown in Figure 1 [see Appendix D for figure 1]. The boxplot gives a pictorial description of how the posttest mean scores of the two groups are compared. This indicates that teaching with the learning cycle approach was more successful in teaching the selected concepts than using the traditional approach.

Table 4: Results of Independent Samples t-test for the Posttest Scores of Experimental and Control Groups

Variable	Group	N	Mean	SD	t	df	p
Posttest	Experimental	59	21.14	2.240	10.192	99	.001*
	Control	42	16.07	2.744			

*Significant, since $p < 0.05$

A linear regression analysis was conducted to evaluate the prediction of posttest scores from the type of intervention used. The regression equation for predicting the overall posttest is:

Predicted posttest scores = -5.064 type of intervention + 26.200

The coefficient of correlation between posttest scores and the type of intervention was $R = -0.716$ which gives a coefficient of determination $R^2 = 0.512$ (t (99) = -10.192, p = .001). This implies therefore that approximately, 51.2% of the variance of the posttest was accounted for by its linear relationship with the type of intervention used [see Appendix C for results of regression analysis].

Research Question Two

How effective is the learning cycle approach and the traditional approach in teaching the interrelated concepts and a number of different concepts involved in direct current electricity?

To answer this question, the t-test for independent samples was used to analyze the two groups' posttest mean scores for the instructional objectives (IOs) to determine how effective the interrelated concepts and the different concepts in direct current electricity were taught in both the experimental and control groups.

From Table 5, the results revealed that the posttest mean scores of students' responses for IO 1 regarding identifying and explaining a short circuit were significantly different between the experimental and control groups. The results indicated that the mean scores of the groups for IO 4 and 5 regarding the application of the concept of resistance to a variety of circuits and the interpretation of diagrams on a variety of circuits including series, parallel and combination of the two were statistically significant.

Table 5: Statistics of Posttest Mean Scores in the Instructional Objectives (IOS) for the Experimental and Control Groups

Instructional Objectives		Group	Posttest			
			Mean	SD	t	p
IO 1	(2 items)	Experimental	1.58	.498	3.803	.001*
		Control	1.14	.647		
IO 2	(1 item)	Experimental	.75	.439	-0.183	.855

Table 5 continued

Instructional Objectives	Group	Posttest			
		Mean	SD	t	p
	Control	.76	.431		
IO 3 (1 item)	Experimental	.81	.393	.343	.742
	Control	.79	.415		
IO 4 (3 items)	Experimental	1.83	.813	2.897	.005*
	Control	1.33	.902		
IO 5 (3 items)	Experimental	2.36	.713	5.919	.001*
	Control	1.52	.671		
IO 6 (1 item)	Experimental	.58	.498	1.179	.241
	Control	.45	.550		
IO 7 (2 items)	Experimental	1.31	.676	1.948	.054
	Control	1.05	.623		
IO 8 (4 items)	Experimental	2.61	0.910	2.412	.018*
	Control	2.14	1.026		
IO 9 (3 items)	Experimental	2.51	.728	2.109	.037*
	Control	2.19	.773		
IO 10 (7 items)	Experimental	4.88	.911	6.669	.001*
	Control	3.52	1.131		
IO 11 (3items)	Experimental	1.93	1.158	3.514	.001*
	Control	1.19	.862		

*Significant, since $p < 0.05$

Results of analysis revealed that posttest mean scores of students' responses for IO 8 and 9 regarding explaining the microscopic aspects of charge flow in a circuit and applying the knowledge that the amount of current is influenced by the potential difference maintained by the battery and resistance in a circuit were found to be statistically significant. Results of analysis also indicated that the posttest mean scores of students' responses for IO 10 and 11 regarding applying the concept of potential difference to a variety of circuits including the knowledge that the total potential difference in a series circuit is the sum of all the individual potential differences whiles in a parallel circuit the total potential differences is equal everywhere in the circuit and combining the concepts of current and potential difference to a variety of circuits were statistically significant.

The results showed that the learning cycle approach was found to be more effective for teaching most of the concepts indicated in the instructional objectives when compared to the traditional method of teaching. Contrary, results of the analysis revealed that posttest mean scores for the groups on IOs 2, 3, 6 and 7 were not statistically significant.

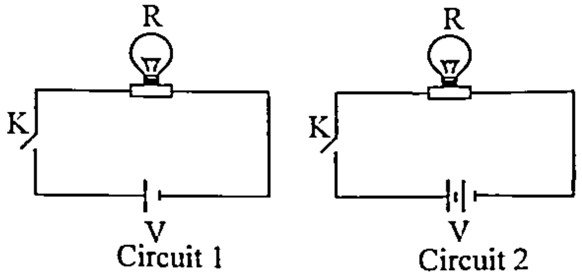
Research Question Three

How effective are the learning cycle activities in exploring students' preconceptions on selected concepts in direct current electricity?

To determine students' preconceptions in the selected concepts in direct current electricity, thematic content analysis technique was used to analyze students' responses and reasons given on students' learning cycle activity sheets.

Students' Learning Cycle Activity 1

Predict what you expect about the brightness of bulb R if one more identical dry cell is added to circuit 1 as shown in circuit 2 [the bulbs are identical]. Explain your response.



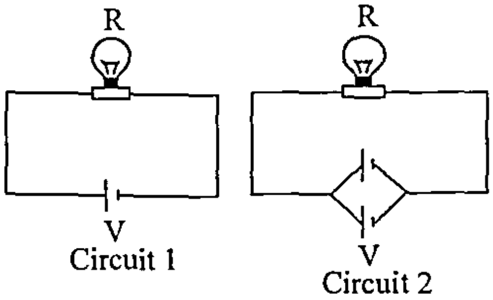
In this activity, the correct prediction is that the brightness of the bulb will increase because the source voltage has been doubled. From Table 6, all the 50 students rightly predicted that there will be an increase in brightness with 47 (94%) of the students giving the correct reason. Again, 3 (6%) students gave a correct reason that more current will be supplied by the two cells than one. They are using the Ohm's law to give their reasons because the law states that voltage is directly proportional to current. This means that their preconceptions are in line with the scientists views.

Table 6: Students' Preconceptions about the Brightness of a Bulb in a Circuit, when Identical Dry Cells are connected in Series (n = 50)

Students' predictions and reasons	Number of students
Brightness will increase	50 (100%)
1. There are two cells in circuit 2 which doubles the voltage.	47 (94%)
2. More current will be supplied by the two cells than one cell.	3 (6%)

Students' Learning Cycle Activity 2

Predict what you expect about the brightness of bulb R if one more identical dry cell is added to circuit 1 as shown in circuit 2 [the bulbs are identical]. Explain your response.



Circuit 1

Circuit 2

In this activity, the correct prediction is that the brightness of the bulb will remain the same because when identical dry cells are connected in parallel in a circuit, their effective voltage is equal to the voltage of one of the dry cells. Since they are ideal cells (i.e. having no internal resistance) each cell will contribute half of its voltage to produce the total voltage in the circuit. As shown in Table 7, 21 (36.8%) students predicted correctly that the brightness of the bulb will remain the same. However, 9 (15.8%) students out of the total students were able to give the correct reason that each of the dry cells will contribute half of its voltage to produce the total voltage in the circuit; 4 (7.1%) students gave an incorrect explanation that the voltage produced by the dry cells is the same as the circuit voltage; whereas 8 (14.1%) students could not explain their predictions.

From Table 7, 31 (54. 4%) students predicted wrongly that the brightness of the bulb will increase with 16 (28.1%) students giving the reason that the voltage in the circuit will be doubled, 7 (12.3%) students reasoned that the current produced by the cells will be added together and 8 (14.1) students gave no reasons for their predictions. Furthermore, 5 (8.8%) students predicted wrongly that the brightness of the bulb will decrease but did not explain their reasoning.

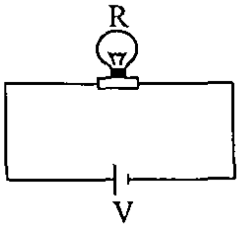
It implies therefore that 16% of the students have the right conception about the brightness of a bulb when identical dry cells are connected in parallel whiles 84% of them have alternative conceptions on the concept.

Table 7: Students' Preconceptions about the Brightness of Bulb in a Circuit, when Identical Dry Cells are connected in Parallel (n = 57)

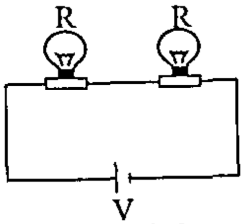
Students' predictions and reasons	Number of students
Brightness will increase	31 (54.4%)
1. The voltage in the circuit will be doubled.	16 (28.1%)
2. The current produced by the cells will be added together.	7 (12.3%)
3. No explanation.	8 (14.1%)
Brightness will decrease	5 (8.8%)
1. No explanation	5 (8.8%)
Brightness will remain the same	21 (36.8%)
1. The voltage produced by the dry cells is the same as the circuit voltage.	4 (7.1%)
2. Each of the dry cells will contribute half of its voltage to produce the total voltage in the circuit.	9 (15.8%)
3. No explanation.	8 (14.1%)

Students' Learning Cycle Activity 3

Predict what you expect about the brightness of bulb R if one more identical bulb is added to circuit 1 as shown in circuit 2 [the dry cells are identical]. Explain your response.



Circuit 1



Circuit 2

In this activity, the correct prediction is that the brightness of the bulbs will decrease because the source voltage will be shared equally among the identical bulbs. From Table 8, 46 (78%) students predicted correctly that the brightness of the bulbs will decrease out of which 13 (22.1%) students gave the correct scientific explanation; 12 (20.3%) students also reasoned correctly that when one more identical bulb is added to the circuit the resistance will increase thereby reducing current flow; 18 (30.5%) students on the other hand, gave an incorrect explanation that the current will be shared among the bulbs. This category of students used current instead of voltage which means they use both words interchangeably. Finally, 3 (5.1%) students gave no explanation for their prediction.

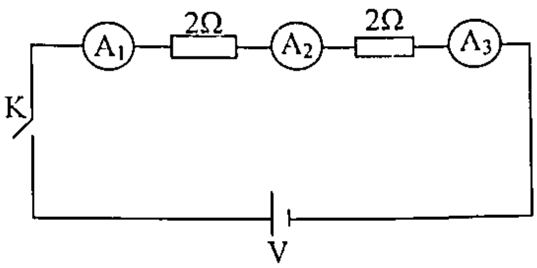
As shown in Table 8, 7 (11.9%) students predicted wrongly that the brightness of the bulbs will increase with 3 (5.1%) students giving the reason that it is because the bulbs are connected in series; whereas 4 (6.8%) students gave no explanation for their reasoning. Again, 6 (10.2%) students predicted wrongly that the brightness of the bulbs will remain the same with 4 (6.8%) students giving the reason that the voltage is constant in the circuit whiles 2 (3.4%) students gave no explanation for their predictions.

This means that 42% of the students have the correct conception about the brightness of bulbs connected in series to a dry cell in a circuit whiles 58% of them have alternative conceptions of the concept.

Table 8: Students' Preconceptions about the Brightness of Identical Bulbs connected in Series to a Dry Cell (n = 59)

Students' predictions and reasons	Number of students
Brightness will increase	7 (11.9%)
1. The bulbs are in series.	3 (5.1%)
2. No explanation.	4 (6.8%)
Brightness will decrease	46 (78%)
1. The current will be shared among the bulbs.	18 (30.5%)
2. The resistance of the circuit will increase.	12 (20.3%)
3. The voltage of the cell will be shared among the bulbs.	13 (22.1%)
4. No explanation.	3 (5.1%)
Brightness will remain the same	6 (10.2%)
1. The voltage is constant in the circuit.	4 (6.8%)
2. The current is the same in the circuit.	2 (3.4%)

Students' Learning Cycle Activity 4



In the circuit above, suppose ammeter A_1 shows a reading of 0.06A. Choose from the alternatives below the correct answer for the current measurements of ammeter A_2 and ammeter A_3.

A. $A_2 = 0.05A$	$A_3 = 0.04A$.
B. $A_2 = 0.06A$	$A_3 = 0.05A$.
C. $A_2 = 0.06A$	$A_3 = 0.06A$.
D. $A_2 = 0.07A$	$A_3 = 0.08A$

Explain your response.

In this activity, the correct option is C because current is constant throughout the main circuit in series connection (i.e. current is not consumed by circuit elements). As shown in Table 9, 28 (47.5%) students predicted correctly and chose option C with 23 (34%) students giving the correct reason that the current is the same in the main circuit in every series connection. On the other hand, 5 (8.5%) students gave no reasons for their prediction.

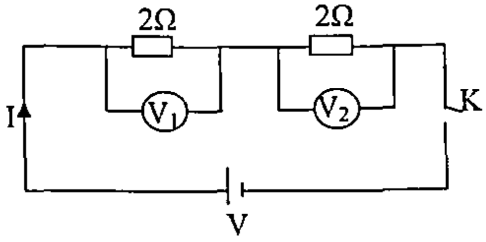
From Table 9, 25 (42.4%) students chose the wrong option A with 18 (30.5%) of the students giving the reason that the resistors will use up the current in the circuit; 7 (11.9%) students gave no explanations for choosing the option. Furthermore, 2 (3.4%) students chose option B giving the reason that the resistors use up the current. As shown in Table 9, 4 (6.8%) students chose option D but gave no explanations for the choice.

From Table 9, 34% of the students have the right conception that current is not consumed by circuit elements. However, 66% of the students have alternative conceptions on the concept out of which 34% reasoned that current is consumed by circuit elements.

Table 9: Students' Preconceptions about the Conservation of Current in a Series Circuit (n = 59)

Students' predictions and reasons	Number of students
Option A	25 (42.4%)
1. The resistors will use up the current in the circuit.	18 (30.5%)
2. No explanation.	7 (11.9%)
Option B	2 (3.4%)
1. The resistors use up the current	2 (3.4%)
Option C	28 (47.5%)
1. The current is the same the main circuit in every series connection	23 (34%)
2. No explanation.	5 (8.5%)
Option D	4 (6.8%)
1. No explanation	

Students' Learning Cycle Activity 5



In the circuit above, will the reading on voltmeter V_1 be the same or different from the reading on voltmeter V_2? Explain your response.

In this activity, the correct prediction is that the readings of the voltmeters will be the same because the source voltage will be shared equally among the resistors in the circuit. As shown in Table 10, 43 (72.9%) students predicted correctly that the voltmeters will have the same readings. Out of this, 13 (22.1%) students gave the correct scientific explanation; 11 (18.6%) students gave an incorrect reason that current is directly proportional to the potential difference; 4 (6.8%) students reasoned incorrectly that voltage is constant in a series circuit; whereas 15 (25.4%) students gave no explanation for their prediction.

Table 10: Students' Preconceptions about the Potential Difference across Identical Resistors connected in Series (n = 59)

Students' predictions and reasons	Number of students
Same readings	43 (72.9%)
1. Current is directly proportional to the potential difference.	11 (18.6%)
2. The voltage is shared equally across similar resistors.	13 (22.1%)
3. The voltage is constant in a series circuit.	4 (6. 8%)
4. No explanation	15 (25.4%)

Table 10 continued

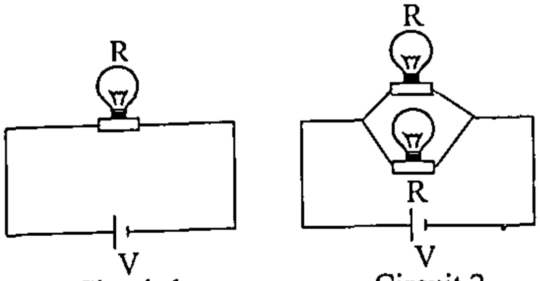
Students' predictions and reasons	Number of students
Different readings	15 (25.4%)
1. The resistors will decrease the voltage in the circuit.	6 (10.2%)
2. The current flow is not the same in the circuit.	1 (1.7%)
3. No explanation.	8 (13.6%)

From Table 10, 15 (25.4%) students predicted wrongly that the voltmeters will have different readings. Out of this, 6 (10.2%) students gave the reason that the resistors will decrease the voltage in the circuit, 1 (1.7%) student reasoned that the current flow in the circuit will not be the same and 8 (13.6%) students gave no explanation for their prediction.

It implies that 22% of the students have the correct conception about the voltage across resistors connected in series in a circuit whiles the rest 78% have alternative conceptions about the concept.

Students' Learning Cycle Activity 6

Predict what you expect about the brightness of bulb R if one more identical bulb is added to circuit 1 as shown in circuit 2 [the dry cells are identical]. Explain your response.



Circuit 1 Circuit 2

In this activity, the correct prediction is that the brightness of the bulbs will remain the same because the voltage across bulbs connected in parallel are the same. As shown in Table 11, 38 (65.5%) students predicted correctly that the brightness of the bulbs will remain the same. Out of this, 15 (25.9%) students gave the scientifically correct explanation that voltage across bulbs connected in parallel are the same; 14 (24.1%) students gave the incorrect explanation that the same current will flow through the two bulbs; whereas 8 (13.8%) students gave no reasons for their prediction.

From Table 11, 20 (34.5%) students predicted wrongly that the brightness of the bulbs will decrease with 5 (8.6%) students giving the reason that current is shared among the bulbs in the circuit, 7 (12.1%) students gave the reason that voltage is shared among the bulbs in the circuit and 8 (13.8%) students gave no explanations for their prediction.

This means that 26% of the students have the correct conception about the brightness of bulbs connected in parallel whiles 74% of them have alternative conceptions about the brightness of the bulbs.

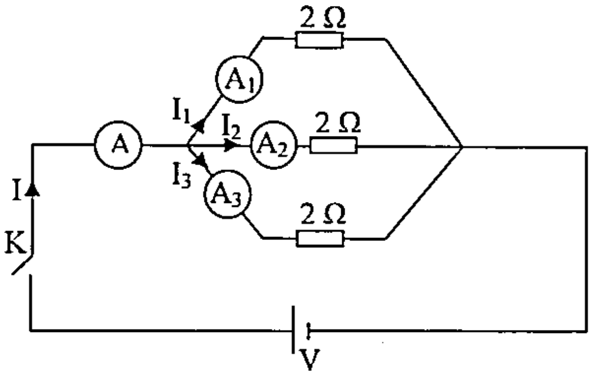
Table 11: Students' Preconceptions about the Brightness of Identical Bulbs connected in Parallel to a Dry Cell (n = 58)

Students' predictions and reasons	Number of students
Brightness will decrease	20 (34.5%)
1. The current is shared among the bulbs in the circuit.	5 (8.6%)
2. The voltage is shared among the bulbs in the circuit.	7 (12.1%)

Table 11 continued

Students' predictions and reasons	Number of students
3. No explanation.	8 (13.8%)
Brightness remain the same	38 (65.5%)
1. The voltage across bulbs connected in parallel are the same.	15 (25.9%)
2. The same current flows through the two bulbs.	14 (24.1%)
3. No explanation.	8 (13.8%)

Students' Learning Cycle Activity 7



In the circuit above, will the readings on ammeters A, A_1, A_2 and A_3 be the same or the ammeters will have different readings? Explain your response.

In this activity, the correct prediction is that the readings on the ammeters will be different because the current through ammeter A will be shared among the branches of the circuits containing ammeters A_1, A_2 and A_3 (i.e. $A = A_1 + A_2 + A_3$). At the junction, the current I will be divided equally among the three 2Ω resistor (i.e. $I_1 = I_2 = I_3$). From Table 12, 34 (58.6%) students predicted correctly that the readings will remain different. Out of this, 18 (31.1%) students gave the correct scientific explanation that the current through A will be shared among A_1,

A_2 and A_3; 6 (10.3%) students gave an incomplete explanation that the resistors are connected in parallel; whereas 10 (17.2%) students gave no explanations for their prediction.

From Table 12, 24 (41.4%) students made an incorrect prediction that the readings will be the same. Out of this, 3 (5.2%) students gave the reason that the circuit has the same 2Ω resistors; 8 (13.8%) students reasoned that the same current flows through the circuit; 2 (3.4%) students gave the reason that the resistors are arranged in parallel; whereas 11 (19%) students gave no explanations for their prediction.

It means therefore that 31% of the students have the correct scientific conception that the ammeter readings are different whiles 69% have alternate conceptions about the concept.

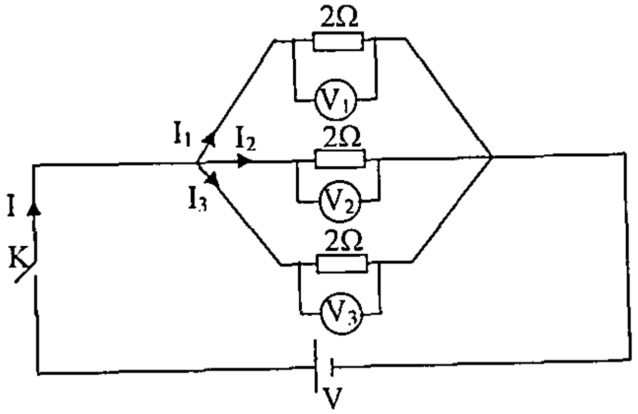
Table 12: Students' Preconceptions about Current Flow in A Circuit when Identical Resistors are connected in Parallel (n = 58)

Students' predictions and reasons	Number of students
Same readings	24 (41.4%)
1. The circuit has the same 2Ω resistors.	3 (5.2%)
2. The same current flows through the circuit.	8 (13.8%)
3. The resistors are arranged in parallel.	2 (3.4%)
4. No explanation.	11 (19%)
Different readings	34 (58.6%)
1. The current through A will be shared among A_1, A_2 and A_3.	18 (31.1%)

Table 12 continued

Students' predictions and reasons	Number of students
2. The resistors are connected in parallel.	6 (10.3%)
3. No explanation.	10 (17.2%)

Students' Learning Cycle Activity 8



In the circuit above, will the reading on voltmeter V_1, V_2, and V_3 be the same or the voltmeters will have different readings? Explain your response.

In the activity, the correct prediction is that the readings of the voltmeters will be the same because the voltage across a parallel connection of resistors is constant. From Table 13, 41 (70.9%) students predicted correctly that the readings on the voltmeters will be the same. Out of this, 24 (41.4%) students gave the correct explanation that the voltage across a parallel circuit is the same with 17 (29.3%) giving no explanations for their prediction.

Table 13: Students' Preconceptions about Voltage across Identical Resistors connected in Parallel in a Circuit (n = 58)

Students' predictions and reasons	Number of students
Same readings	41 (70.9%)
1. The voltage across a parallel circuit is constant.	24 (41.4%)
2. No explanation.	17 (29.3%)
Different readings	17 (29.3%)
1. The voltage is shared among the resistors.	9 (15.5%)
2. No explanation.	8 (13.8%)

From Table 13, 17 (29.3%) students predicted wrongly that the readings of the voltmeters will be different with 9 (15.5%) giving the reason that the voltage is shared among the resistors and 8 (13.8%) students giving no explanations for their prediction.

It means that 41% of the students have correct conception about voltage across identical resistors connected in parallel in a circuit while 59% of them have alternative conceptions about the concept.

In summary, the results showed that the use of the learning cycle approach was more successful and promotes students' understanding of concepts in direct current electricity than the traditional approach. It also indicated that the learning cycle approach is more effective for teaching most of the interrelated concepts and the different concepts than the traditional approach.

The results from students' learning cycle activity sheets on various tasks revealed the following preconceptions of students about selected concepts in direct current electricity: All the students have the correct conception that the brightness of a bulb will increase when identical dry cells are connected in series in a circuit, giving the reason that the voltage will be doubled to supply more current; 16% of the students have the right conception about the brightness of a bulb when dry cells connected in parallel giving the reason that the brightness will remain the same since each dry cell will contribute half of its voltage whiles 84% of them have alternative conceptions on the concept; 42% of the students have the correct conception about the brightness of bulbs connected in series to a dry cell in a circuit by predicting that the brightness of the bulbs will decrease giving the reason that the source voltage will be shared among the bulbs while 58% of them have alternative conceptions of the concept; 34% of the students have the right conception that current is not consumed by circuit elements (resistors) in a series circuit while 66% of the students have alternative conceptions on the concept; 22% of the students have the correct conception that the source voltage will be shared equally among similar resistors connected in series in a circuit while 78% have alternative conceptions about the concept; 26% of the students have the correct conception about the brightness of bulbs connected in parallel predicting that the brightness will remain the same giving the reason that voltage across bulbs connected in parallel are the same while 74% of them have alternative conceptions about the concept; 31% of the students have the correct scientific conception that the ammeter readings are different with the reason that the current through ammeter A will be shared among ammeters A_1, A_2 and A_3 (i.e. $A = A_1 + A_2 + A_3$) while 69% have alternate conceptions about the concept; and 41% of the students have correct conception about voltage across identical resistors connected in parallel in a circuit giving the reason that voltage across a parallel circuit is constant while 59% of them have alternative conceptions about the concept.

The most common alternative conceptions identified among the students are as follows: The brightness of a bulb connected in series to dry cells connected in parallel will increase because the voltage of the cells will increase; the brightness of bulbs connected in series will decrease because the current will be shared among the bulbs; current is consumed or used up by circuit elements or resistors; voltage is constant in a series circuit; the brightness of bulbs connected in parallel to a dry cell will decrease because the source voltage is shared among the bulbs in the circuit; The voltage is shared equally among resistors connected in parallel in a circuit; and resistance decreases the voltage in a circuit.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Overview

This study was conducted to compare the learning cycle approach and the traditional teaching approach on senior secondary school students' understanding of selected concepts in direct current electricity. The study sought answers for the following research questions:

2. What are the differences in achievement between students instructed on selected concepts in current electricity using the learning cycle approach and those instructed using the traditional teaching approach?
3. How effective is the learning cycle approach and the traditional approach in teaching the interrelated concepts and a number of different concepts involved in direct current electricity?
4. How effective are the learning cycle activities in exploring students' preconceptions on concepts in direct current electricity?

In all, 101 form three (3) General Science students from two senior secondary schools in the New Juaben Municipality participated in the study. The study employed the quasi experimental design with 59 students in one intact class from one of the schools as the experimental group while 42 students from the other school formed the control group. The experimental group was instructed using the learning cycle approach whiles the control group was instructed using the traditional approach. Both groups took a pretest before the interventions to ascertain their prior knowledge on the selected concepts in direct current electricity and a posttest after the interventions. The lessons were taught by the researcher.

The study used a combination of quantitative and qualitative research methodology. The quantitative data comprised the pretest and posttest scores which were analyzed using the dependent and independent samples t-test. The qualitative data comprised responses made by students on their learning cycle activity sheets which were used to identify students' preconceptions about concepts in direct current electricity and were analyzed using the thematic content knowledge technique.

Summary of Findings

The analysis of the results gave the following findings:

1. Analysis of the pretest scores using the independent samples t-test indicated that there was no statistically significant difference in achievement between the mean scores of the experimental and control groups before the interventions.

This may imply that the two groups were comparable and all the students had approximately the same prior knowledge about concepts in direct current electricity before the interventions.

2. The pretest and posttest scores of each group were compared using the t-test for dependent samples which indicated a statistically significant difference between the two groups' pretest and posttest mean scores.

This means that both the traditional and the learning cycle approaches had a significant effect on students' understanding of the selected concepts in direct current electricity.

3. Analysis of the posttest scores using the independent samples t-test indicated that there was a statistically significant difference in achievement between the mean scores of the experimental and control groups after the interventions. Students in the experimental group out scored those in the control group.

This implies that the use of the learning cycle approach was more successful and promoted students' understanding of the selected concepts in direct current electricity than the traditional approach. This finding is consistent with the view that correct use of the learning cycle accomplishes effective learning of science concepts (Lawson *et al.*, 2000; Lawson, 2001). It also supports the findings of Ates (2005) and Yilmaz and Cavas (2006) that the learning cycle method is more successful in teaching concepts in electricity than the traditional method.

4. Analysis of the two groups' posttest scores for the instructional objectives (IOs) to determine how effective the interrelated concepts and the different concepts in direct current electricity were taught, it revealed that there was a statistically significant difference between the groups' mean scores in

IOs 1, 4, 5, 8, 9, 10 and 11. Students in the experimental group outscored those in the control group with regard to the above mentioned IOs. It also indicated that there was no statistically significant difference between the groups' mean scores in IOs 2, 3, 6 and 7.

These findings show that the learning cycle approach is more effective for teaching the concepts of short circuit, resistance in circuits, circuit combinations, charge flow in circuits, and potential difference across circuit elements more successfully than the traditional approach.

However, the findings showed that there was no statistically significant difference between the learning cycle group and the traditional approach group students' understanding of some of the concepts. These concepts were connections in circuits, identification of complete circuits, battery as a source of energy and conservation of current in circuits.

These findings support those of Ates (2005) that the learning cycle approach is more effective in teaching most of the interrelated concepts and a number of different concepts involved in direct current electricity than the traditional approach.

5. Analysis of students' responses reveal the following preconceptions of students about the selected concepts in direct current electricity:
   A. All the students have the correct conception that the brightness of a bulb will increase when identical dry cells are connected in series in a circuit, giving the reason that the voltage will be doubled to supply more current.

B. Sixteen percent (16%) of the students have the right conception about the brightness of a bulb when identical dry cells connected in parallel giving the reason that the brightness will remain the same since each dry cell will contribute half of its voltage while 84% of them have alternative conceptions on the concept.

C. Forty-two percent (42%) of the students have the correct conception about the brightness of bulbs connected in series to a dry cell in a circuit by predicting that the brightness of the bulbs will decrease giving the reason that the source voltage will be shared among the bulbs while 58% of them have alternative conceptions of the concept.

D. Thirty-four percent (34%) of the students have the right conception that current is not consumed by circuit elements (resistors) in a series circuit while 66% of the students have alternative conceptions on the concept.

E. Twenty-two percent (22%) of the students have the correct conception that the source voltage will be shared equally among similar resistors connected in series in a circuit while 78% have alternative conceptions about the concept.

F. Twenty-six percent (26%) of the students have the correct conception about the brightness of bulbs connected in parallel predicting that the brightness will remain the same giving the reason that voltage across identical bulbs connected in parallel are the same while 74% of them have alternative conceptions about the concept.

G. Thirty-one percent (31%) of the students have the correct scientific conception that the ammeter readings are different with the reason that the current through ammeter A will be shared among ammeters A_1, A_2 and A_3 (i.e. $A = A_1 + A_2 + A_3$) while 69% have alternate conceptions about the concept.

H. Forty-one percent (41%) of the students have correct conception about the voltage across identical resistors connected in parallel in a circuit giving the reason that the voltage across a parallel circuit is constant while 59% of them have alternative conceptions about the concept.

The most common alternative conceptions identified among the students are as follows:

A. The brightness of a bulb connected in series to dry cells connected in parallel will increase because the voltage of the cells will increase.

B. The brightness of identical bulbs connected in series will decrease because the current will be shared among the bulbs. This means that the concepts, current and voltage are confused and used interchangeably by students.

C. Current is consumed or used up by circuit elements or resistors.

D. Voltage is constant in a series circuit.

E. The brightness of identical bulbs connected in parallel to a dry cell will decrease because the source voltage is shared among the bulbs in the circuit.

F. The voltage is shared equally among similar resistors connected in parallel in a circuit.

G. Resistance decreases the voltage in a circuit.

These findings support some of the findings of Osborne (1983); Sebastia (1993) and Engelhardt and Beichner (2004) who are of the view that students hold alternative conceptions about some concepts in direct current electricity.

Conclusions

Based on the findings from this study the following conclusions can be drawn:

1. The learning cycle approach has been more effective in this study for teaching concepts in direct current electricity than the traditional teaching approach.
2. The learning cycle approach has been more effective in teaching most of the interrelated concepts and a number of different aspects involved in direct current electricity than the traditional approach in this study.
3. The learning cycle teaching activities in this study has been very effective for identifying students' correct preconceptions about the selected concepts in direct current electricity as well as their alternative concepts.

Recommendations

The following recommendations have been made for educational practice:

1. In teaching concepts in direct current electricity, the practice of feeding students with information should be minimized since its effect on students' understanding is not as significant as those instructed with the learning cycle approach.

2. The learning cycle approach which uses inquiry based activities should be encouraged in many physics instructions, since it offers students more opportunities to explore, discuss, challenge and test their pre-existing ideas about concepts before formal instruction.
3. Teachers should as much as possible try to learn and use the learning cycle approach in their instructions since it exposes students' correct and alternative conception about concepts in science prior to instruction.
4. The learning cycle approach helps students to develop scientific concepts adequately with limited teacher guidance.

Suggestions for Further Research

1. Further research needs to be conducted to identify the shortcomings or limitations of the learning cycle approach.
2. The study should be replicated using the learning cycle approach in other regions and districts in Ghana.
3. It is suggested that in-service training should be organized for physics teachers to train them on how to use the learning cycle approach effectively.

REFERENCES

Abraham, M. R., & Renner, J. W. (1986). The sequence of learning cycle activities in high school chemistry. *Journal of Research in Science Teaching,* 23 (2), 121-143.

Anamuah-Mensah, J. (2007). *Relevant data collected for PRACTICAL project plan.* A paper presented at the PRACTICAL workshop. NPT/PRACTICAL project, Elmina, 18-20 December, 2007.

Arnold, M., & Miller, R. (1987). Being constructive: An alternative approach to the teaching of introductory ideas in electricity. *International Journal of Science Education,* 9 (3), 553-563.

Ary, D., Jacobs, L. C., & Razavieh, A. (1990). *Introduction to research in education* (4th ed.). New York: Holt, Rinehart and Winston, Inc.

Ates, S. (2005). The effects of learning cycle on college students' understandings of different aspects in resistive dc circuits. *Electronic Journal of Science Education,* 9 (4), 1-20.

Aubrecht, G.J., & Raduta, C. (2005). American and Romanian student approaches to solving simple electricity and magnetism problems. *Association for University Regional Campuses of Ohio Journal,* 11, 51-66.

Beisenherz, P. C., Dantonio, M., & Richardson, L. (2001). The learning cycle and instructional conversations. *Science Scope,* 24 (4), 34–38.

Best, J. W., & Kahn, J. V. (1993). *Research in education* (7th ed.). London: Allyn and Becon.

Borges, A. T., & Gilbert, J. K. (1999). Mental models of electricity. *International*

Journal of Science Education, 21 (1), 95-117.

Bybee, R. W., & Sund, R. B. (1990). *Piaget for educators* (2nd ed.). Illinois: Waveland Press, Inc.

Carlton, K. (1999). Teaching electric current and electrical potential. *Physics Education*, 34 (6), 341-344.

Choi, K., & Chang, H. (2004). The effects of using the electric circuit model in science education to facilitate learning electricity-related concepts. *Journal of the Korean Physical Society*, 44 (6), 1341-1348.

Clement, J. (1987). *The Use of Analogies and Anchoring Intuitions to Remediate Misconceptions in Mechanics.* Paper presented at the Annual Meeting of the American Educational Research Association (Washington, DC, April 20-24, 1987).

Clement, J., & Steinberg, M. S. (2002). Step- wise evolution of mental models of electric circuits: A "learning- aloud" case study. *International Journal of the Learning Sciences*, 11 (4), 389-452.

Closset, J. L. (1984). *Sequential reasoning in electricity.* Research on Physics Education: Proceedings of the first international workshop (La Londe les Maures, France: Editions du Centre National de la Recherche Scientifique).

Cohen, L., & Manion, L. (1994). *Research methods in education* (4th ed.). London: Routledge.

Colburn, A. (2000). An inquiry primer. *Science Scope*, 23 (6), 42-44.

Cosgrove, M. (1995). A study of science-in-the-making as students generate an analogy for electricity. *International Journal of Science Education*, 17 (3), 295-310.

Creswell, J. W. (1994) *Research design: Qualitative and quantitative approach.* London: Sage Publications.

Duit, R., & Rhöneck, C. (1998). Learning and understanding key concepts of electricity. In A. Tiberghien, E. L, Jossem & J. Barojas (Eds.), *Connecting Research in Physics Education with Teacher Education* (pp. 50-55). Glasgow: Open University Press.

Engelhardt, P. V., & Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics*, 72 (1), 98-101.

Eylon, B. S., & Ganiel, F. (1990). Macro-Micro relationship: The missing link between electrostatics and electrodynamics in students' reasoning. *International Journal of Science Education*, 12, 79-94.

Fleener, M. J., & Marek, E. A. (1992). Testing in the learning cycle. *Science Scope,* 15 (6), 48-49.

Garmston, G. J. (1996). Adult learners, instruments and the "big C". *Journal of Staff Development,* 17 (3), 53-54.

Gunstone, R. F. (1991). Learners in science education. In P. Fensham (Ed.), *Development and Dilemmas in Science Education.* New York: Falmer Press.

Hanuscin, D. L., & Lee, M. H. (2007). *Using a learning cycle approach to teaching the learning cycle to preservice elementary teachers.* A paper presented at the 2007 annual meeting of the Association for Science Teacher Education, Clearwater, FL.

Heller, P. M., & Finley, F. N. (1992). Variable uses of alternative conceptions: A case study in current electricity. *Journal of Research in Science Teaching,* 29 (3), 259-275.

Henson, K. T. (2003). Foundations for learner-centered education: A knowledge base. *Education,* 124 (1), 5-16.

Hewson, P. W. (1992). *Conceptual change in science teaching and teacher education.* A paper presented at a meeting on "Research and Curriculum Development in Science Teaching," under the auspices of the National Centre for Educational Research, Documentation and Assessment, Ministry of Education and Science, Madrid, Spain, June 1992.

Hewson, P., & Hewson, M. (1992). The status of students' conceptions. In R. Duit, F. Goldberg, & A. Niedderer (Eds.), *Research in Physics Learning: Theoretical Issues and Empirical Studies* (pp. 59-73). Kiel: IPN – Leibniz Institute for Science Education.

Hogan, K., & Berkowitz, A. R. (2000). Teachers as inquiry learners. *Journal of Science Teacher Education,* 11 (1), 1-25.

Huang, H. M. (2002). Toward constructivism for adult learners in online learning environments. *British Journal of Educational Technology,* 33 (1), 27-37.

İpek, H., & Çalık, M. (2008). Combining different conceptual change methods within four-step constructivist teaching model: A sample teaching of series and parallel circuits. *International Journal of Environmental & Science Education*, 3 (3), 143-153.

Joshua, S., & Dupin. J. (1987). Taking into account students conceptions in instructional strategy: An Example in Physics. *Cognition and Instruction,* 4, 117-135.

Küçüközer, H., & Kocakülah, S. (2007). Secondary school students' misconceptions about simple electric circuits. *Journal of Turkish Science Education,* 4 (1), 102-115.

Küçüközer, H., & Kocakülah, S. (2008). Effect of simple electric circuits teaching on conceptual change in grade 9 physics course. *Journal of Turkish Science Education*, 5 (1), 59-74.

Lawson, A. E. (2001). Using the learning cycle to teach biology concepts and reasoning patterns. *Journal of Biological Education*, 35 (4), 165-169.

Lawson, A. E., Alkhoury, S., Benford, R., & Falconer, K. A. (2000). What kinds of scientific concepts exist? Concept construction and intellectual development in college biology. *Journal of Research in Science Teaching*, 37, 996-1018.

Liew, C., & Treagust, D. F. (1998). *The Effectiveness of Predict-Observe-Explain Tasks in Diagnosing Students' Understanding of Science and in identifying Their Levels of Achievement.* Paper presented at the annual meeting of American Educational Research Association, San Diego.

Maloney D. P., O'Kuma T. L., Hieggelke C. J., & Van Heuvelen A. (2001). Surveying students' conceptual knowledge of electricity and magnetism.

American Journal of Physics, 69, 12-23.

Mansfield, H., & Happs, J. (1996). Using student conception of parallel lines to plan a teaching program. In D. F. Treagust, R. Duit, & B. J. Fraser (Eds.), *Improving teaching and learning science and mathematics.* New York: Teacher College Press.

Marek, E. A., & Cavallo, A. M. L. (1997). *The Learning Cycle: Elementary School Science and Beyond* (Rev. ed.). Portsmounth, NH: Heinemann.

Marek, E. A., Eubanks, C., & Gallaher, T. (1990). Teachers' understanding and the use of the learning cycle. *Journal of Research in Science Teaching*, 27, 821-834.

Marek, E. A., Laubach, T. A., & Pedersen, J. E. (2003). Preservice elementary school teachers' understanding of theory based science education. *Journal of Science Teacher Education*, 14 (3), 147-159

Martin-Hansen, L. (2002). Defining inquiry: Exploring the many types of inquiry in the science classroom. *The Science Teacher*, 69 (2), 34–37.

McDermott, L. C. (1991). Millikan lecture 1990: What we teach and what is learned - closing the gap. *American Journal of Physics*, 59, 301-315.

McDermott, L. C., & Shaffer, P. S. (1992). Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of student understanding. *American Journal of Physics*, 60 (11), 994–1003.

McDermott, L. C., & van Zee, E. H. (1985). Identifying and addressing student difficulties with electric circuits. In R. Duit, W. Jung, & C. von Rhöneck

(Eds.), *Aspects of Understanding Electricity* (pp.39-48). Kiel: IPN–Leibniz Institute for Science Education.

Merriam, S. B., Caffarella, R. S., & Baumgartner, L. M. (2007). *Learning in adulthood: A Comprehensive guide* (3rd ed.). San Francisco, CA: Jossey-Bass.

Nussbaum, J., & Novick, S. (1982). Alternative framework, conceptual conflict and accommodation: toward a principled teaching strategy. *Instructional Science*, 11, 183-200.

Osborne, R. (1983). Towards modifying children's ideas about electric current. *Research in Science and Technological Education*, 1 (1), 73-82.

Osborne, R. J., Bell, B. F., & Gilbert J. K. (1983). Science teaching and children's views of the world. *European Journal of Science Education*, 5, 1- 4.

Periago, M. C., & Bohigas, X. (2005). A study of second-year engineering Students' alternative conceptions about electric potential, current, intensity and Ohm's law. *European Journal of Engineering Education*, 30 (1), 71-80.

Pfister, H. (2004). Illustrating electric circuit concepts with the Glitter circuit. *The Physics Teacher*, 42, 359-363.

Pfundt, H., & Duit, R. (1991). *Bibliography: Students' alternative frameworks and science education.* Kiel: IPN–Leibniz Institute for Science Education.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982).

Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education,* 66 (2), 211 – 227.

Proulx, J. (2006). Constructivism: A re-equilibration and clarification of the concepts, and some potential implications for teaching and pedagogy. *Radical Pedagogy,* 8 (1), 64-89.

Psillos, D. (1998). Teaching introductory electricity. In A. Tiberghien, E. L, Jossem, & J. Barojas (Eds.), *Connecting Research in Physics Education with Teacher Education* (pp. 128-151). Glasgow: Open University Press.

Renner, J. M., Abraham, M. R., & Birnie, H. H. (1986). The occurrence of assimilation and accommodation in learning high school physics. *Journal of Research in Science Teaching,* 23 (7), 619-634.

Rhöneck, C., & Grob, K. (1987). Representation and problem-solving in basic electricity, predictors for successful learning. In J. D. Novak (Ed.), *Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics* (pp. 90-182). Ithaca, NY: Misconceptions Trust.

Scott, P. H., Asoko, H. M., & Driver, R. H. (1992). Teaching for conceptual change: A review of strategies. In R. Duit, F. Goldberg, & A. Niedderer (Eds.), *Research in Physics Learning: Theoretical Issues and Empirical Studies* (pp.310-329). Kiel: IPN–Leibniz Institute for Science Education.

Sebastia, J. M. (1993). *Cognitive mediators and interpretation of electric circuits.* Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Ithaca, NY:

Misconceptions Trust.

She, H. C. (2004). Facilitating changes in ninth grade students understanding of dissolution and diffusion through DSLM instruction. *Research in Science Education*, 34, 503-525.

Shipstone, D. M. (1985). Electricity in simple dc circuits. In R. Driver, E. Guesne, & A. Tiberghein (Eds.), *Children's Ideas in Science* (pp. 33-51). Milton Keynes, England: Open University Press.

Spigner-Littles, D., & Anderson, C. E. (1999). Constructivism: A paradigm for older learners. *Educational Gerontology*, 25 (3), 203-209.

Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. Duschl, & R. Hamiltonn (Eds.) *Philosophy of Science, Cognitive Psychology and Educational Theory and Practice* (pp. 147-176). Albany, NY: State University of New York Press.

Trochim, W. (2000). *The Research Methods Knowledge Base* (2nd ed.). Cincinnati, OH: Atomic Dog Publishing.

Türkmen, H. (2006). How should science be taught by using learning cycle approach in elementary schools? *Elementary Education Online*, 5 (2), 1-15. [Retrieved August 26, 2006 from http://ilkogretim-online.org.tr]

Türkmen, H., & Usta, E. (2007). The role of learning cycle approach overcoming misconceptions in science. *Kastamonu Education Journal*, 15 (2), 492-500.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction*, 4, 45-69.

Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (1994). Reserch on alternative conceptions in science. In D. L. Gabel (Ed.), *Handbook of Research on Science Teaching and Learning* (pp. 542-558). New York: Macmillan.

Wang, T., & Andre, T. (1991). Conceptual change text versus traditional text and application questions versus no question in learning about electricity. *Contemporary Educational Psychology*, 16, 103-116.

WAEC (2000). *Chief Examiner's report on Senior Secondary certificate Examination*. Accra: Wisdom Press.

WAEC (2001). *Chief Examiner's report on Senior Secondary certificate Examination*. Accra: Wisdom Press.

WAEC (2002). *Chief Examiner's report on Senior Secondary certificate Examination*. Accra: Wisdom Press.

WAEC (2003). *Chief Examiner's report on Senior Secondary certificate Examination*. Accra: Wisdom Press.

WAEC (2006). *Chief Examiner's report on Senior Secondary certificate Examination*. Accra: Wisdom Press.

Wheatley, G. H. (1991). Constructivist perspectives on science and mathematics learning. *Science Education*, 75 (1), 9-21.

White, R., & Gunstone, R. (1992). *Probing understanding*. London: The Falmer Press.

Yanfeng, D. (2004). Using new teaching strategies to improve teaching and learning in Organic Chemistry. *The China Papers*, 6-9.

Yilmaz, H., & Cavas, H. (2006). The effect of the 4-E learning cycle method on students' understanding of electricity. *Journal of Turkish Science Education*, 3 (1), 1-5.

APPENDIX A

CURRENT ELECTRICITY CONCEPTS ACHIEVEMENT TEST

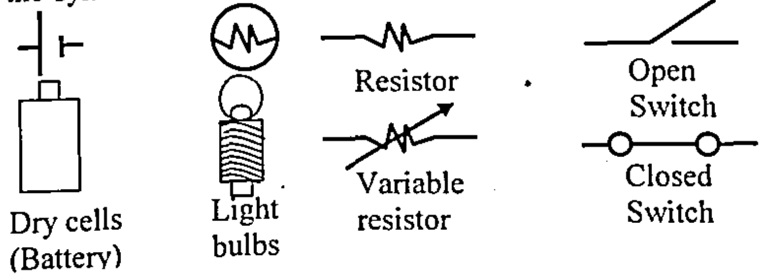
(CECAT)

PLEASE READ THE FOLLOWING INSTRUCTIONS:

1. This test has nothing to do with your final grade.
2. Please think carefully and answer the questions accurately and as best as possible.
3. There is only one correct answer for each item. Feel free to use the calculator.
4. Give a brief explanation for the choice of a particular option in the space provide on the answer sheet where required.
5. Use pencil to circle round the correct answer on the answer booklet. Do all rough work on the blank sheet provided at the back of the answer booklet.
6. You have $1\frac{1}{2}$ hours to complete the test. If you finish early, kindly check your work before handing in both the answer and test booklets.

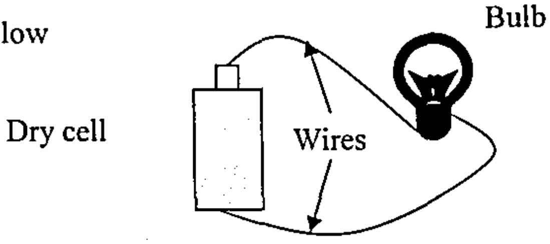
ADDITIONAL COMMENTS ABOUT THE TEST

All light bulbs, resistors and dry cells (battery) should be considered identical unless you are told otherwise. The battery is to be assumed as ideal (i. e. with no internal resistance). Also, assume the wires have negligible resistance. Below is a key to the symbols used in this test. Study them carefully before you begin the test.



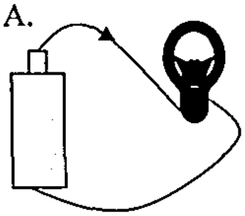
Please read the questions carefully before choosing an answer. Each question is followed by three to five options lettered A to E. Circle the correct option for each question.

1. A dry cell is connected up to a bulb and the bulb glows as shown in the diagram below



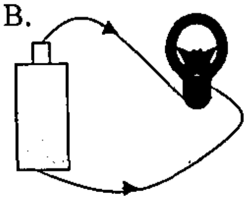
Which of the following best describes the path of the electric current in the wires?

A.



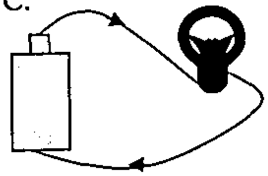
There will be no electric current in the wire attached to the base of the cell

B.



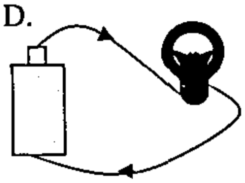
The electric current will be in a direction towards the bulb in both wires.

C.



The direction of the electric current will be as shown and the current will be less in the 'return' wire as shown.

D.



The direction of the electric current will be as shown and the current will be same in both wires.

2. Are charges in a wire used up in a light bulb when converted to light?

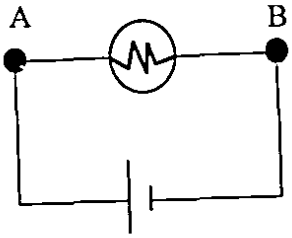
   A. Yes, charges moving through the filament produce ‘friction’ which heat up the filament and produce light?

   B. Yes, charges are emitted to the bulb.

   C. No, charges are conserved or not emitted. They are only converted to another form of energy such as heat and light.

   D. No, charges are conserved. Charges moving through the filament produce ‘friction’ which heats up the filament to produce light.

3. Comparing the current at point ‘A’ to the current at point ‘B’ as shown in the diagram below, which point has the larger current?



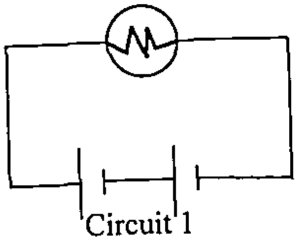
   A. Point ‘A’ because the current passes through it before point ‘B.’

   B. Point ‘A’ because the bulb will consume some of the current.

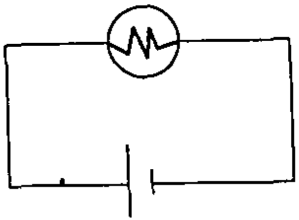
   C. Both points have the same current.

   D. Point ‘B’ because current increase as it moves along.

4. Comparing the brightness of the bulb in circuit 1 to the bulb in circuit 2, which of them will be brighter? [the bulbs and dry cells are identical]



Circuit 1



Circuit 2

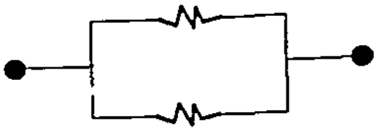
   A. Bulb in circuit 1

   B. Bulb in circuit 2

   C. Both bulbs will have the same brightness

5. If the resistors have the same resistance, which of the two branches of the circuits shown below represents the branch with the least effective resistance?

Branch 1



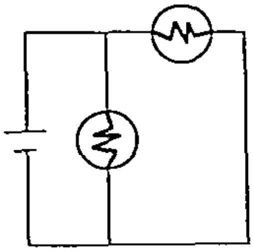
Branch 2

A. Branch 1

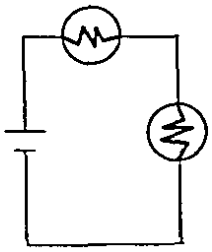
B. Branch 2

C. Both Branches are the same.

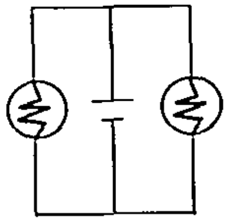
6. Consider the following circuits:



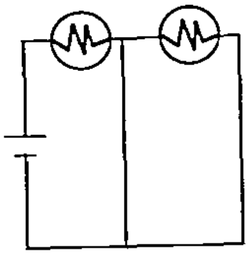
1



2



3



4

Which circuits above represent a circuit consisting of two light bulbs connected in parallel to the cell?

A. 1and 2

B. 2 and 3.

C. 1and 3

D. 3 and 4

E. 1 and 4

7. The battery in a circuit supplies constant ____________

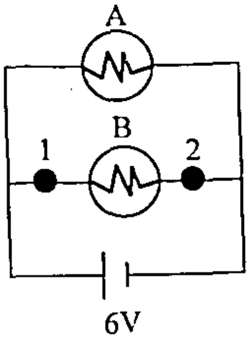
A. electric current.

B. electrical energy.

C. electrical resistance.

D. potential difference.

8. What is the potential difference between points 1 and 2, if bulb A is removed?



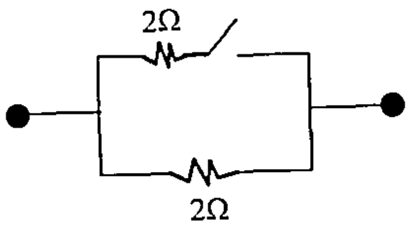
A. 0 V

B. 3 V

C. 6 V

D. 9 V.

9. What is the value of the resistance between the endpoints of the circuit if the switch is closed?



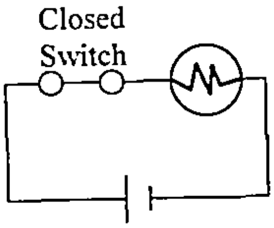
A. 0 Ω

B. 1 Ω.

C. 2 Ω.

D. 4 Ω.

10. What becomes of the resistance of the bulb in the circuit, when the switch is immediately opened?



A. The resistance increases.

B. The resistance decreases.

C. The resistance stays the same.

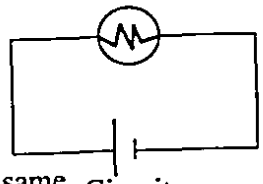
D. The resistance goes to zero.

11. Comparing the brightness of bulb 'A' in circuit 1 to the bulb 'B' in circuit 2, which bulb is dimmer? [the bulbs and dry cells are identical]

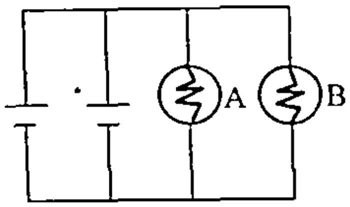
A. Bulb A in circuit 1

B. Bulb B in circuit 2

C. Neither, they are the same.

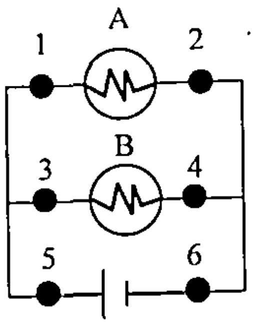


Circuit



Circuit

12. Rank the currents at the points 1, 2, 3, 4, 5 and 6 from highest to the lowest if the bulbs are identical.



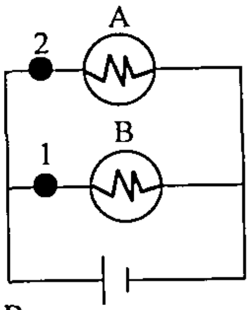
A. 5, 1, 3, 2, 4, 6.

B. 5 = 6, 3 = 4, 1 =2

C. 5 =6, 1 = 2 =3 =4.

D. 1 = 2 = 3 = 4 = 5 = 6.

13. What becomes of the brightness of bulb 'A' and that of bulb 'B' when a wire is connected between points 1 and 2?



A. Decreases

B. Increases

C. Stays the same

D. Bulb A becomes brighter than bulb B.

E. Neither of the bulbs will light.

14. If you double the current from a battery, will the potential difference across that battery be doubled too?

A. Yes, because as you increase the resistance, you automatically increase the potential difference.

B. Yes, because potential difference is directly proportional to the current.

C. No, because as you double the current, you reduce the potential difference by half.

D. No, because the potential difference is a property of the battery.

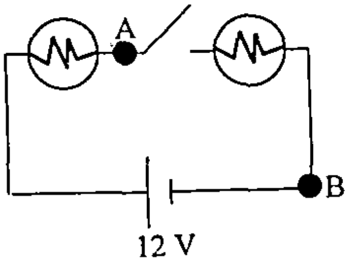
15. What is the potential difference between points A and B?

A. 0 V

B. 3 V

C. 6 V

D. 12 V



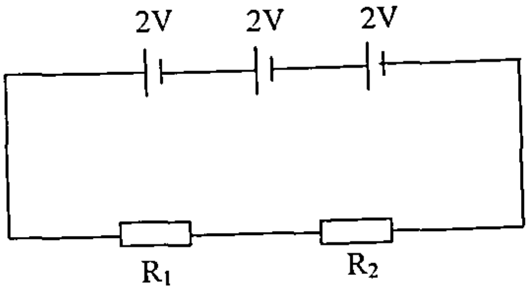
17. In the circuit diagram below, what is the total voltage across the resistor R_1 if that across resistor R_2 is 3V?

A. 12 V

B. 9 V

C. 6 V

D. 3 V



18. Which schematic diagram represents the circuit shown below?

A. Circuit 1.

B. Circuit 2.

C. Circuit 3.

D. Circuit 4.

E. None of the above.

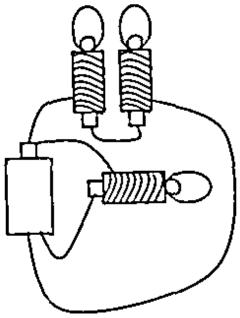
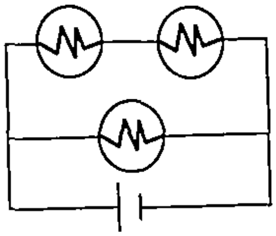
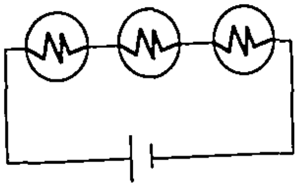


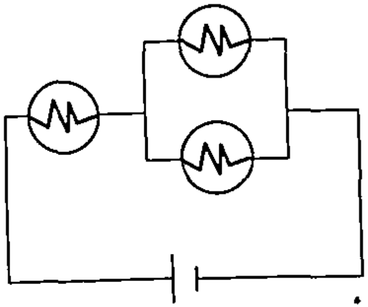
Fig.



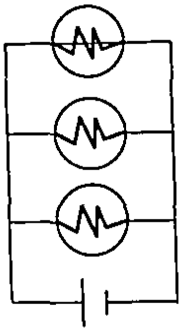
Circuit 1



Circuit 2



Circuit 3



Circuit 4

19. Which circuit(s) will let the bulb light the up?

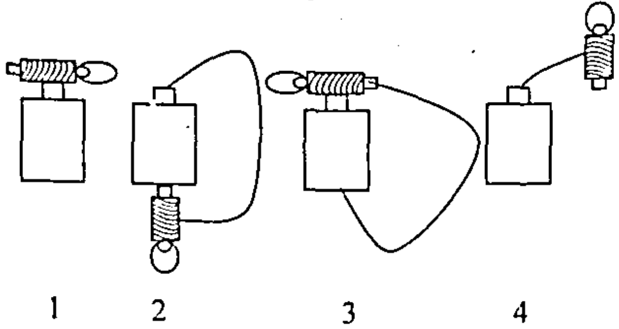
A. 2

B. 3

C. 4

D. 2 and 3

E. 1 and 4



20. Which circuit(s) represent(s) the schematic diagram shown below?

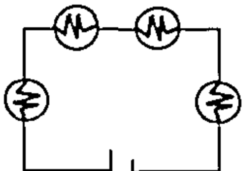
B. 2.

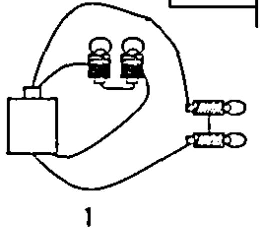
C. 3

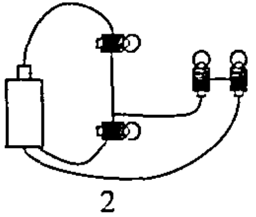
D. 4

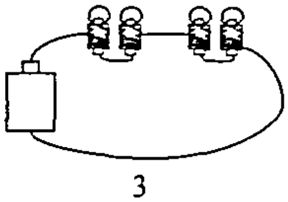
E. 1 and 2

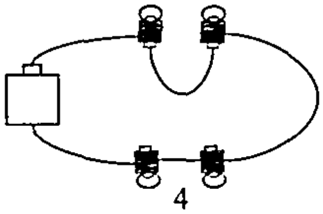
F. 3 and 4











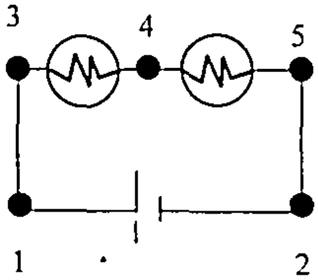
21. Rank the potential difference between points 1 and 2, points 3 and 4, and points 4 and 5 in the circuit shown below from highest to lowest if the bulbs are identical.

B. (1 and 2); (4 and 5); and (3 and 4).

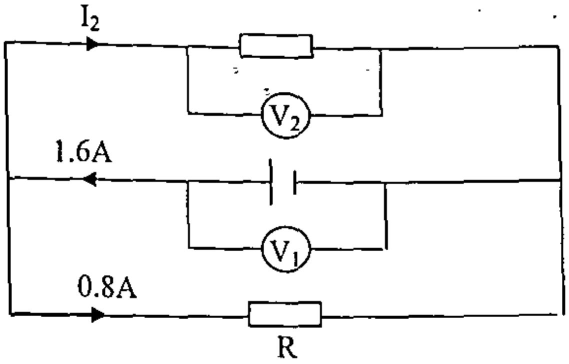
C. (3 and 4); (4 and 5); (1 and 2).

D. (3 and 4) = (4 and 5); and (1 and 2).

E. (1 and 2); (3 and 4) = (4 and 5).



Use the circuit diagram below to answer questions 21 and 22.



21. What is the value of V_1, if V_2 reads 4V

V_2 reads 4V?

A. 4V

B. 3V

C. 2V

D. 1V

22. What is the value of the current I_2?

A. 0.4 A

B. 0.6 A

C. 0.8 A

D. 1.0 A

23. What happens to the brightness of bulbs 1 and 3 if the switch is closed?

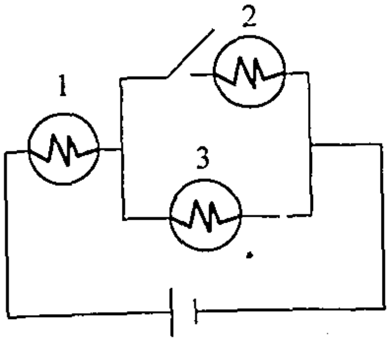
[the three bulbs are identical]

A. 1 and 3 remain the same.

B. 1 is bright and 3 dims.

C. 1 and 3 increase.

D. 1 and 3 decrease.



24. Comparing the brightness of bulbs X and Y in circuit 1 to the brightness of bulb Z in circuit 2, if the bulbs are identical, which bulb or bulbs are the brightest?

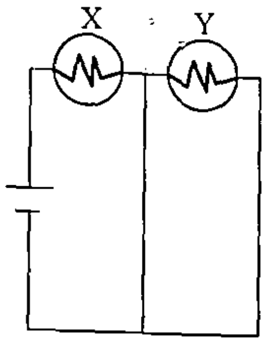
A. X

B. Y

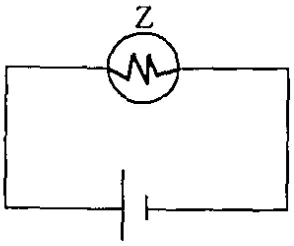
C. Z

D. X = Y

E. X = Z



Circuit 1



Circuit 2

25. In the circuit diagram below, what is the effective voltage?

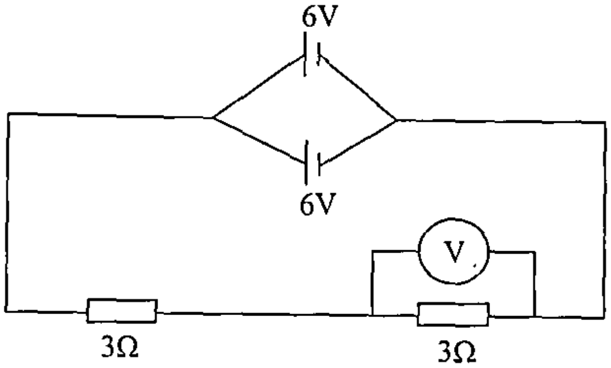
A. 0.33 V

B. 3 V

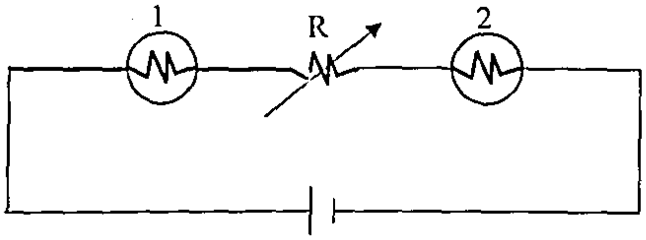
C. 6 V

D. 9 V

E. 12 V



Use this circuit to answer questions 26 and 27.



26. If the value of the resistor R is decreased, what happens to the brightness of bulb 1?

A. Decreases.

B. Increases

C. Remains unchanged.

27. If the value of the resistor R is increased, what happens to the brightness of bulbs 1 and 2?

A. 1 stays the same and 2 dims.

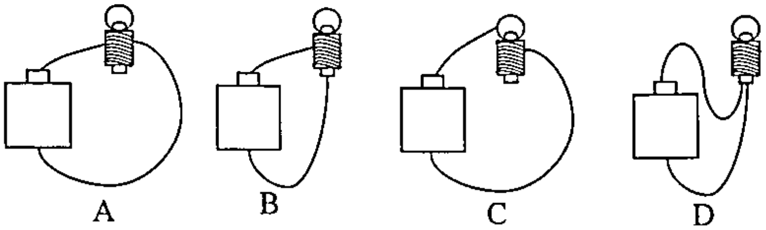
B. 1 dim and 2 stays the same.

C. 1 and 2 increase.

D. 1 and 2 decreases.

E. 1 and 2 remain the same.

28. Will all the bulbs in the circuits below be of the same brightness?



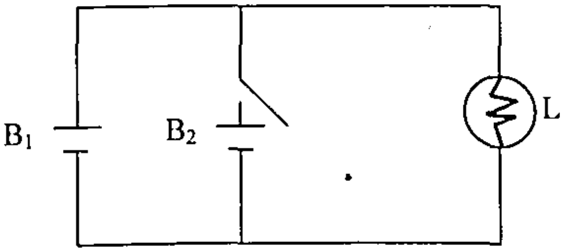
A. Yes, because all of them have the same type of circuit wiring.

B. No, only B will light because the connections of A, C and D are not correct.

C. No, only D will light because D is the only complete circuit.

D. No, C will not light, but A, B and D will.

29. Two identical dry cells B_1 and B_2 are connected in parallel with the bulb L as shown in the circuit as below. What happens to the current through the bulb when the switch is closed?



A. decreases

B. increases

C. remains the same

D. doubles

30. Why do all the lights in your home controlled by one switch come on almost instantaneously when switched on?

A. Charges are already in the wires so there is a rapid rearrangement of charges in the circuit when the circuit is complete.

B. When the circuit is complete, charges store energy and release them.

C. Charges in the wire travel very fast.

D. Current is already flowing because circuits in the home are wired parallel.

APPENDIX B

Table 14: Results of Current Electricity Concepts Achievement Test (CECAT) for Each Question

Question	Answer	Discrimination index	Difficulty index (p)	I raction choosing incorrect item (q)	pq
1	D	0.11	0.30	0.70	0.21
2	D	0.05	0.21	0.79	0.17
3	C	0.11	0.36	0.64	0.23
4	A	0.21	0.83	0.17	0.14
5	B	0.53	0.69	0.31	0.21
6	C	0.26	0.57	0.43	0.25
7	B	0.63	0.41	0.59	0.24
8	C	0.42	0.47	0.53	0.25
9	B	0.42	0.50	0.50	0.25
10	C	0.68	0.50	0.50	0.25
11	C	0.42	0.64	0.36	0.23
12	C	0.26	0.36	0.64	0.23
13	C	0.53	0.26	0.74	0.19
14	B	0.42	0.66	0.34	0.22
15	D	0.37	0.63	0.37	0.23
16	D	0.58	0.49	0.51	0.25
17	A	0.16	0.76	0.24	0.18

Table 14 continued

Question	Answer	Discrimination index	Difficulty index (p)	Fraction choosing incorrect item (q)	pq
18	D	0.32	0.56	0.44	0.25
19	B	0.58	0.41	0.59	0.24
20	D	0.53	0.53	0.47	0.25
21	A	0.63	0.51	0.49	0.25
22	C	0.53	0.46	0.54	0.25
23	B	0.68	0.46	0.54	0.25
24	E	0.63	0.77	0.23	0.18
25	C	0.74	0.44	0.56	0.25
26	B	0.32	0.61	0.39	0.25
27	D	0.47	0.43	0.57	0.25
28	B	0.63	0.64	0.36	0.23
29	C	0.42	0.49	0.51	0.25
30	C	0.42	0.53	0.47	0.25

APPENDIX C

Output of regression analysis of posttest scores

Descriptive Statistics

A	Mean	Std. Deviation	N
Scores	19.03	3.506	101
Groups	1.42	0.495	101

Correlations

		Scores	Group
Pearson Correlation	Scores	1.000	-0.716
	Group	-0.716	1.000
Sig. (1-tailed)	Scores	-	0.001
	Group	0.000	-
N	Scores	101	101
	Group	101	101

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.716	0.512	0.507	2.461

a. Predictors: (Constant), Group

Anova[b]

Model		Sum of Squares	df	Mean Square	F	sig.
1	Regression	629.210	1	629.210	103.871	0.001[a]
	Residual	599.701	99	6.058		
	Total	1228.911	100			

a. Predictors: (Constant), Group

b. Dependent Variable: Scores

Coefficients[a]

Model		Unstandardized Coefficients		Standardized coefficients	t	sig.
		B	std. Error	Beta		
1	(constant)	26.200	0.745		35.171	0.001
	Group	-5.064	0.497	-0.716	-10.192	0.001

a. Dependent Variable: Scores

APPENDIX D

Boxplot of Posttest Mean Scores

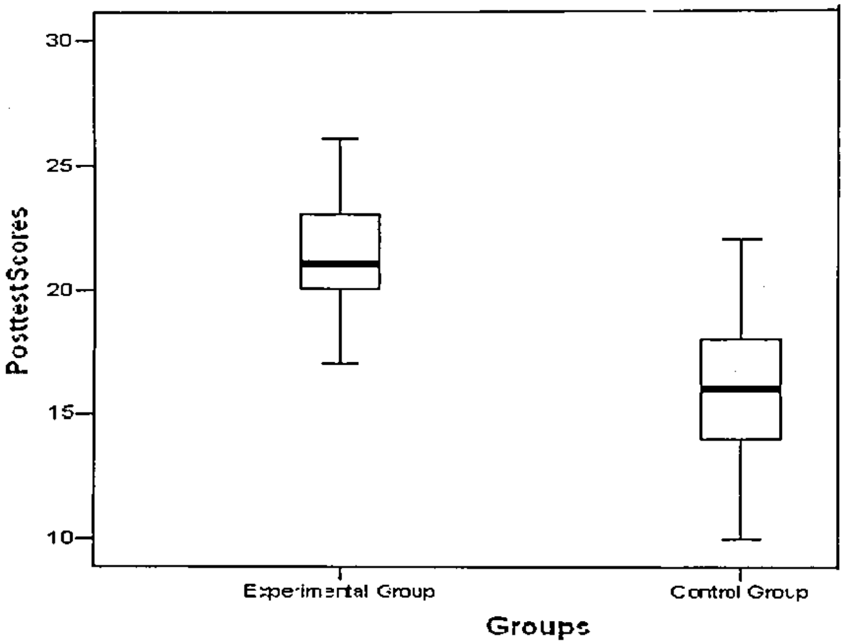


Figure 1. **Boxplot of posttest mean scores for the experimental and control groups.**

APPENDIX E

Calculation of All Effect Size Statistics

The value of effect size statistics, d ranges from negative infinity to positive infinity. Regardless of sign, d values of 0.2, 0.5 and 0.8 traditionally represent small, medium and large effect sizes, respectively.

Calculating the Effect Size Statistics for Dependent Samples t-test of pretest and posttest mean scores for the experimental group

$$d = \frac{t}{\sqrt{N}}$$

Where d = Effect size

t = Value of t in the output under the dependent samples t-test.

N = Number of students

$$d = \frac{21.177}{\sqrt{59}} = 2.76$$

Calculating the Effect Size Statistics for Dependent Samples t-test of pretest and posttest mean scores for the control group

$$d = \frac{t}{\sqrt{N}} = \frac{8.918}{\sqrt{42}} = 1.38$$

Calculating the Effect Size Statistics for independent Samples t-test of posttest mean scores for the experimental group

$$d = t\sqrt{\frac{N_1 + N_2}{N_1 N_2}}$$

Where N_1 = Number of students in the experimental group.

N_2 = Number of students in the control group.

t = Value of t in the output under the independent samples t-test.

$$d = 10{,}192\sqrt{\frac{59+42}{59 * 42}} = 10{,}192\sqrt{\frac{101}{2479}} = 10{,}192\sqrt{0{,}0408}$$

$$= 10{,}192 * 0{,}2019 = 2{,}06$$