The impact of the conceptual change model on grade 10 learners using simple electric circuits

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It all starts here ™

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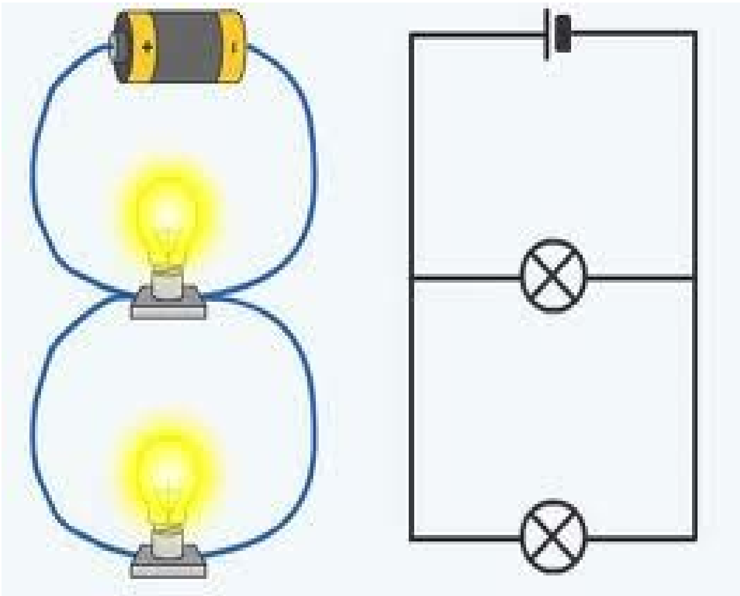

MP MANABILE

DECLARATION

I, **Mmaletsegetla Paulus Manabile**, declare that the impact of the Conceptual Change Model on grade 10 learners using simple electric circuits, is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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(Manabile M.P) Date

ABSTRACT

Poor academic performance in science is a problem in the world. Numbers of factors contribute to this academic performance. Secondary school learners, particularly those in grade 10 are experiencing problems in understanding simple electric circuits in Physical Sciences. Lack of exposure to practical work might be one of the factors that contribute to lack of understanding of simple electric circuit and inability to link what they learn in class with the outside world.

For that reason, it is the purpose of this study to determine what grade 10 learners' alternative conceptions in electricity are and to explore the impact of conceptual change model on grade 10 learners using simple electric circuits. The study further highlights a number of issues that lead to poor academic achievements in physical sciences. This study further provides the learning strategy in physical science for learners to improve their learning process of simple electric circuits.

Four secondary schools from Mankweng cluster, Capricorn District of Limpopo Province were randomly selected to participate in this study. From these schools a sample of 136 learners of different sex were also randomly selected. Two survey instruments, an open-ended questionnaire and the Simple Electric Circuit Conceptual Test were used to collect data.

The data was collected over a period of 3 weeks. Learners (in the experimental group) were taught the same electric circuit topics using Conceptual Change Model (CCM) while Regular Teaching Approach (RTP) was used in the control group. Data collected was analysed using descriptive analysis, ANOVA and ANCOVA. The explanations the respondents gave were analysed using nomothetic and ideographic analyses.

Misconceptions were identified as one of the learning barriers. The results from the questionnaire also revealed that learners were willing to learn electric circuits' concepts but they lacked effective learning strategies and techniques to enhance their academic performances. It was also established that learners could not relate what they had learnt on electric circuit with their daily experiences and that practical work was rarely conducted at most schools.

The statistical results showed that when teaching simple electric circuits using Conceptual Change Model, there is equal improvement in academic results across all sexes. There was no significant difference between academic achievements of males and females taught using the Conceptual Change Model.

Key terms: electrical circuits; misconceptions; academic achievement; conceptual change model.

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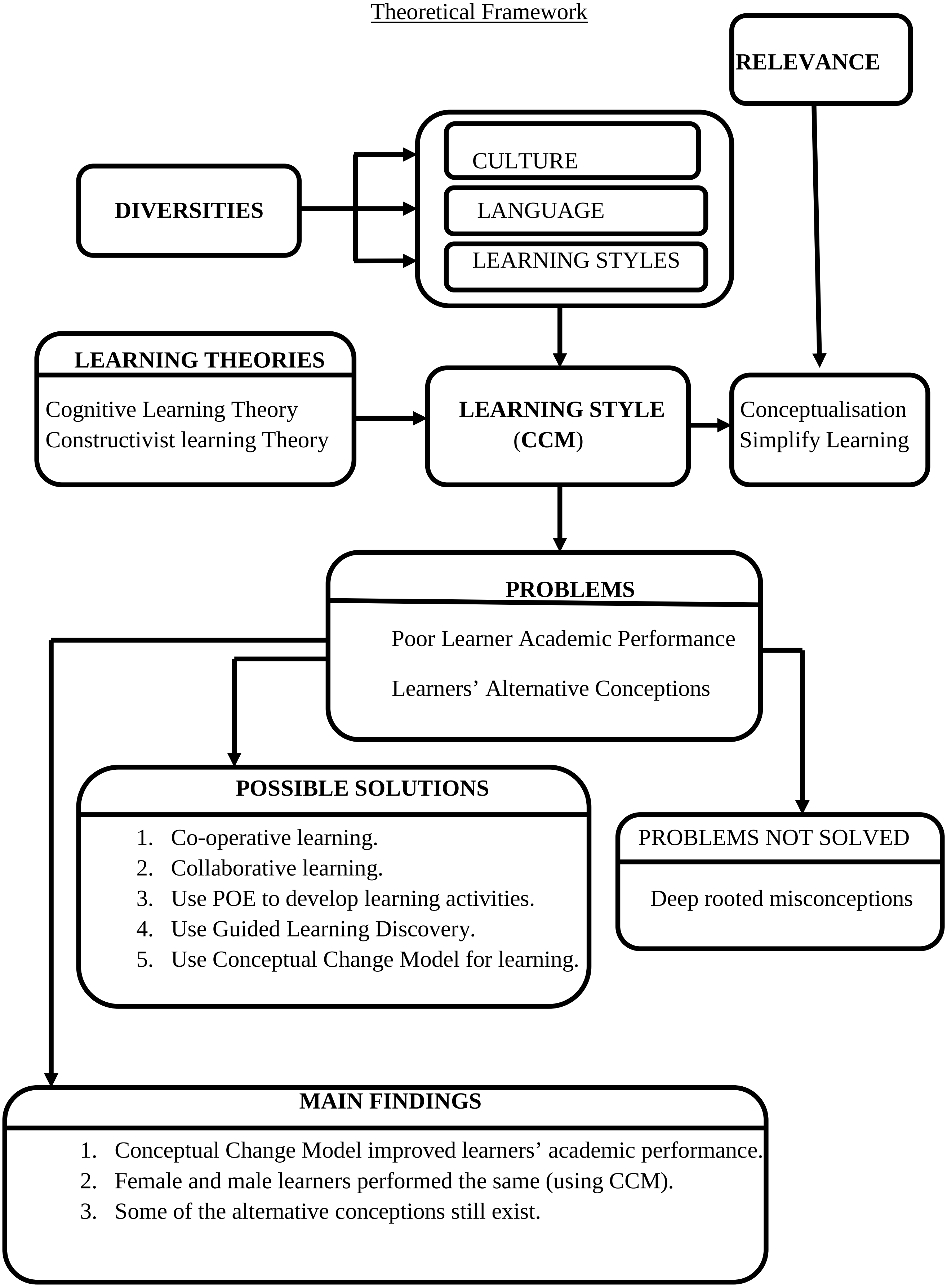
DIVERSITY IN SCIENCE CLASSROOM

Theoretical Framework



4. Practical work is seldom conducted at schools.

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CHAPTER 1

ORIENTATIVE INTRODUCTION

1.1. Statement of the problem and motivation

Poor academic performance is a major problem in the world today. Number of factors contribute to this poor academic performance. In field of physical science (e.g simple electric circuits),these concepts prove to the major challenge for learners to conceptualise them (İpek and Ḉalik, 2008; Çepni and Keleş, 2006; Wesi, 1998). Learners at secondary schools perform poorly in electricity, partularly in simple electric circuits. The research in science education (Küçüközer and Kocakülah, 2008; Grotzer and Sudbury, 2000; Smit, 1994) had documented that secondary school learners, particularly those who are in grade 10, experienced problems with the understanding of simple electric circuits.

The reasons why electric circuits are difficult for learners to understand is that they enter the secondary school without proper knowledge (good bakground knowldege) of these conecpts (Novak, 2002). The learners who entered the secondary school not having mastered these concepts are like not do well in this area (Tsai, 2001). Usually these learners tend to withdraw from aprticipation and often perfom poorly in both formal and informal assessments. Their in abililty to make meaning of the concepts of electricity deny them the opportunity to link what they learnt in class with the outside world of science (Duit, 2002; Pabale, 2005). Lack of exposure to hands-on activities on electricity (Rapule, 2005) can be one reason, while inappropriate teaching and learning methods are also contrbuting factors.

The provincial Internal Moderator’s report on Physical Sciences, (October/November 2009 NCS Examination) matric results, (Limpopo Department of Education, Arts and Culture) indicated that only 25% of 20 sampled candidates who sat for Physical Scienc Paper 1 responeded well to questions on electric circuits (DoE, 2009a). The report indicated that many candidates struggled with the concepts of electric circuits. This study, therefore, intends to test as whether the Conceptual Change Model (CCM) as a learning tool may have any effect on learners' academic performace in electric circuits (Choi and Chang, 2004; Stepans, 1994).

This study is motivated by the research of Heering (2000:363) and Hodson (1998:97), which probe the need to apply his theory in a classroom. Although Hodson conducted his research in England on grade 10's, this research seecks to unravel as whether the grade 10 learners in Limpopo have the same difficulties in conceptualising the electric circuits. The main challenge is that electric circuits play a major role in the understanding of Physical Science at FET (Wesi, 2003).

The Conceptual Change Model may assist learners to develop their own understanding, taking responsibility and the control of their own learning (Dekkers, 2005:76). Therefore, the use of CCM in this study may assist learners to improve their understanding of these concepts and further enhances good performance in Physical Science. The understanding of concepts in electric circuits' could also prompt most learners to pursue careers in Physics (electrical engineering in particular).

1.2. Review of relevant literature.

Leraners knowledge of electrical circuits may be improved if misconceptions are identified and fully addressed at the aerly stages of their learning as suggeted by Dekkers (2005:76) and Posner *et al*., (1982), who find that conceptual change in learners could happen only if it is embedded in an appropriate set of conceptual supporting conditions, such as:

- The learners must be dissatisfied with their existing view.
- The new concept must appear somewhat plausible.
- The new conception must be more attractive than the learners' existing concept.
- The new conception must have explanatory and predictive power.
- The learners must find the concept potentially fruitful.
- The concept should be intelligible to the leaners.

Hewson and Hewson (1992) had developed the conceptual change theory that supppoted Posner's theory. The theory postulated that conceptual change is the change of status. The theory emphasises that while learner's pre-conception is losing its status, the new concept is gaining its status, hence it is understood, accepted and become useful to the learner. This theory was refined into Conceptual Change Model (CCM) by Stepans (1994).

In Physical Science literature, there are many teaching strategies to address the misconceptions in teaching electric circuits (Singh, 2010; Chang *et al*., 2008; Baser, 2006a). This study has discovered that learners put little effort to chnage their own pre-conceptions during the learning process. This study intends to use CCM to investigate learners performance in electric circuits as CCM can be used as the basic model of teaching electric circuits to learners who have the barriers in it, as supported by the constructivist theory (Çalik *et al*., 2007; Duit & Treagust, 1998: 8), social constructivist theory (Pollard, 1997:124-128) and cognitive learning theory (Schunk, 2000:229) on learning science concepts.

These learning theories formed the bedrock of the theoretical framework of this study. According to the constructivist theory, learning is the process where individuals construct new ideas or concepts based on prior knowledge or experiences (Ípek and Çalik, 2008:145). In support of constructivist learning theory, Collins (2002:9) maintains that it is imperative that learners will always bring with them prior personally constructed knowledge and beliefs that could either be relevant or not with the scientific concepts. Therefore, constructivism did not divorce itself from social constructivism theory which strongly suggests the importance for learning of the social context and interaction with others.

On the other hand the cognitive learning theory attests that learners should take the leading role in their learning, find knowledge for themselves and test the formulated hypotheses (Schunk, 2000:171). This theoretical views on learning seemed to be in accordance with the kind of the learner envisaged by the National Curriculum Statement (DoE, 2003a:5), which put emphasis on self discovery in learning, collaborative learning and interdependence between learners and teachers.

CCM was used together with other learning and teaching strategies such as predict-observe-explain (POE) as alluded by Kearney *et al*., (2003:590-602), White and Gunstone (1992:58) and Wesi (1998:127), the collaborative teaching (Baquete, 2006:76; Vranesh, 2002) and the maize grain model (Dekkers, 2005:24-28). Rapule (2007:244) points out that POE gives learners an opportunity to state the hypothesis and triggers them to give reasons to support their hypothesis. POE finally allowed learners to predict, observe (do hands-on activities), thereafter discuss and explain their results. These supportive learning tools were used as a simple mechanism through which learners engagement was augmented.

The literature shows that the teaching-based studies in simple electric circuit , the starting point is on one of three concepts: Voltage (Lee & Law, 2001), energy (Berg & Grosheide, 1997) or current (Tsai *at al*., 2007; Cosgrove, 1995). The teaching strategies mostly used are cognitive conflict and analogy activities. This study followed the electric circuit work schedule for grade 10 as proposed in the DoE (2006:28-32; 2009b:6-7).

Jaakkola and Nurmi (2004) and Lemmer and Edwards (2007) find that some of electricity's study materials or textbooks do not alter learners' misconceptions**.** These textbooks failled to apply the constructivist principle of taking learners' alternative conceptions into account before a new concept is introduced. This situation is aggravated by lack of skills (Lemmer *et al.*, 2008:184) in choosing the appropriate textbook for learners. This study intends to develop the electrical circuit learning programme, that would be user friendly to grade 10.

Ates (2005), Engelhardt, Gray and Rebeilo (2004) and Slaiter *et al*., (2000) have used the Evans' study (as cited in Baser, 2006a:337) for teaching strategy of batteries and bulbs to foster understanding of concepts related to simple electric circuits in their studies. However, the stratergy could not eradicate all misconceptions that learners have. The strategy of bulb and batteries could become more effective if teachers become the facilitators and mediators of the learning process while learners take the leading role. Ronen and Eliahu (2000) warn that some deep misconceptions may not be altered by direct experience with simple electric circuits. Therefore, good learning strategies in electrical circuit is still a debate.

Wesi (1998:110) in his study on electricity with science teachers revealed that they did have alternative conceptions. In support to this finding, Küçüközer and Demirci (2008:308) and Pardham and Bano (2001) observed that the existence of misconceptions in learners' minds during teaching sometimes depends on the extent to which teachers identify these misconceptions. These findings instigate a need and search for a better simple electric circuits' learning tool which may enable learners to learn circuits concepts better.

It is against this background that this study is conducted. The purpose is to examine the impact of CCM on learners' performance in simple electric circuit. The question this study tries to answer is: To what extent has the CCM improved the grade 10 learners undertstanding of simple electric circuit?

1.3. Research aim and objectives of the study.

The aim of this study is to investigate the impact of CCM on learners ability to use simple electric circuits in class. The research aslo aimed at pursuing the following secondary objectives:

a) To improve learners conceptual understanding of concepts related to simple electric circuits.
b) To identify learners misconceptions in the simple electric circuits and address them.

1.4. Hypotheses

(a) When teaching the simple electric circuits using Conceptual Change Model, the experimental group will score more than the control group.
(b There will be no significant differences in learners (males and females) scores in simple electric circuit taught using the Conceptual Change Model.

1.5. Research design and methodology

1.5.1. Liturature study

The information was acquired from both secondary and primary sources. The following definitions were used in this study:

- *Learners*, are secondary school pupils who study Physical Sciences in grade 10.
- *Alternative conception (misconception)*, refered to a conception which in some aspect is contradictory to, or inconsistent with, the concept as intended by the scientists. A conceptual change model, therefore, referred to a model which holds that a new concept which is more intelligible, plausible, fruitful and attratcive should be found.
- *Scores (performance)* referred to a point/s a learner get for a correct respond in a model test where he or she indicates the degree of understanding science concepts on simple electric circuit.
- *Simple electric circuit* is an electric circuit consisting of batteries, connectors, electrical components such as bulbs, ammeters, voltmeters and simple switches.

1.5.2. Emperical study

The researcher empolyes both quantitative and qualitative approaches in pursuing the objectives of the study. The quantitative approach best examines constructs (scores) which are measurable (Struwig and Stead, 2004:4). In addition, the quantitative approach gives the researcher advantage to control the threats to internal validity (McBurney, 2001). The explanations learners give on oepen-ended questionnaire are analysed qualitatively.

1.5.2.1. The experimental design.

An experimental design (Graziano and Raulin, 2004:210) with a stratified random sampling method is used in this study because it has two benefits. It appropriately tests the effect or impact of the independent variable on the dependent variable. This means that the experimental design determines whether a conceptual change model is responsible for the observed statistical change in the learners' score in simple electric circuits. Secondly, the experimental design ensures internal validity.

1.5.2.2. Population and sample

The study is conducted in secondary schools in the rural area of Limpopo Province, in Mankweng Cluster of Capricorn District. Mankweng Cluster has five circuits and 65 secondary schools which offer Physical Sciences in grade 10. A stratified random sampling technique (Welman and Kruger, 1999) is used in selection of learners (i.e from four schools out of four circuits). A stratified random sample is preferred over other probability sampling techniques because it is more representative of the population in the sense that it does not favour one unit of analysis over another. However, grade 10 learners (within the selected schools) are sampled using a stratified random sampling.

Using the probability sampling technique, two schools (one from Lebopo Circuit and the other from Mankweng Circuit) are selected to form a control group while the other two schools, one from Kgakotlou Circiut and the other from Mamabolo Circuit constitutes the experimental group. The two groups are assigned in this manner to avoid the occurrence where the subjects of the experimental group share the intervention information with the subjects of the control group..

Population targeted for the study comprised N = 1442 learners who are in grade 10 and enrolled for Physical Sciences in the academic year, 2011. The learnres' age ranges from 14 to 15 years, with a meam age of 14.7. In the sampled schools, the 34 learners are selected from one school,using the class list. The stratified random sampling technique gives a sample size n = 136. The current teacher - learner ratio in secondary schools as recommended by the Department of Education is 1:35 (DoE, 2003b). Therefore class size for the intervention is adequate. The gender ratio is 50% males and 50% females. The sample is selected in this manner for the following reasons: first, it is easily accessible and secondly, the cost involved is fairly low.

1.5.2.3. Variables

In this study the independent variable is the CCM and the dependent variable is learners' scores in simple electric circuits. The extraneous variables are learner characteristics (age), classroom environment (type of the school) and teacher training. These extraneous variables are controlled in this study.

1.5.2.4. Measuring instruments

The questionnaire and a Simple Electrical Circuit Conceptual Test (SECCT) are used to collect primary information. These instruments are pilloted. Pilloting helps the researcher to detect possible flaws in the measurement procedures, such as ambiguous instructions and inadequate time limits (Punch, 2000).

1.5.2.4.1. Questionnaire

This study uses the questionnaire developed by Rapule (2007:288) and modified it in order to pursue its objectives. A modified questionnaire consists of three sections, namely, biographical information of the respontents (10 items), the information on learning at school (6 items) and information on simple electric circuit (two parts each with 16 items). The entire questionnaire includes questions which entail socio-demographic and personal information from the respondents (learners). Lastly, it encompasses items that sought information to ascertain what the subjects know about their learning.

The section which seeks information on teachers was discated from the original questionnaire because it does not address the objectives of the study. Item 2 was altered to name of circuit instead of province (all learners in the study are from the same province). The item on age was also changed to accomodate lerners with 13 and 14 years old. Item 5 was left out since all learners are in the same grade. The item on recent mark in physical sciences includes levels instead of symbols. This exclusion of some of the items (5, 8 and 9) from the original questionnaire resulted in 9 items on part one.

On part two, information on learning at school, the five likart scale was modified. Iterm 2 and 3 (‘agree’ and ‘agree with reservations’)were swoped to create a balance scale. A balance scale will make it possible for the researcher to determine the central tendencies, means and average when needed. The items were aliegned to learning at school based on simple electric circuit. This part has 16 items instead of 31.

Lartly modification of this instrument involved information on learning based on Conceptual Change Model instead of science centres and environment. The last part had 32 items and all its items intened to assess the impact of Conceptual Change Model.

In constructing the questionnaire, a 5-point Likert-scale is used. The 5-point Likert-type scale is chosen because it offeres a wide range of constructs on measurement (Rapule, 2007:145). Schnetler’ study (as cited in Rapule, 2007) pointed out that a 5-point Likert-scale is flexible in terms of construction and administration.

1.5.2.4.2. Simple Electric Circuit Conceptual Test (SECCT)

The literature seeks to guide the construction of the test items. A partially open-ended SECCT developed by Küçüközer’s study (as cited in Küçüközer and Demirci (2008:310-311) is used (Appendix 3). A test consisting of 8 multiple-choice type questions is partially open-ended because learners are asked to explain their choices. The test is adopted on the grounds that it has high reliability (r = 0.75) coefficient. This test is modified to pursue the aim and objectives of this study.

The same test items are used in the pre and post-testing. The purpose is to determine whether the conceptual model improved learners’ academic achievement in simple electric circuits. Learners were not fore-warned about the date for the tests (Wesi, 1998). It was done to ensure that learners did not prepare for these tests through rote learning and memorization, as the study aimed at testing for an enduring change.

SECCT is used to ascertain if there are significant differences in learners' scores in electric circuits between the experimental and control groups. The design is also used to find out if there are any significant differences in male and female scores.

The validity of a measurement instrument referred to the extent to which the instrument measures what was supposed to be measured (Kumar, 2005:154; Graziano & Raulin, 2004:90). To establish the validity of these instruments, the researcher constantly asks himself the question: 'Am I measuring what I am suppose to measure?'. That is, the impact the Conceptual Change Model has on learners conceptualisation of electric circuits. The instruments used helps to gathere information on the learners' ability to acquire knowledge relating to electric circuits.

According to Kumar (2005:90) the reliability of the instrument is ensured when the design is such that it consistently yield the same results when characteristics being measured has not changed. It is for this reason that the instruments used in this study are carefully chosen and designed to measure exactly what they intend to measure.

1.5.2.5. Data analysis

The data obtained is analysed using the statistical services of North-West University (Potchefstroom campus). The inferential and descriptive statistics (Welman and Kruger, 1999) is used to analyse the data. Descriptive statistics (frequency distributions, central tendency and variability) is used to analyse the questionnaire. This assisted the researcher, before the intervention, to ensure that the groups start off with similar understanding of the topic.

The inferential staststic, ANOVA and t-test statistic (Baser, 2006a) is used after the intervention, to investigate the significant difference between pre- and post test of the SECCT in the groups. It was further used to determine whether there are no significant differences in learners' (males and females) score in simple electric circuit taught using the CCM. The explanations on the SECCT were analysed using the procedure as outlined by Küçüközer and

Demirci (2008: 304). The analysis of covariance (ANCOVA) using pretest score as covariate measures is perfomed to measure the effect of CCM on learners'scores.

1.5.2.6. Ethical aspects

A request was sent to the HOD Limpopo Province, the district manager, circuit managers, school governing bodies, learners and learners' parents or guardians and educators to ask for permission to conduct the study. It was made clear to the participants that they might withdraw any time from the research. The participants were assured that the information given would be used only for the purposes of the present study (Appendix 2). Their actual names or schools were not used. On request, the feedback would be available to participants on the outcome of the investigation. This study used the self-explanatory participant consent form (Appendix 2) drawn up by Struwig & Stead (2004:68).

1.5.2.7. Data collection procedure

The questionnaire (Appendix 3) is given to the two groups a week before the intervention session. The questionnaire is conducted on the same day, and at the same time to both groups. The Physical Sciences educators responsible for grade 10 administered this instrument in each of the earmarked schools. The pre-test was given two days after the questionnaire. A similar procedure was followed in conducting the questionnaire.

After a week, the two groups were subjected to the intervention sessions. Two trained educators offered lessons using Traditional Physics Instruction (TPI) to the control group while the reseacher offered lessons based on CCM to the experimental group. A 1 hour lesson was presented per each session, i.e three weeks of interventions. The post-test was administered to the two groups two days after the intervention.

The TPI involved teaching in which teaching-learning activities are teacher-centred. The lecture method dominated in this approach. Rote learning, without understanding science concepts was encouraged. The CCM on the other hand was a learner-centred approach, where the teacher was the mediator, engineer and facillitator of the learning process.

1.6. Contribution of the study

The outcomes of this investigation provides knowledge to stakeholders (circuit managers, subject specialists, Curriculum advisors, teachers and learners) in education so that they become familiar with the new learning tool. The study might assist in the academic improvement of learners who are doing Physical Sciences.

The study eventually provides conceptual knowledge (Rapule, 2007:28-3) to its focused area and diversity in the classroom (diversity in learning style). The liturature indicates that knowlegde of learning styles in the classroom is said to have a powerful influence on the teaching and leraning process (Searson and Dunn, 2001; Kulturel-Konak, Diekison and; Heffler, 2001; Tindal and Hamil, 2003; Kolb and Kolb, 2005). This type of contribution is in line with the new learning dispensation brought by the National Curriculum Statement.

1.7. Division of chapters

- **Chapter 1:** Focuses on the background to the problem, a brief problem analysis, statement of the problem, significance of the study, hypotheses, theoretical framework and study outline.
- **Chapter 2:** Deals with the theoretical framework on conceptual change model, alternative conceptions, learning theories and Intervention stratergy.
- **Chapter 3:** Focuses on the core knowledge on simple electric circuits.
- **Chapter 4:** Entails research design which is informed by the sampling method, instruments, method of collecting and analysing data.
- **Chapter 5:** Findings, analysis and interpretation (discussion) of the data.
- **Chapter 6:** Conclusion and recommendations.

1.8. Summary

The orientative introduction given above meant to give a brief introduction to this study. It vividly outlined the statement of the problem and motivation for conducting this study. The liturature is reviewed to find more information about the topic under investigation. The information from the liturature assists the researcher to coin the aims and objectives of this study. The formulated hypotheses serves as the guiding path for the entire research journey. The choice of the research methodoloy is based on the quantitative nature of this study. The ethical aspects are embeded in the participant's concern form. Finally, chapter division in this study clearly demonstrates the study layout.

The next chapter focuses on the literature review regarding the Conceptual Change Model.

CHAPTER 2

CONCEPTUAL CHANGE MODEL

2.1. **Introduction**

In the previous chapter the problem statement, context, rational of the study and the research questions that guided the study were identified. This chapter outlines the theoretical literature review on conceptual change model and academic performance of grade 10 learners. It provides the layout for understanding the research problem and research aim stated in chapter one. In order to shed light on the complex nature of the relationship between conceptual change and academic performance of grade 10 learners, the learning theories and the alternative conceptions (misconceptions) in simple electric circuits were considered.

2.2. Conceptual Change Model

Posner *et al.,* (1982) maintain that the conceptual change is the outcome of a complex cognitive and social process whereby rational is changed or abandoned the existing conceptions to the widely empirical supported evidence. Chi and Roscoe (2002) consider conceptual change as a repair of misconceptions (miscategorisations of concepts), that is, the reassignment of concepts to correct categories. According to diSessa (2002) conceptual change is the reorganisation of diverse kinds of knowledge into complex system in learners' minds. Vosniadou (2002) views a Conceptual Change Model (CCM) as a process that enabled learners to synthesize model in their minds. In this study the conceptual change would refer to the cognitive restructuring of the existing concept by (Duit & Confrey, 1996:80).

This study adopts the conceptual model due to its predictive and explanatory powers. To understand CCM, a distinction has to be made between abstract and concrete conceptual models. An abstraction conceptual model is the conceptual model that has abstract base domain, for example, mathematical model. A concrete conceptual model is a synthetic representation of the underlying conceptual structure of a target system and it is characterised by its concrete base domain such as concrete objects. In this study a concrete conceptual model, namely CCM is earmarked because it entails the process that improved learning.

Posner, Strike, Hewson & Gertzog (cited in Küçüközer and Kocakülah, 2008:60) used Piaget’s (1929) two terms: ‘assimilation’ and ‘accommodation’ to propose their theory of conceptual change. The literature define assimilation as the fitting of new experiences into existing schemes, whereas accommodation in this context refers to the changing of mental schemes that are unable to explain one’s new experiences (Treagust and Duit, 2008:9; Piaget, 1929). It is clear that new concept is assimilated by the pre-conceptual structure while conceptual structure is accommodated if a learner’s existing concepts contradict the newly learnt concepts.

Posner *et al*., (1982) also used Kuhn’s description of ‘scientific revolution’ (Kuhn, 1970), Lakatos’s notion of ‘theoretical hard core’ (Lakatos, 1970) and Toulmin’s idea of ‘conceptual ecology’ (Toulmin, 1972) to consider the context in which conceptual change occurs. The conceptual ecology is vital to CCM because learner’s conceptual ecology forms a base for a learner to find the new conception intelligible, plausible, and fruitful in a variety of new situations.

The Conceptual Change Theory (Hewson & Hewson, 1992) emphasises that while learner’s pre-conception is losing its status, the new concept is gaining its status, hence it is understood, accepted and became useful to learners. This theory is refined into the six-stage Conceptual Change Model that would provide a framework to improve learning by Stepans (1994). It is sequentially outlined in diagram 2.1 below (Stepans *et al.*, 1999:141).

The literature points out other models of conceptual change that have been proposed over the years (Carey, 1991; Chinn and Brewer, 1993; Champagne *et al*., 1985). All these models acknowledge that learners’ prio knowledge must become explicit, learners resist change to their preconceived knowledge structure, the process of conceptual change is time consuming and learners must become active participants in the learning process.

The Conceptual Change Model (CCM)

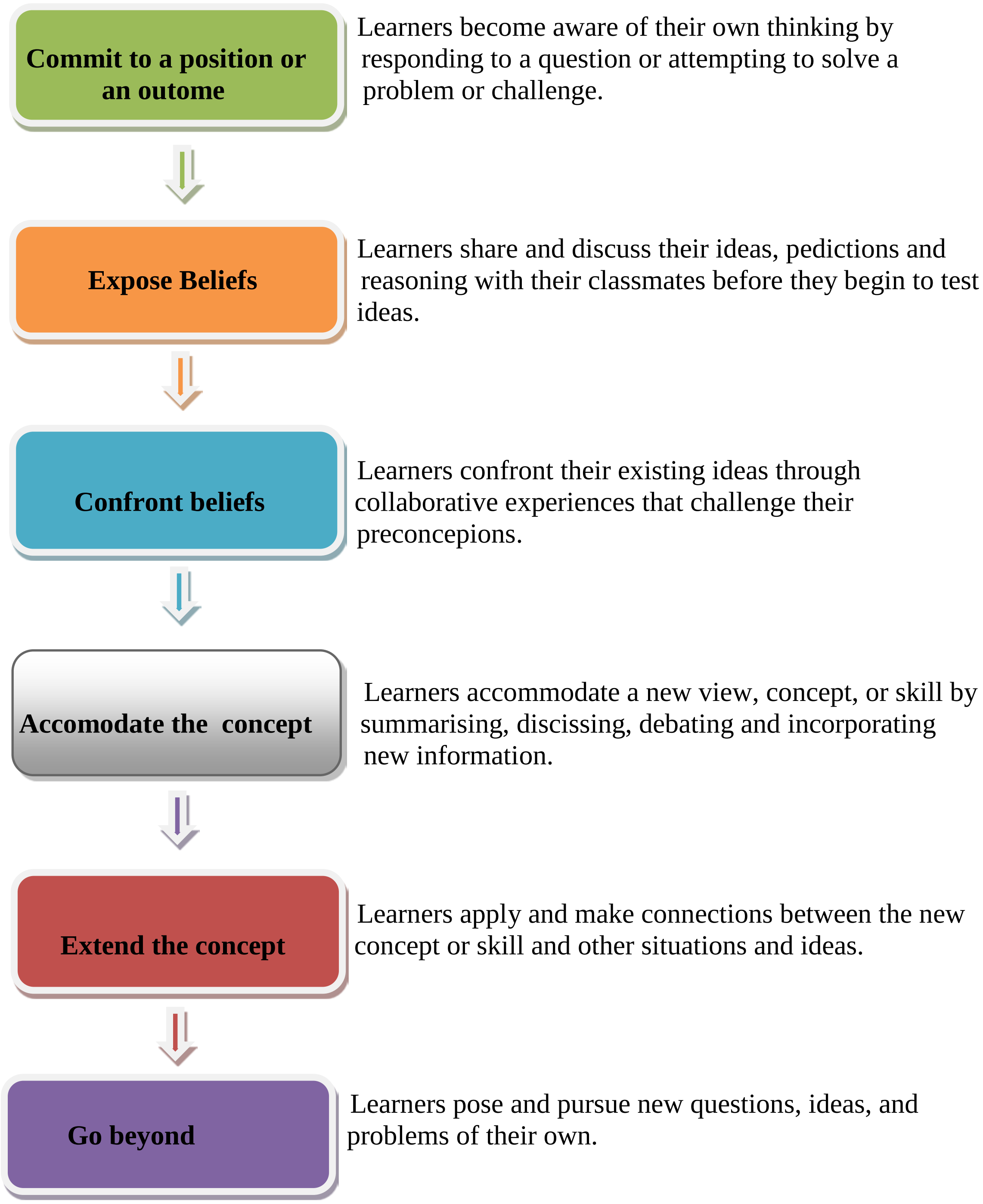


Figure 2.1: The Conceptual Change Model (Stepans *et al.*, 1999: 141).

The CCM is used in this study to inform the learning activities for the classroom intervention. Each learning activity is aliegned to the stages of this model. Learners are made to commit themselves to the lesson outcomes. Learners commitment was achieved by presenting them with a challenging event which invited their thinking. Automatically learners exposed their beliefs by sharing their ideas and predictions about the event.

Hands-on activities conducted through POE assisted them to confront their beliefs. The debates, arguments and discussions that arose, reinforced the accomodation of a new concepts. In the application stage, learners extented the concept. A project given at the end of the topic cemented the learnt concept and assisted them to go beyond (to solve their own problems).

The conceptual change instructional model (Nassbaum and Novick, 1982 cited in Davis, 2001) is used since it supports the six-step of CCM, in the sense that it provides the following teaching stratergies;

- Reveal learners' preconceptions by creating an 'exposing event'. The educator should encourage learners to discuss and evaluate their preconceptions.
- Create a 'discrepant event' to induce conceptual conflict with those preconceptions.
- Ecourage and guide conceptual restructuring. The educator should present a scientific explanation and learners are encouraged to restructure their ideas in order to accommodate the new concepts.

Other instructional stratergies are proposed in order to promote the conceptual understanding and concept change among learners (Kapartzianis, 2012; Trundle and Bell, 2010; Koltsakis and Pierratos, 2006; Kolb, 2000; Duit, 1999; McDermott and Shaffer, 1992; Grayson, 1994) would also be considered when developing learning activities for intervention.

In science teaching literature, little effort is made on how learners may be helped to change their own pre-conceptions during learning process. More emphases is put on how educators could be assisted to minimise learners' misconceptions in the classroomm (Singh, 2010;

Baser and Durmus, 2010; Ates, 2005). This study is committed to challenge learners own misconceptions through the lens of CCM.

The collaborative teaching and POE stratergies are used as main pillars of the CCM. During treatment phase (POE), learners are gaven the opportunity to state their prediction about the event. Learners are able to give reasons to support their predictions. In the hands-on activity sesssions, learners were able to observe the actual scienctific outcomes. The discussions and debates embeded in POE assisted them to explain their results, breaching the discrepancis between their predictions and observatons.

On the other hand, collaborative learning is an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a project (Kollar *et al*., 2006). Anderson (2009) maintains that in a collaborative-transformational learning, learners have the opportunity to converse with peers, present and defend ideas, exchange diverse beliefs, question conceptual frameworks, and be actively engaged. This study adopts three key conditions for effective collaborative learning, namely, group composition, task features, and communication media (Anderson, 2009).

Scott, Asoko & Driver (1991) suggest three levels of pedagogical decision an educator has to make for successful implementation of CCM. Firstly, an educator needs to foster a learning environment which is supportive of conceptual change learning (learning that is characterised by discussions, consideration of alternative viewpoints and arguments). The second level involves the selection of teaching strategies. These strategies serve as a guide for the presentation of the sequence of leaning activities within a particular topic. Lastly, the choice of the specific learning tasks. These levels served as a guide to the educator-researcher in developing the appropriate learning tasks for classroom intervention.

Novak (2002) maintains that learners come to Physical Science classroom with a range of misconceptions. These misconceptions arise from learners' prior experiences and interpretations of information (Sungur, Tekkaya and Geban (cited in Baser, 2006b)). Eryilmaz (2002) and Liégeois *et al.*, (2003) added that misconceptions contribute to the poor academic performance because passive learning environments in traditional instruction do not assist learners to attain conceptual change. The CCM is used to address misconceptions learners have in learning simple electric circuit.

However, Ronen and Eliahu (2000) warn that there are some deep rooted misconceptions that are resistance to change. Hart (2008) maintains that many models of and analogies for electricity have been used, but none of them fully explained all of its aspects. Therefore, how, when and where the model is used also contributes significantly. Hence, the limitations of the classical conceptual change approaches as pinpointed by Duit & Treagust (2003) and Chiu, Chou and Lin (2002) need a careful consideration when using CCM in the classroom setting.

2.3. **Academic performance or achievement**

Mothiba (2007:10) describes academic performance as a measured ability or achievement of a learner in a school subject or particular skill. Santrock (2007:379) views academic performance as an attainment of goals based on motivation from social approval. On the other hand, Mahlatji (2000:29) maintains that academic performance is the attainment of required academic standards with a variety of aspects such as school subjects, qualification and aspects of competence. In this study, academic performance is defined as a degree of understanding science concepts within a school calendar year.

Academic performance is affected by factors such as learning and teaching strategies (Mahlatji (2000:29), learning environment, motivation (Santrock, 2007), self-esteem and self-efficacy (Pervin, 2001:468; Bandura, 1993:120), curriculum design (McKimm, 2007), learners' prior knowledge and misconceptions (Stepans, 2008). In the school setting, the interaction of both internal and external factors also determines learner's task performance.

In Physical Sciences (DoE, 2003a:16; 2011:14) the academic achievement is measured using the following levels.

Table 2.1: Physical Sciences Achievement Levels.

Description	Level	Mark (%)
Outstanding	7	(80 – 100)%
Meritorious	6	(70 – 79)%
Substantial	5	(60 – 69)%
Moderate	4	(50 – 59)%
Adequate	3	(40 – 49)%
Elementary	2	(30 – 39)%
Not Achieved	1	(0 - 29)%

A learner, who obtained level 1, has not made it. Performance corresponding to level 2 and 3 would assist a learner to obtain a certificate. Level 4 academic achievements would help the learner to obtain diploma whereas achievement in level 5 to 7 could make a learner to obtain a bachelor. We all aspire to obtain level 5 to 7 in Physical Sciences.

In this study the academic performance of the Physical Sciences grade 10 learners is informed by the CCM. Therefore, in designing learning activities for this study, the CCM sequential learning tenants in section 2.2 together with the adopted learning theories in section 2.4 was used as guiding pillars.

2.4. **Learning and learning theories**

This section sought to review learning as a means to knowledge construction. Rapule (2007) indicates that a learner must undergo a learning process so as to re-organise her knowledge framework. Kolb (1999) maintains that learning is the process whereby knowledge is created through the transformation of experience. Therefore learning may be defined as a process that allows learners to retain acquired information.

Rapule (2007) maintains that types of learning depend on a particular learning theory to be adopted by the learner. For instance, if ones learning focuses on how learners' behaviour changes over time, that is called behavioural nature. However if one's point of view about learning focuses on the internal process (thinking), then is called cognitive learning. A particular learning theory leads educators and learners to have a good understanding of a pedagogical situation which informs the nature of learning to be unfolded. A science learning and teaching based on these premises may results in good academic performance.

This study adopts and explores the following learning theories in order to pursue its objectives.

2.4.1. **Cognitive learning theory**

According to the cognitive theorists (Schunk, 1991:225; Schultz & Schultz, 1996:453; Vygotsky, 1986:81) learning is considered as the cognitive process that influences the nature of what was learned. This theory was selected on the assumption that it gives learners opportunity to be selective of what they process and learn; to construct the meaning of information in order to formulate their own knowledge and to be actively involved in their learning. It is, therefore, at heart of this theory that meaning of information is constructed by the learner, rather than derived directly from the environment.

The cognitive learning theory has two main processes of learning. Namely, concrete-abstract continuum in which learners perceive new information. That is, in the new situation, some learners prefer to sense and feel their way (concrete experiences) while others prefer to think their way through (abstract conceptualization).

The second dimension is active-reflective continuum; it is how learners process new information. It entails active experimentation (when learners prefer to try things) and reflective observation (learners processing new information by reflecting on it). It is important to note that each individual learner developed a learning style, to perceive and process new information (Heffler, 2001). Therefore a science educator must ensure that the instructional strategies for a particular topic should match the learning styles of learners.

2.4.1.1. **A learner in a cognitive learning style**

The cognitive learning theory attests for teaching and learning to be learner centred **(**Piaget, 1977). Learners take the leading role in their learning. Therefore they should be given an opportunity to organise and structure their learning. According to Schunk (2000:171), this learning theory's context created a didactic environment where learners obtained knowledge for themselves and test the formulated hypothesis. Therefore cognitive learning theory advocated for self-discovery learning and it seems to be in accordance with the kind of the learner envisaged by the National Curriculum Statement (DoE: 2003b).

2.4.1.2. **The role of the teacher in cognitive learning style**

The role of the educator in incorporating the cognitive learning theory to a teaching of Physical Sciences in a classroom setting, is to arrange learning activities in which learners explore, search, manipulate and investigate (Rapule, 2007:70). The educator frequently has to ask learners leading questions which related to their prior knowledge. During lesson presentation, the educator remained a facilitator, engineer and mediator of the cognitive lesson activities. Schunk (2000:205) advised that the cognitive lesson activities might also (for example) be done by supplying worked out examples of physics calculations that vary in order of complexity. This kind of an educator could accelerate the conceptual understanding and at the same time improves the academic performance.

2.4.1.3. **The shortcomings of cognitive theory**

The literature reveals that some of the cognitive learning theory's assumption about learning and teaching does not fully address the complexity of how learners learnt and understood (Schunk, 2000:299). The studies in support of this observation, suggest that constructivist theory of learning is appropriate as it can account for the learning and the development of the learner holistically (Meyer, 2009; Collins, 2002; Jonassen *et al.*, 1999). Vygotsky (1978, 1986) emphasise the importance of knowledge acquisition and skills, which is not actually implied in the cognitive learning theory. Even though these studies noted an important gap in the cognitive learning theory, they acknowledged that cognitive theorists were constructivists, in that they assumed that understanding was not automatic.

2.4.2. **The theory of constructivism**

Learning, according to constructivist theorists (Novodvorsky, 1997:242; Duit and Treagust, 1998:8) is defined as the process where individuals construct new ideas or concepts based on prior knowledge or experiences. According to Rapule (2007:73) the constructivist theory, contends that learning is an active process in which meaning is accomplished on the basis of experiences. Therefore constructivists believe that learner-centric instructional didactic situations will increase the commitment and involvement of self-motivated learners because of their high level of interaction.

This study adopts the theory of constructivism in the sense that the theory of constructivism emphasises learning rather than teaching. The theory encourages and accepts learner autonomy and initiatives, considers learning as a process, bases itself on the principle of cognitive theory. It further emphasises performance and understanding when assessing a learner, considers how learners learn about their learning. It provides learners with the opportunity to construct new knowledge and understanding from authentic experiences.

The constructivism theory is based on three premises; namely, knowledge is constructed in the mind of the learner (Novodvorsky, 1997:242). In this process learners select and transform information, construct hypothesis and make informed decisions. Rapule (2007:72) maintains that this principle implies that learning is a constructive process in which a learner is building a personal interpretation of experience. This principle helped the educator-researcher in selecting appropriate learning activities for this study.

In the second premise of constructivist theory, learners bring with them prior personally constructed knowledge and beliefs that they may be either relevant or not with the scientific concepts (Collins, 2002:9; Novodvorsky, 1997:242; Haney *et al.*, 2003:366). This premise suggests that an educator must consider learners' prior knowledge, whenever a new concept is introduced. According to Wesi (1998:12), personally constructed knowledge base has a tendency of being resistant to teaching and learning. The third premise assumes learning as a long life process (Novodvorsky, 1997:242). This premise suggests that learning is not confined to a specific period in the life of individual. It regards learning as an on-going process.

2.4.2.1. **The role of the teacher in constructivist classroom**

In the constructivist classroom, the educator's role is to prompt and facilitate discussion, to ask questions that will enable learners to actively construct knowledge and be in the position to draw their own conclusions on the subject under discussion. According to Jonassen (1999) the major roles of an educator in supporting learners in constructivist learning environments are modelling, coaching and scaffolding. Educators who create such pedagogical environments within the classroom often provide an authentic context for the task. Driver (cited in Bodzin, Cates, Price and Pratt, 2003) maintains that the constructivist teaching sequence below (figure 2.2) yields a good academic performance.

To enhance the applicability of constructivism and constructivist teaching sequence, the four-steps of constructivist teaching model, 4E (Bodzin *et al.,* 2003) was developed from the Driver's model. Çalik, Ayas, Coll, Ünal and Coştu (2007) confirm many advantages of 4E for efficient and effective teaching of scientific concepts. The model has four phases, namely, eliciting learners' pre-existing ideas, focusing on the target concept, challenging learners' ideas and applying newly constructed ideas to similar situation (Ípek and Çalik, 2008:145). The 4E oscillates well with CCM.

Constructivist teaching cycle

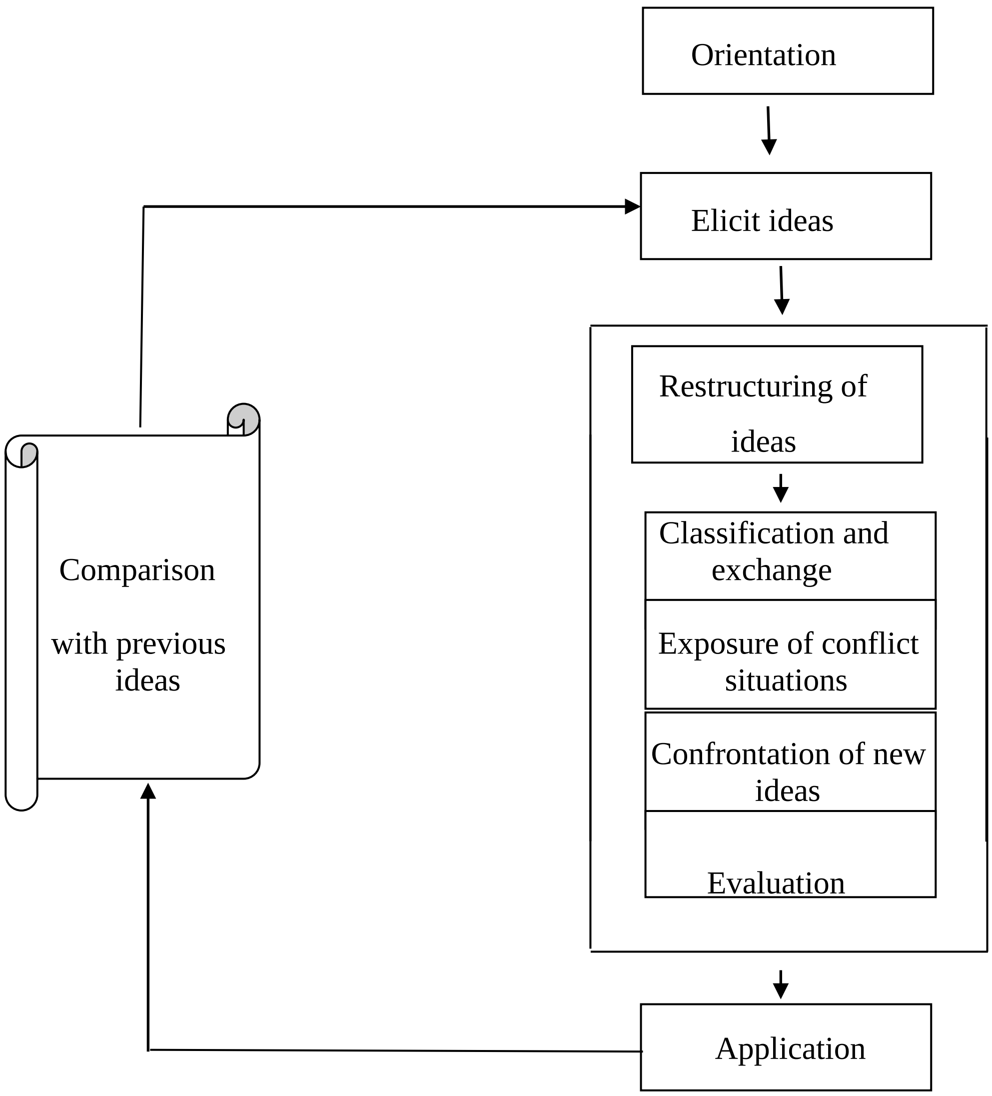


Figure 2.2: The constructivist teaching cycle from Driver (1989).

2.4.2.2. **The constructivist learner**

In the constructivist classroom, the main goal is to promote the cognitive growth for each individual learner. Therefore, it becomes the learners' responsibility to be active participants in the meaning-making process. Teachers cannot force learners to learn, nor can they pour knowledge into learners' head. Learners must learn to classify ideas and negotiate meanings.

Walbert (2011) says that the constructivist learning cycle is designed to promote disequilibrium, argumentation and improve reasoning. This learning cycle which includes three phases, namely, exploration, introduction and application correspond well with the tenants of the Conceptual Change Model.

During exploration phase the teacher attempts to find out ideas student hold about the topic. It is in this phase where learners must ask questions, develop hypotheses and make predictions. Learners are also expected to collect and analyse data so that they can refine their ideas. During the second phase (introduction) learners report their data, describe patterns and share information gained in phase 1. In the final phase, learners apply knowledge gained to new situations. This stage assists learners in making connections with prior knowledge.

The constructivist learner is encouraged in this study because all the learning activities are geared towards active participants in the meaning-making process. The first three stages of CCM (figure 2.1, section 2.2) encompass the exploration phase of the learning cycle. Therefore, the Conceptual Change Model presents a modified version of the constructivist learning cycle.

2.4.2.3. **Critics against the constructivist approach to teaching and learning**

However, the critics have voiced the following arguments against constructivist based teaching and learning. Mayer (2004) argues that the formula constructivism equals to hands-on activity is a formula for educational disaster. His argument is that educators subscribing to this philosophy tend to produce learning materials that require learning to be behaviourally active rather than cognitively active. He recommends the use of guided discovery, a mixture of direct instruction and hands-on activity, rather than pure discovery for promoting constructivist learning.

Kirchner, Sweller and Clark (2006:78) argue that the constructivist description of learning is accurate, but the instructional consequences suggested by this theory do not necessarily follow. They alluded that constructivist theory often accommodates unguided designed instruction that rely on the learners to discover or construct essential information for themselves (Kirchner *et al*., 2006:75). These critics are vital in the sense that a learner with learning problems such as attention deficit or hyperactive disorder may not successfully build a required knowledge base from unguided designed instruction.

The constructivism learning theory, regardless of its limitations, seems to be in line with the type of learner as envisaged by the National Curriculum Statement (DoE, 2003a:13) as its tenants aim to develop learner's abilities of constructing and applying scientific knowledge, while instilling values and attitudes. The understanding of science concepts and academic performance may be achieved through learners active involvement in their learning.

2.5. **Misconceptions in simple electric circuits**

Misconceptions are naive concepts develop by learners originated from the interpretation of ideas gained from, culture, language and everyday experiences (Leura, Otto & Zitzewit, 2005). According to Marin *et al*., (cited in Küçüközer and Demirci, 2008:303) misconceptions are alternative concepts, children's science, spontaneous ideas, spontaneous reasoning or conceptual misunderstanding.

Sherin (2006) avers that misconceptions are the preconceptions or intuitive conceptions held by young people at different age levels. Chi and Roscoe (2002) maintain that misconceptions are miscategorisations of concepts. In this study misconception refers to a conception which is contradictory to, or inconsistent with, the concept as intended by the scientists.

Misconceptions arise from prior experiences and misinterpretations of information, resulting in understanding that is inconsistent with the scientific view (Sugar, Tekkaya & Geban, 2001; Duit, 2002). Therefore it is imperative for instructors to recognise learners prior knowledge in assisting them to attain full conceptual change. However, many studies have warned that some of learners misconceptions (particularly those that emanating from culture) are resistant to change (Wesi, 2003; Ronen & Eliahu, 2000). It is in this context that other approaches that may maximise the effective learning of science concepts have to be sought.

Misconceptions have been the focus area of many studies in Physical Science. The electricity as a theme in physics has no exception. Research studies (Baser and Durmus, 2010; Küçüközer & Demirci, 2008; Ípek and Çalik, 2008; Baser, 2006b; Kuphaldt, 2006; Koltsakis and Pierratos, 2006; Küçüközer, 2003; Engelhardt and Beicher, 2004:100; Senencar & Eryilmaz, 2004; Lee & Law, 2001; Wesi, 1998:45;) have been coducted to investigate learners ideas about simple electric circuits. These studies were conducted in different countries and for different age groups. They revealed that learners (and some teachers) have the following unscientific ideas about simple electric circuits:

- The unipolar model. Learners think that one connecting wire is sufficient between the bulb and the battery (figure 2.3), they do not consider the other polar of the battery.

bulb

battery

Figure 2.3: The unipolar model.

The clashing current. They hold a view that current comes from both poles of the battery, when they collide on the bulb (figure 2.4), the bulb gives light. (Engelhardt and Beicher, 2004:100)

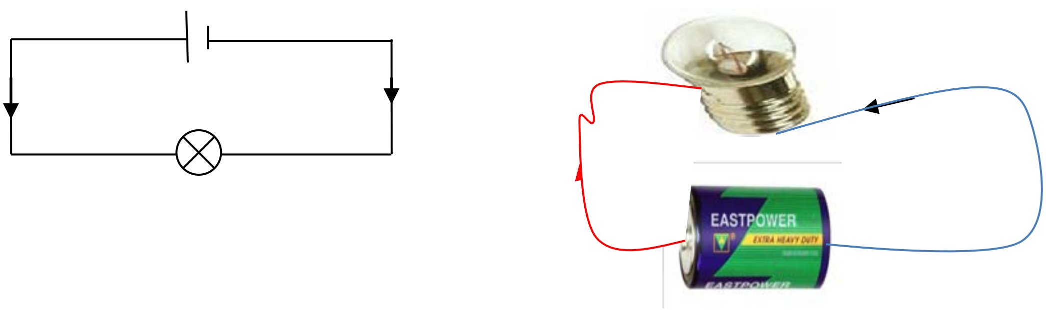


Figure 2.4: The clashing current model.

➢ The consumer’s model, learners are saying current is consumed by its circuits components, causing it to diminish when it returns to the battery. That is, current strength at X (figure 2.5) is greater than than the current strength at Y.

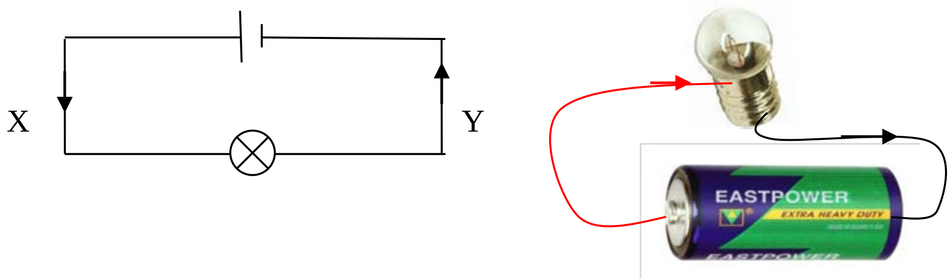


Figure 2.5: The consumer’s model.

➢ Current shared between components in series circuits. Learners assert that since equal components are connected in series (figure 2.6), then current is shared equally amongst the components (bulbs).

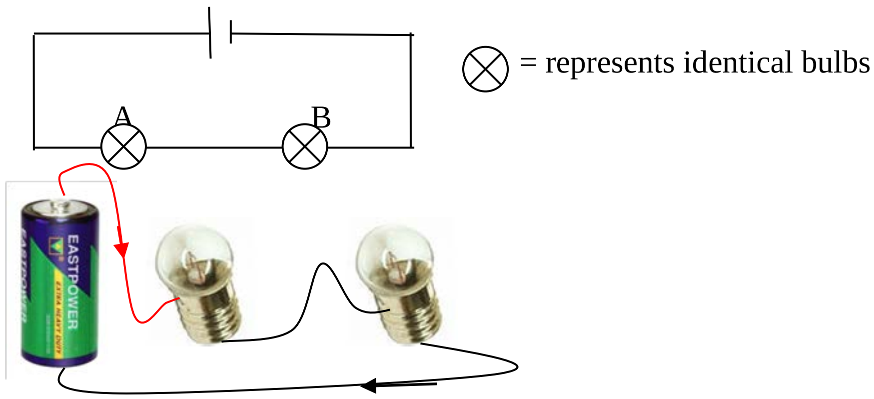


Figure 2.6: The current shared between electrical components in series.

➢ Batteries as the source of costant current. Many learners fail to understand that a battery is a source of energy, it supplies emf (figure 2.7). They think that a battery is a source of current. The markings, 1.5 V and 12 V have no meaning to them.

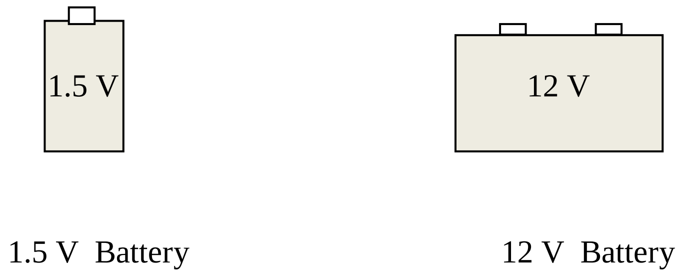


Figure 2.7: Types of batteries.

- Undifferentiated concepts (eg. Potential and potential difference). They usually use the concept of current, energy and potential difference for one another.

- Sequential reasoning (time-dependent model). Learners think that current flows from one component to the other (figure 2.8). That is, current first flow through bulb A then B and lastly through C. They fail to understand that once the switch is closed, the flow of the current is triggered at all points in the circuit (Wesi, 1997:51).

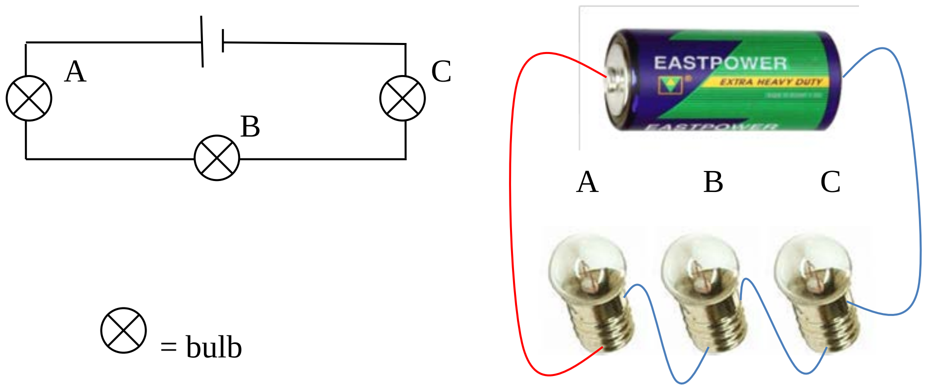


Figure 2.8: The sequential reasoning model.

- Local reasoning. Dealing with branched (parallel) circuits, learners focus their attention upon what happens at one point in a circuit and tend to ignore what happens elsewhere in the circuit. They fail to understand, for example, in figure 2.9, that total current divides at point X and further divides at point Y, and that the current through A equals the curent that will approach point Y, resulting in current in B and C being equal but less than that of A.

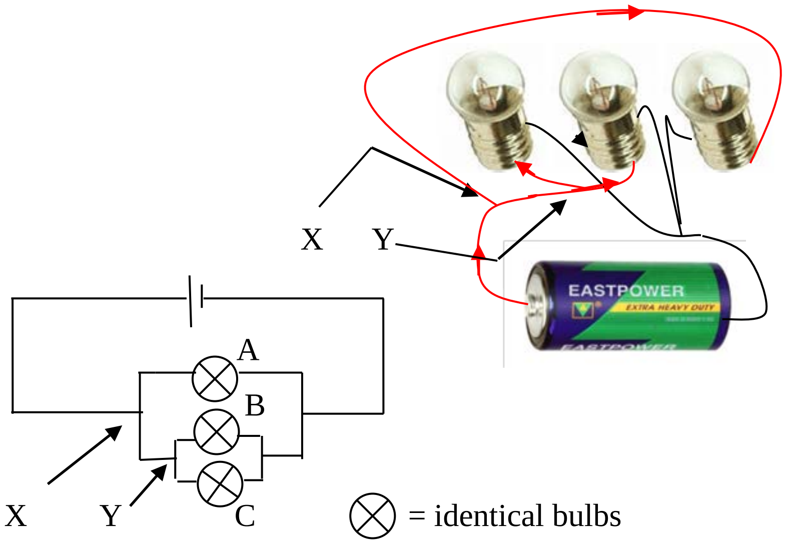


Figure 2.9: The local reasoning model.

- Identification of series and parallel connections. McDermott and Shaffer (1992:999) endorse that learners have difficulties in intepreting the circuit where a single component (bulb) is in series with two components which are connected in parallel. In their study learners think that the single componet (figure 2.9) is in series with one of the parallel combination. That is, bulb A is in series with either bulb B or C.

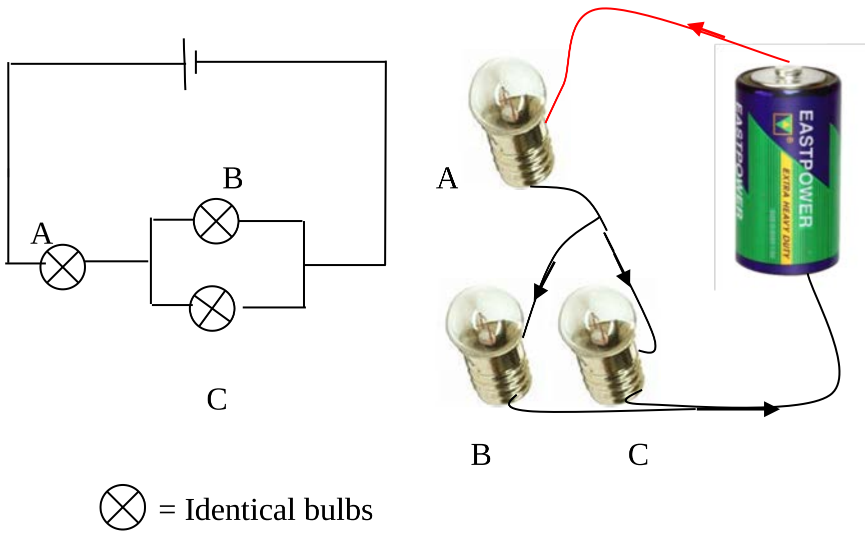


Figure 2.10: The misconception on combination of series and parallel connection.

- A short circuit model (Figure 2.11). Learners believe that a blue wire connecting without a device can be ignored; they think that current shall flow normally, regardless of a short circuit (Engelhardt and Bichner, 2004).

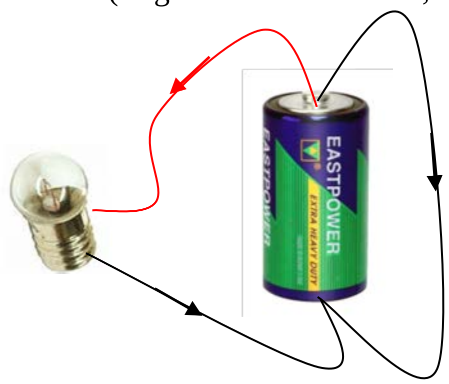


Figure 2.11: Short circuit model.

- Topology error (Engelhardt and Beichner, 2004). Learners consider all resistors lined up in series to be in series, not considering whether there is a junction or not. They also consider resistors lined up in parallel to be in parallel, even if the battery is connected within the branch. These learners think that bulb A and B are connected in series. They fail to observe the similarity in the diagrams below (Figure 2.12).

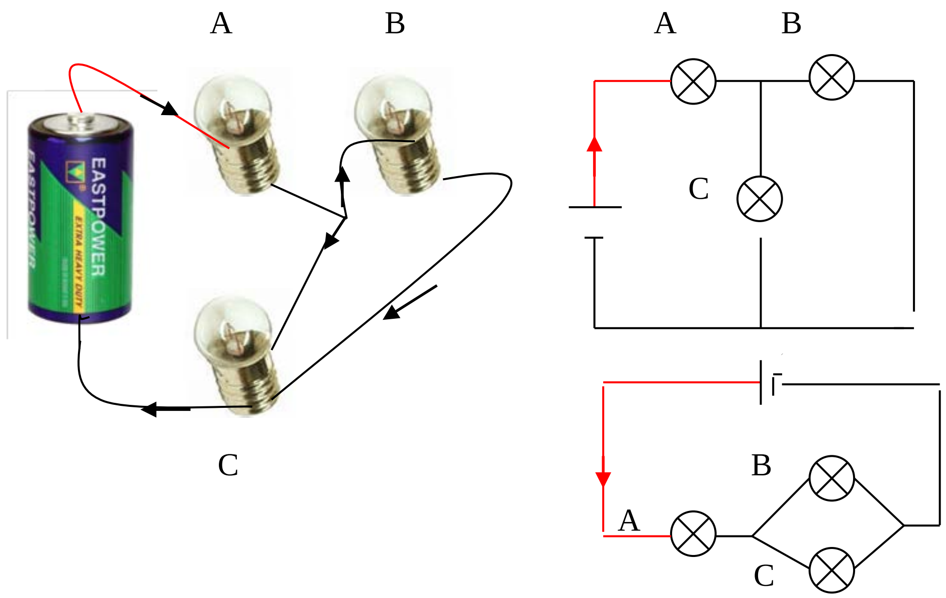


Figure 2.12: Topology.

2.6. **Conclusion**

The review of the literature on the Conceptual Change Model, academic achievement, learning theories and misconception learners and teachers had on simple electric circuits assisted the researcher to have broader information on the research topic. The information gathered helped in developing appropriate learning activities.

The next chapter focused on the in-depth review of literature on core knowledge of simple electric circuits.

CHAPTER 3

CORE KNOWLEDGE ON SIMPLE ELECTRIC CIRCUIT

3.1. **Introduction**

The chapter intends to review the literature on core knowledge of simple electric circuits. In this chapter the electric concepts are not necessarily presented in the same sequence as they are in school text books. The emphasis is on areas (concepts) that pose a challenge to both learners and educators. The special attention is given to the core concepts (charge, electric field, potential difference, emf, current and resistance) in simple electric circuit (Appendix 5) and misconceptions as pointed out in the literature review in chapter 2 of this research.

3.2. **Electric Charge**

The concept "charge" is traced back to the era of Christian Oersted (1777-1851) and Michael Faraday (1791-1867) who made discoveries on the generation of electricity using coal, oil or water powered power station. In 1873 James Maxwell (1831-1879) formulated an equation to sum the theory of electricity and magnetism. In 1897 Joseph John Thomson (1856-1940) discovered electron which led to the explanation of electricity using the nature of atom. In 1906 Robert Millikan (1868-1953), with his famous oil drop experiment, determines the magnitude of a charge to be -1.6×10^{-19} C. The electron (FET) is then regarded as the most elementary charge carrier. It must be emphasised that electron is not a charge.

Wesi (2003:11) maintains that a charge cannot be isolated nor made visible. Charge is the elementary particle of the matter and it is associated with electrons, protons and neutrons. Charges on a charged object may be measured by an instrument called electrometer and its SI units are Coulomb (C). The symbol used to denote a charge is Q or q. An object can be charged negatively (by acquiring negative or positive charges or by loosing negative charges), hence the two types of charges are negative charges and positive charges.

An electric field exists around the electrical charge. Electric field is defined as a region in space within which a unit positive test charge will experience a force when placed in it (Kelder *et a*l., 2007). Electric field can be represented by means of the field lines (imaginary lines in space, drawn in such a way that a tangent to any line at any point gives the direction of the force on a positive test charge when placed at that point). A flow of a positive unit charge, in an electric field, as results of attraction or repulsion electric forces, gives rise to the concept of the 'electric current'.

3.3 **Electric current**

According to Lombard *et al.*, (2008:269) electric current is the rate of a flow of charge. The electric current is a physical quantity denoted by the letter 'I'. The SI unit for the current strength is ampere (A). An ampere is defined as the current in the electric circuit when one coulomb of charge flows past a point in one second (Elferink, *at al*., 2012:80). Broster, Horn and James (2011:158) define ampere (A) as a coulomb per second.

Mathematically, the current strength can be defined as $I = Q/t$, where Q represents a charge and t denotes time (s) taken by the charge (C) to flow in a circuit. For the electric current in a circuit to exist, electrical circuit needs to be constructed. It is important to note that current can only flow in a closed circuit. According to the conventional current model (Wesi, 1998:29), current is considered to be the flow of charges from the positive terminal of the battery to the negative terminal. The model (figure 3.1), clearly puts it, a positive charge flows from a point at higher electrical potential to a point at lower electrical potential. The model makes description of energy transfer in the circuit more explicit. The current strength is measured by ammeter.   This instrument is always connected in series in electric circuit.

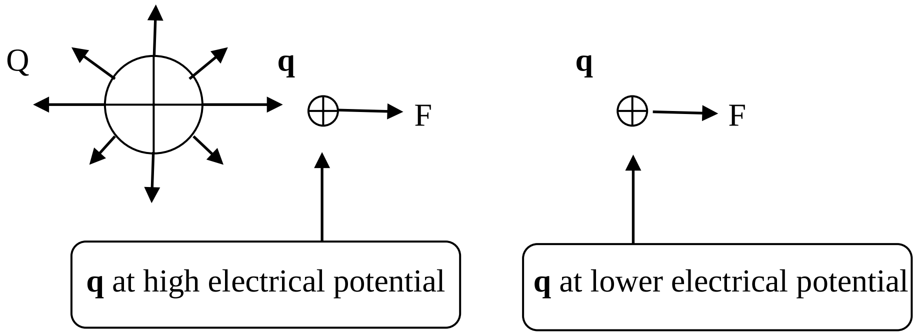


Figure 3.1: The behaviour of a small positive test charge.

The study used a bicycle analogy (Elferink *et al.*, 2012:74) to assist learners to visualize the current flow. In the analogy, the bicycle chain in figure 3.2, illustrates a continuous motion as long as the chain is linked up.

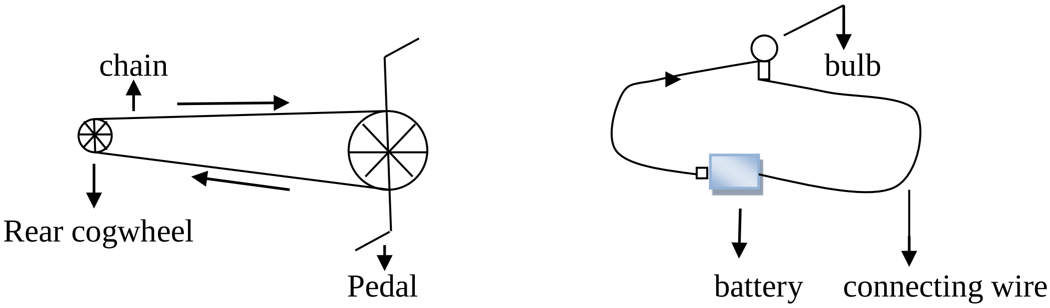


Figure 3.2: An analogy of Bicycle Pedalling System.

In the same way, a flow of electric charge within a conductor continues to flow, only if the circuit remain closed. In the bicycle, the energy supplied at the pedals equals to the energy used up at the back wheel. Similarly the amount of the energy that the battery in a closed electric circuit supplies equals the amount of energy transfer to the bulb (in case only one bulb is connected). Table 3.1 compares a bicycle chain to the electric circuit.

In the bicycle chain analogy, as soon as the pedals are pressed on, the chain becomes tight and this ‘tightness’ in the chain becomes comparable to the energy in the circuit. Comparatively, when the switch is closed, an electromagnetic field is generated outside the connecting wires and this field facilitates energy transfer throughout the circuit almost instantaneously.

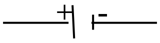
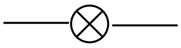
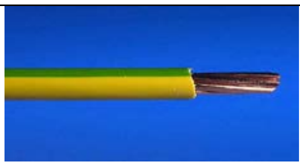
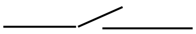
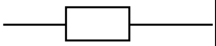
It is very interesting to review the discoveries made by Luigi Galvani (1737-1798) about ‘animal electricity’. He discovered that the leg of a dead frog (Hendricks *et al.*, 2012:157) moved when touched with two different metals. He concluded that the electricity came from the animal. He called that ‘animal electricity’. Three years later, Alessandro Volta (1745-1827) proved him wrong by showing that animal juice in the dead frog acted as an electrolyte.

Table 3.1: The bicycle versus the electric circuit.

	Bicycle	**Electric circuit**
Components	Bicycle’s pedals, chain’s rotation, chain and rear cogwheel centre.	Battery, current, conducting wire, and a bulb.
Source of energy	Chemical energy in the rider’s muscles	Electrical potential energy in the battery’s chemicals.
Energy carriers	The chain moving around the crank and the cassette (or between two cogs).	The charges flowing through the closed circuit.
Energy used	In the back wheel.	In the bulb or resistor connected in the circuit.
Transfer of energy	Possible if the chain is not broken.	Possible when the circuit is not open.
Energy lost	Some energy ‘los’due to friction.	Some energy lost due to friction called resistance

3.4. **Simple Electric Circuit**

Electric circuit is a connection of electrical components. Kapartzianis (2012) maintains that a simple electric circuit is an electric circuit consisting of a battery, connecting wire(s) to serve as a conductor, a switch, and a bulb or any electric device (figure 3.2). The electrical circuit provides a path through which the electrical energy stored in a battery can be utilised by the electrical devises connected to it. The table 3.2 below illustrates some of the electrical devices that may be connected to the electric circuit.

Name of the devise	Picture	Diagram	Usage
1. Battery			Provides energy for charge to flow through the circuit.
2. Bulb			Glows when charge flows (moves) through it.
3. Conductor			Connects all the elements of the circuit together.
4. Switch (open)			Allows a circuit to be open or closed.
5. Resistor			Resists the flow of charge.

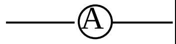
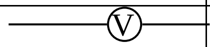
6. Ammeter			Measures the current strength. It is (always) connected in series within a circuit.
7. Voltmeter			Measures the potential difference or emf. It is (always) connected in parallel with the circuit components.

Table 3.2: Basic electrical devises/components.

Whenever the electric circuit is drawn, the diagram of the electric device will be used. It is vital for the learner to get used to these diagrams. The knowledge of how to draw and label these diagrams for various electric devises correctly will enhance the learning of simple electric circuit. Two conditions must be met for current to flow in a circuit. That is,

(a) There must be a closed conducting loop in the external circuit from the high potential, positive terminal, to low potential, negative terminal.

(b) There must be an energy supply capable of creating electric field which will do work on a charge, to move it from a low energy location to a high energy location and thus

3.4.1. **Electrical devices**

(a) Conductor

Conductors are substances through which charges can flow. In metals the electrons are the moving charge carrier, hence the electrons are associated with the negative charges (-) while protons with positive charges (+). Simply put, the current in the metallic conductors is the flow of charges (electrons) while in conducting solutions (electrolytes), the charge carriers are positive and negative ions.

The conductor conducts current as follows: Atoms of a metallic conductor such as copper wire, has delocalized (free to move) electrons. These loosely bound electrons move in all directions throughout the interior of the conductor (figure 3.3).

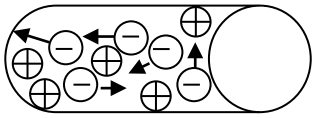


Figure 3.3: The conductor without current flow.

Once the external electric field is applied, all ‘free’ electrons will flow within the conductor in the same direction at the same time (figure 3.4). Conductivity of conductors varies. Platinum is the best while tungsten is the worst conductor. Conductors cannot be charged by rubbing (charging an object in electrostatic) because of the presence of the delocalised electrons. Many learners hold this misconception; think that current can be generated by rubbing a conductor.

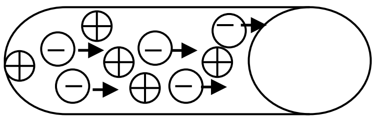
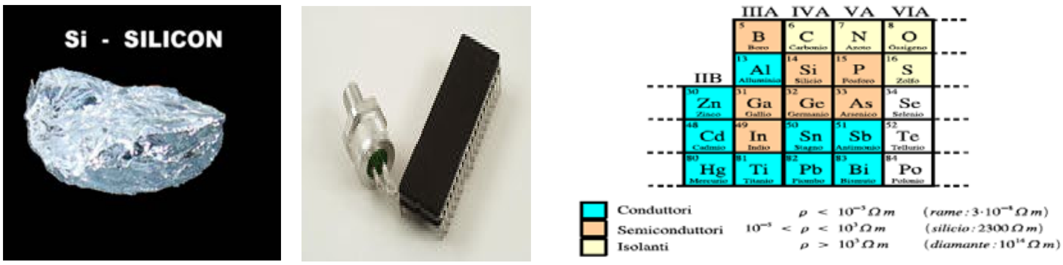


Figure 3.4: The conductor carrying current.

Substances through which charges may not flow are called insulators. In these substances electrons are trimly bound to their nuclei. Insulators such as plastics, are used to prevent leakage of charges, hence the electric wires in home’s electrical appliances are covered with insulating plastic materials.

Semiconductors are conductors between good conductors and insulators. These substances can only allow little amount of charges to flow through them. They are used where limited current is needed. Semiconductor can become a good conductor by doping. During doping process the impurity atoms can donate or accept electrons thereby increasing the conductivity of the semiconductor (Kelder, Govender and Govender, 2007:129). In the *n*-type semiconductor the impurity atoms donate electrons while in the *p*-type semiconductor, the impurity atoms accept electrons.

What is interesting about these two types of the semiconductors is the fact that when they are combined, *p*-*n* junction diode is created. The *p*-*n* junction diode is used to convert alternating current (AC) into direct current. Semiconductors are mostly used in TV, computers, cell phones, digital watches, etc. The common semiconductor is silicon. Others include elements (B, P, Ga, Ge, As, and In) in pink colour as shown in the picture 3.1.

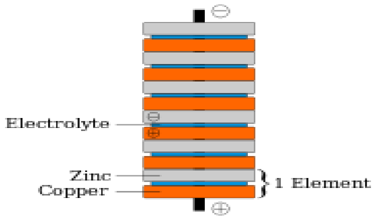


Picture 3.1: Silicon and other semiconductors.

The question is ‘What makes electric charges to flow through the conductor?’ or ‘How can the electric field be generated inside the conductor to make charges to flow?’ The subsequent paragraphs discussed answers to these questions.

(b) Battery

A battery is an electrical device containing chemicals with electrical potential energy. In 1800 Alessandro Volta (photograph 3.1) invented the first battery. His battery was 27 cm high. The model below depicts his battery.

Photograph 3.1: Alessandro Volt (1745-1827).

The battery does not contain current, as many learners put it (section 2.5), but contains chemicals with chemical energy stored in them. When the battery is connected in a circuit, an electrochemical reaction takes place in the battery. Chemical potential energy is converted into electrical potential energy. The potential energy of charges at the positive terminal is higher than at the negative terminal. The difference in the potential energies between these two points (terminals) creates the electric field inside the conductor.

The battery supplies the charges with the electrical energy. The electric devices will use the energy, which changes into another form, for example, heat and light in the case of a bulb.

It must be noted that the current, which is the flow of charges, does not change as the charge flows through the circuit. What changes from one form to the other is the energy. Most learners hold this misconception (consumption model, section 2.5). They think that current before the device, is more than the current after the device. Reasoning that some of the current has been used up (consumed) by the device.

To emphasise the concept of the potential difference, Wesi (1998:26) analogically demonstrates similarity of falling stone due to the difference in the gravitational potential energy and that of a moving charge due to the difference in the electric potential between two points (battery's terminals). He calls these phenomena 'gravitational tension' and 'electric tension'.

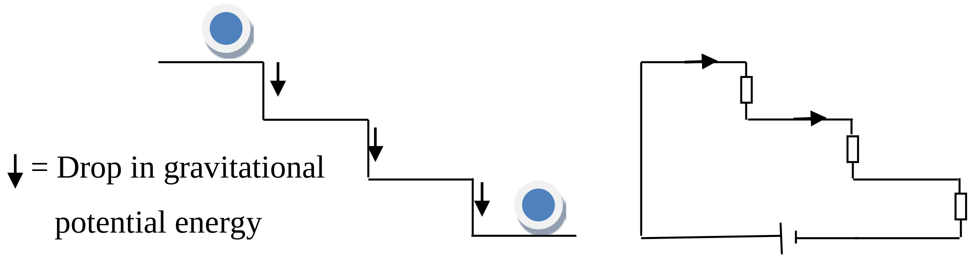
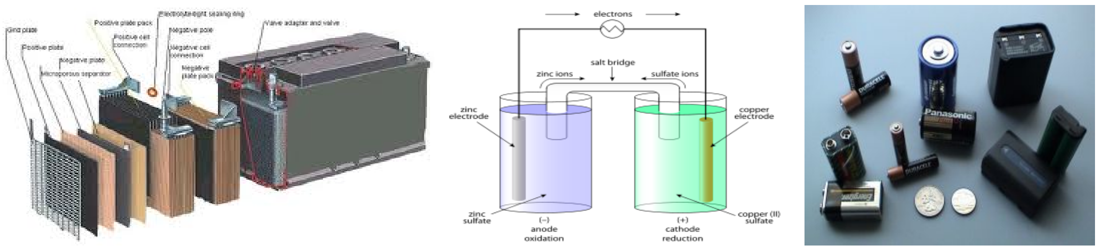


Figure 3.5: The potential drop

The instrument to measure the electric potential difference across the terminal of the battery or any electric device is called the voltmeter (table 3.2, device No. 7). Its reading gives the electric energy that is transferred to the circuit component. For example, 12 V = 12 $J.C^{-1}$ means 12 Joules of energy is to be transferred to every charge that has to move when the battery is in operation. Batteries come with different sizes and shapes (picture 3.2, a – c). They also differ with capacity (the amount of the chemical potential energy they can store).



(a) 12 dc battery (b) Electrochemical cell (c) Types of batteries

Picture 3.2: Batteries.

The energy the battery supply may be increased by connecting more batteries in series (figure 3.5, a). Batteries connected in this fashion do not last long. If batteries of the same voltage are connected in parallel (figure 3.5, b), then they last for longer period, but this type of connection does not increase the current in the circuit.

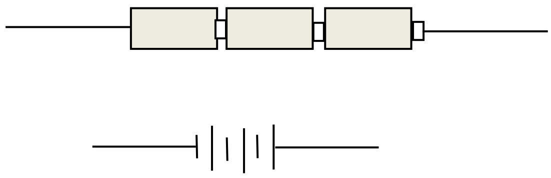


Figure 3.6 (a): Batteries in series.

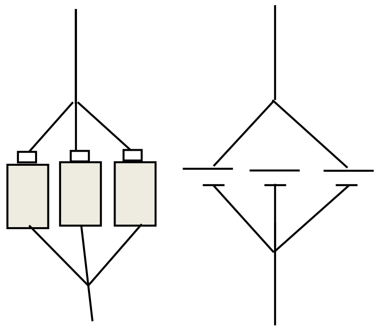
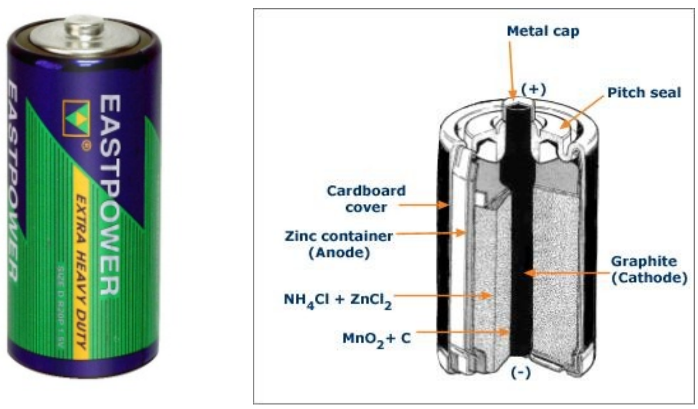


Figure 3.6 (b): Batteries in parallel.

There are two main types of batteries, namely, primary and secondary batteries. Primary battery is any kind of batteries in which the electrochemical reaction is not reversible, rendering the battery non-rechargeable. The Daniell battery (the battery which was invented in 1836 by an English chemist and physicit, John Frderick Daniel (1790 – 1845)) is the example of a primary battery (picture 3.3).



Picture 3.3: The Dry Cell (battery).

These batteries are disposable batteries, which are designed to be used once and discarded. They are called dry cells/batteries because the chemicals are in the form of moist paste. The table below presents the summary on the types, properties and uses of primary batteries.

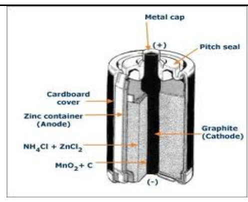
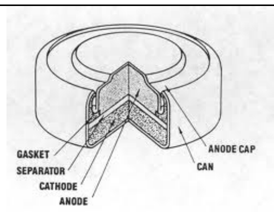
Type	Properties	Uses	Picture
Dry battery	Common, low cost	Torches, radio, toys, etc	
Alkali dry battery	Common, high working ability, high selling price	Most popular, many uses, including toys, torches, etc	
Mercury dry battery	High capacity, good shelf life	Hearing aids, Photography, calculators, etc.	
Lithium dry battery	High capacity, high energy density, long life span, large temperature range	Utility meters, medical electronics, memory circuits, etc.	

Table 3.3: Primary batteries.

On the other hand secondary batteries (rechargeable batteries), are designed to be recharged (by applying electric current, which reverses the chemical reactions that occur during its use) and used multiple times (picture 2.3).

Picture 3.4: Rechargeable (secondary) batteries.

Some batteries contains strong acids, mercury or strong alkaline, therefore learners must be cautioned as these substances are harmful. These substances are poisonous when swallowed. Inhaling too much mercury fumes may even result in death. Discharging (Short circuiting) the battery rapidly can make it explode. The material used to make most 12 Volts batteries (car battery) are not environmental friendly (plastic like, lead) hence biogradable and there is always danger that acid can be spilled. Battery life can be extended by storing the batteries at a low temperature, as in a refrigerator or freezer, which slows the chemical reactions in the battery.

The battery can be created by inserting two electrodes made of different metals into a lemon fruit, potato, (Hendricks *et al*., 2012:158; Grayson *et al*., 2011), and generate small amounts of electricity. Sakal (2007) maintains that the "Two-potato clocks", wired in series to form a battery may have enough voltage to power a digital clock. The picture below depicts the “clock”.

Picture 3.5: Homemade battery adapted from (Sakal, 2007).

Sakal (2007) develops a biological battery that generates electricity from sugar in a way that is similar to the processes observed in living organisms. The battery generates electricity through the use of enzymes that break down carbohydrates, which are, in essence, sugar. Bio battery has a great potential as a recent generating energy device. Diagram 3.1 and picture 3.6 below show the bio battery mechanism and bio battery respectively. However Olive (2012:278) warns that the homemade cells of this kind (picture 3.5) are of no real practical use, because they produce far less energy per charge.

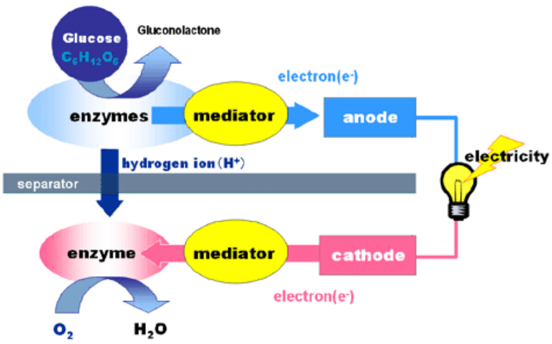
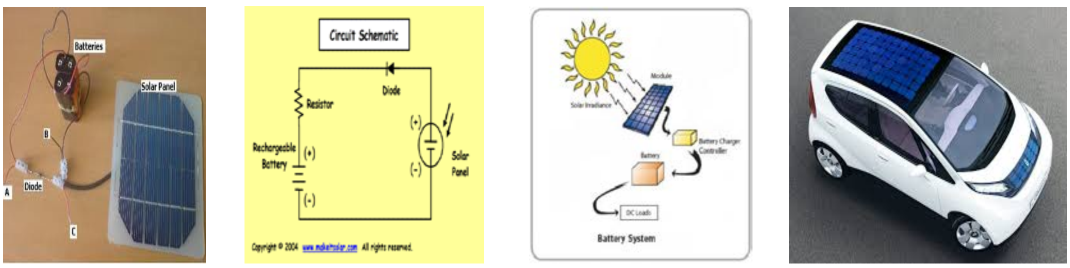


Diagram 3.1: The bio battery mechanism.

Picture 3.6: The bio battery.

In 1954 Gerald Pearson (1942 - 1984), Calvin Fuller (1902 - 1994) and Daryl Chapin (1906-1995) invented the first solar battery. A solar battery (solar panel) converts the sun's energy (solar energy) to electricity. The generated electric current is then stored into any energy collecting device like a rechargeable battery as electrical potential energy (picture 3.4).



Picture 3.7: The solar (cells) battery.

The easy with which the solar energy is stored makes it efficient and sufficient to be used in multiple forms even after sunset. For example, solar cars depend on photovoltaic (PV) cells to convert sunlight into electricity. When sunlight (photons) strikes PV cells, they excite electrons and allow them to flow (generating an electrical current). These cells are made of semiconductor materials such as silicon and alloys of indium, gallium and nitrogen. Therefore solar battery provides sustainable energy resource for the future.

(c) Electric bulb and resistors

The first electric light was made in 1800 by an English scientist, Humphrey Davy (1778-1829). Later, in 1860 the English physicist Sir Joseph Wilson Swan (1828-1914) devised a practical, long-lasting electric light. In 1878, he demonstrated his new electric lamps in Newcastle.

In 1879, the inventor Thomas Alva Edison (1847-1931) experimented with thousands of different filaments to find the right materials to glow well and be long-lasting. Edison eventually produced a bulb that could glow for over 1500 hours. Lewis Howard Latimer (1848-1928) improved the bulb by inventing a carbon filament. In 1903, Willis R. Whitney (1868-1958) invented a treatment for the filament so that it wouldn't darken the inside of the bulb as it glowed. In 1910, William David Coolidge (1873-1975) invented a tungsten filament which lasted even longer than the older filaments.

Electric bulb is an electric device which when connected in a circuit gives light. A light bulb has a resistor (a fine wire or filament) made of a metal called tungsten (Broster and James, 2008:78). The filament is made of tungsten because tungsten has high melting point (figure 3.7). In high temperatures tungsten oxidises (reacts with oxygen) quickly and breaks. To prevent this from happening, the bulb manufacturer encloses the filament in a glass bulb and fills it with unreactive gases such as argon and nitrogen. The filament is attached to two wires. One wire is connected to the ribbed side of the bulb while the other wire is connected to the bottom base of the bulb. The grooved edge and the bottom base are separated by an insulating material.

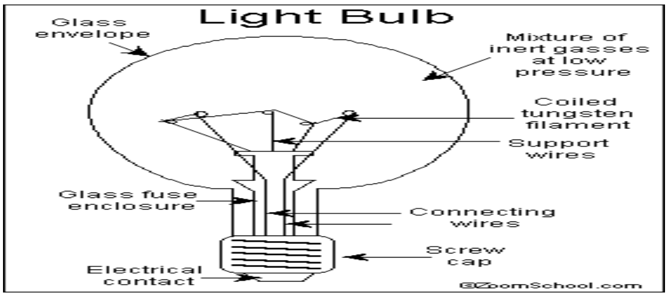


Figure 3.7: The anatomy of light bulb adopted from EnchantedLearning.com.

When the bulb is switched on, this filament become white hot and radiates light. The energy output of the filament in the form of light is less than 10%; the rest is in the form of heat. The brightness of the bulb is associated with the power (the amount of energy transferred to a bulb per unit time) of the bulb.

Picture 3.8 (a): Fluorescent tube.

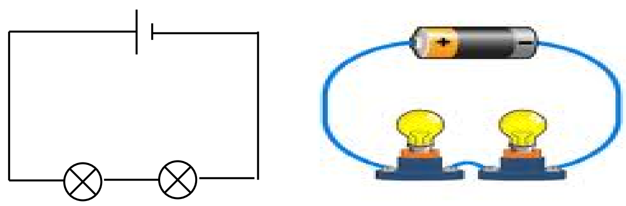
Picture 3.8 (b): Energy-saving bulbs.

The research has shown that the fluorescent tube lights are much more efficient than filament light bulbs (Siyavula *et al*., 2012:283). The recent energy-saving bulbs, even though they are much smaller, work on the same principle as fluorescent tubes.

When bulbs are connected in series (figure 3.8, a) the resistance increases, the current in the circuit decreases and the energy is reduced, as the results the brightness of the bulbs will be the same but dimmer. Two bulbs in series with one battery will last longer than two similar bulbs in parallel with one battery. If the voltmeter readings are taken across each bulb, while those bulbs are in series, then the sum of the potential difference across the individual bulb will be equals to the potential difference across the terminals of the battery. We say the resistors in series are the potential dividers.

The bulbs connected in parallel increase (figure 3.8, b) the total current in the circuit. The electric bulbs of the same voltage connected in parallel do not utilise more energy. Bulbs connect in this way have the same brightness, all of them become brighter. Parallel connection of electric devices reduces the resistance of the circuit. Therefore, we say resistors in parallel are current dividers. Simply put, when current arrives at the branch, divides. The device with high resistance will get less current, while the one with low resistance will allow more current through it.

Bulbs in series **Bulbs in parallel**



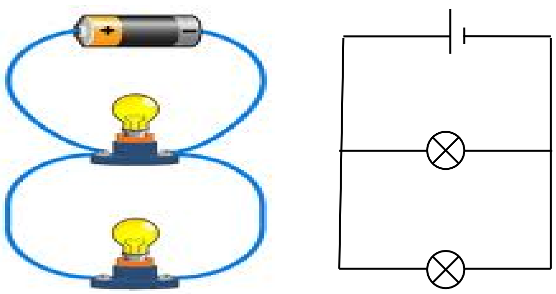


Figure 3.8 (a): Series circuit. Figure 3.8 (b) Parallel circuit.

The resistor is also an electric device. It is used to slow down the flow of current or to regulate the flow of current for a particular device. They differ in resistance. According to Wesi (1998:33) the resistance may be defined as the number of volts needed to drive one ampere of current through the conductor (electric device such as a bulb). Hendricks *et al*., (2012:157) defines the resistance as a measure of the difficulty an electric charge experiences when flows through a given material. The SI unit of resistance is Ohm (Ω). This SI unit was named after Italian physicist, George Ohm (1789-1854), his photograph is shown below.

Photograph 3.2: George Ohms (1789-1854).

Ohm equals one volt per ampere, 1 Ω = 1V/A (Young, 1992:720). In other words, the ratio of V to I for a particular conductor is called resistance (R = V/I). The relationship of V and I is termed Ohm's law (the ratio of the potential difference is directly proportional to the current strength, provided the physical conditions (temperature, tension, shape changes) of the conductor remain constant.

Ohm's law can be illustrated graphically as in figure 3.9. The potential difference becomes the independent variable while current strength is dependent variable. The control variables are temperature, tension, bending, and shape changes of the conductor. The temperature is the most important variable to be controlled.

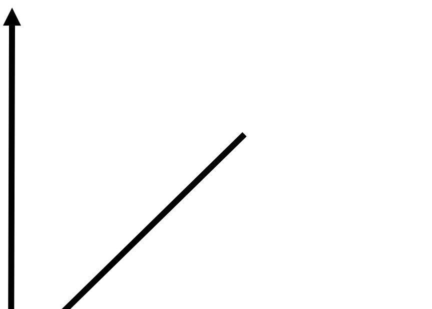
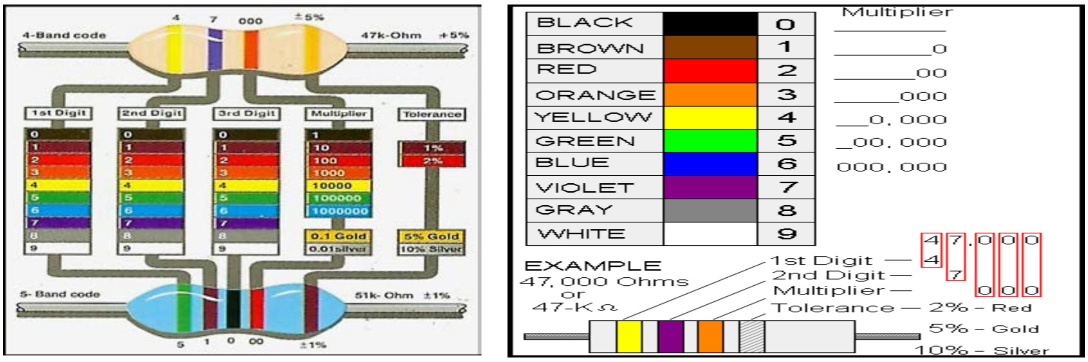


Figure 3.9: The relationship between the potential difference and current strength.

The slope or gradient of V/I graph above signifies the resistance of the conductor. The graph reveals that V and I are directly proportional to each other. It has been established through experiment that the following four factors may affect the resistance of the conductor.

- The type of the conductor used: It is already discussed in section 2.6.3.1 (a) that materials constituting a conductor differ; these make some materials better conductors than others.
- The length of the conductor: The longer the conductor the more the resistance. This factor compels Eskom to use transforms (step-up), when transporting current over a longer distance.
- The thickness of the conductor: The thinner the conductor, the more the resistance. The use of thicker conductors minimises the resistance.
- The temperature of the conductor: The higher the temperature of the conductor, the more is the resistance. People who wires houses and cars, make use of wires with different thickness depending on the electric component to be supplied. In the house wires supplying current to bulbs differ in thickness from those that supply the plugs. These wires (to plugs and light) differ in thickness with those that supplies the stoves.

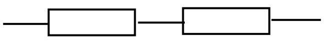
Internal resistance (r) is the resistance within the electrical device. The battery is one of those devices that exhibit the internal resistance when the charge passes through it. In facts, all conductors do have internal resistance. When such resistance is too high in the battery, we normally say the battery is flat.

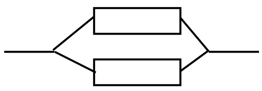


Picture 3.9: Colour coding resistor.

The filament of the bulb acts as a resistor, it has a resistance. Its high resistance results in electrical energy transforming to light and heat energy as current passes through it. The colour codes (picture 3.9) on the resistor assist us to determine its resistance without measuring instruments. Tolerance is always given by the colour code which is far from others. Resistors can be connected in series (figure 3.10, a) or in parallel (figure 3.10, b) in a circuit.

Resistors in series **Resistors in parallel**

(a) 

(b) 

$R = r_1 + r_2$

$1/R = 1/r_1 + 1/r_2$

Figure 3.10: Resistors connected in series and parallel.

There are other electrical devices such as capacitor, conductance, fuse, LED, etc., that are not discussed here because this study is confined to simple electric circuit (figure 3.11). The simple electric circuit is very important vehicle through which the concept of energy and power may be discussed.

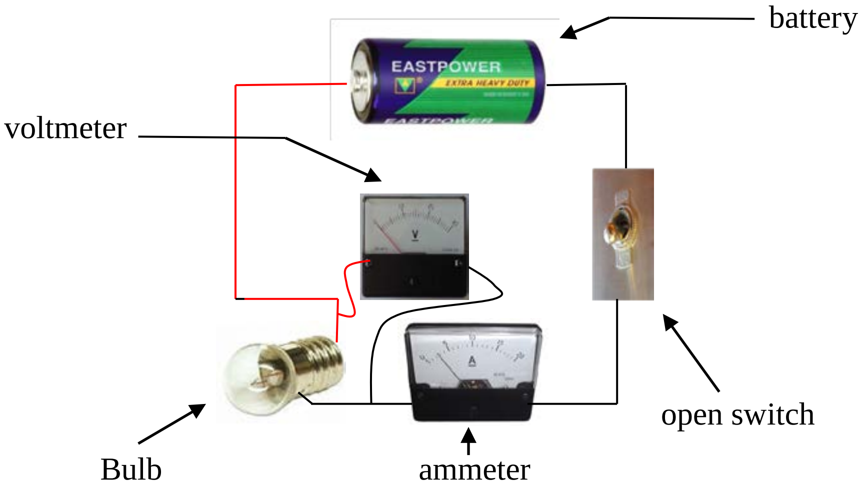


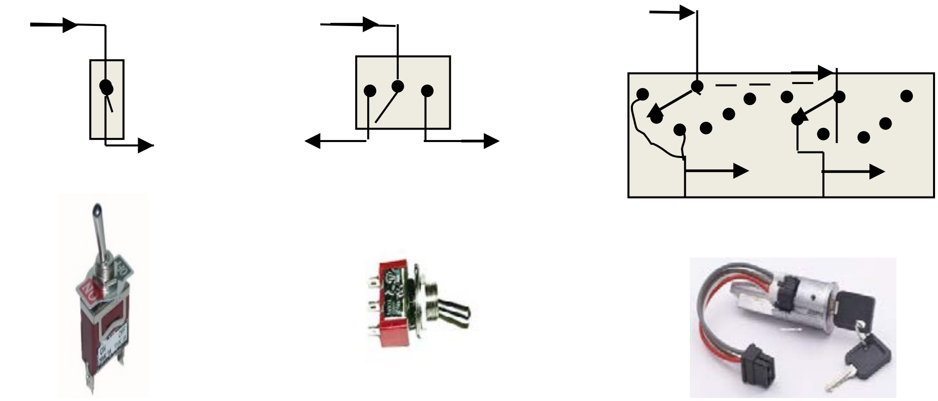
Figure 3.11: Simple dc electric circuit.

Simple (dc) electric circuit (figure 3.11) forms the foundation in understanding the L-R, L-C and L-R-C circuits. These circuits are associated with the alternating current (ac) model.

(d) The switch

The switch is one of the control electric devices which are used to ‘turn off’ or ‘turn on’ the current flow in an electric circuit. Other control devices include relays, solenoids, capacitors, diodes and transistors. These devices are needed to start, stop and redirect the current in the electric circuit. Some require physical operation while others operates with electromagnetism.

A switch is the most common control device used in simple dc electric circuit. They are described by number of poles (number of input circuit terminals) and throws (number of output circuit terminals). There are three popular types of simple switches, namely, SPST (single-pole, single-throw), SPDP (single-pole, double-throw), MPMT (multiple-pole, multiple-throw) as shown in figure 3.12.



a) SPST switch (b) SPDT Switch (c) MPMT switch

Figure 3.12: Types of switches.

The SPST switch is the simplest type. This switch is in the form of ‘hinged pawl’ or ‘knife blade’. It either ‘completes’ or ‘breaks’ the circuit. The SPDT switch is similar to the one controlling the headlamps of a car, to a high beam (bright) or low beam (dim). MPMT switch on the other hand, supply different sets of output contacts with current. Ignition switch of a car is an example of this type. The SPST type is used in this study.

3.4.2. **The Potential, potential difference and the emf**

According to Young (1992:662) the potential is potential energy (U) per unit charge. Therefore the potential (V) at any point in an electric field is defined as the potential energy per unit charge associated with the test charge (q) at that point. Mathematically, it is defined as $U = qV$. In the electric circuit analysis, potential is called voltage.

The amount of energy that a battery can supply to one coulomb of charge passing through it is called emf of the battery. The term emf refers to the ‘electromotive force’. Electromotive force was later discarded after realising that it does not describe the actual situation, but its abbreviation was retained. The emf is measured in volts. It is worth to associates emf with the energy gained by each coulomb of charge passing through the battery. Simply put, emf is the voltages across the battery when the switch is open (the battery in not in use). It is also described by the sum of the voltage in the external circuit pus the ‘lost volts’. That is, Emf = terminal voltage + lost volts (emf = IR + Ir)

The terminal voltage equals the total potential difference in the external circuit whereas the lost volts equal the potential drop caused by the internal resistance of the battery.

The potential difference is the difference in potential energies between any two points in the electric circuit. It is measured in volts. It is mathematically described as V = IR. Potential difference is measured across an electrical device with a voltmeter when the switch is closed. Grussendrorff *et al.*, (2005:26) maintained that voltmeter has high resistance and it does not affect the current flow when connected across the component. Many learners find difficulties in differentiating these two concepts, namely, potential difference and emf. They use them interchangeably; hence demonstrate the misconception of ‘undifferentiated concepts’.

A linear model (figure 3.13) for the learning and teaching of emf and potential difference as suggested by Young (1992:726) and Smith & Vreken (cited in Wesi, 1998: 37) proved to be a very useful model in dispelling misconceptions associated with these concepts. This model will be incorporated in this study for the learning of these concepts.

The linear model in figure 3.13 consists of an electric circuit (with battery, bulb, buzzer and electric bell) mounted on the lower end of the drawing board. With the switch open, the voltmeter readings of all the points between point X and Y are recorded. The same procedure is repeated with the switch closed. Then both set of voltmeter readings are plotted to obtain similar graphs as depicted below.

The graphs vividly illustrate that when the switch is open or closed, the voltmeter reads 0 V between X and A. In the open circuit, the graph XABY further indicates that the voltmeter reads 9 V= 9 J/C between all points connected to X, from B to Y. Therefore 9 V is the **emf**. When the switch is closed the graph XAB’CDEFHY shows that the voltmeter readings drops from 9V to 8V. The reading of 8V shows the difference in electrical potential energies between the positive and negative terminal of the battery. That is, the potential difference. In essence, these graphs further tell us that the battery has internal resistance, which should account for the lost voltage of 1V.

If we assume the potential to be zero at the negative terminal of the battery, as suggested by both graphs from X to A, then we have a rise in emf from 0V to 9V and a drop Ir in the battery and additional drop IR in the external circuit. In other words, 8J given to each coulomb of charge experiences a drop in 3J, 2J and 3J as the charge passes through the bulb, bell and buzzer respectively.

The information given, further accentuates the differences between the potential difference and the emf, and guides us to consider the potential difference as the energy lost by one coulomb of charge when passing through the electric device while emf as the total energy gained by one coulomb of positive charge passing through the battery.

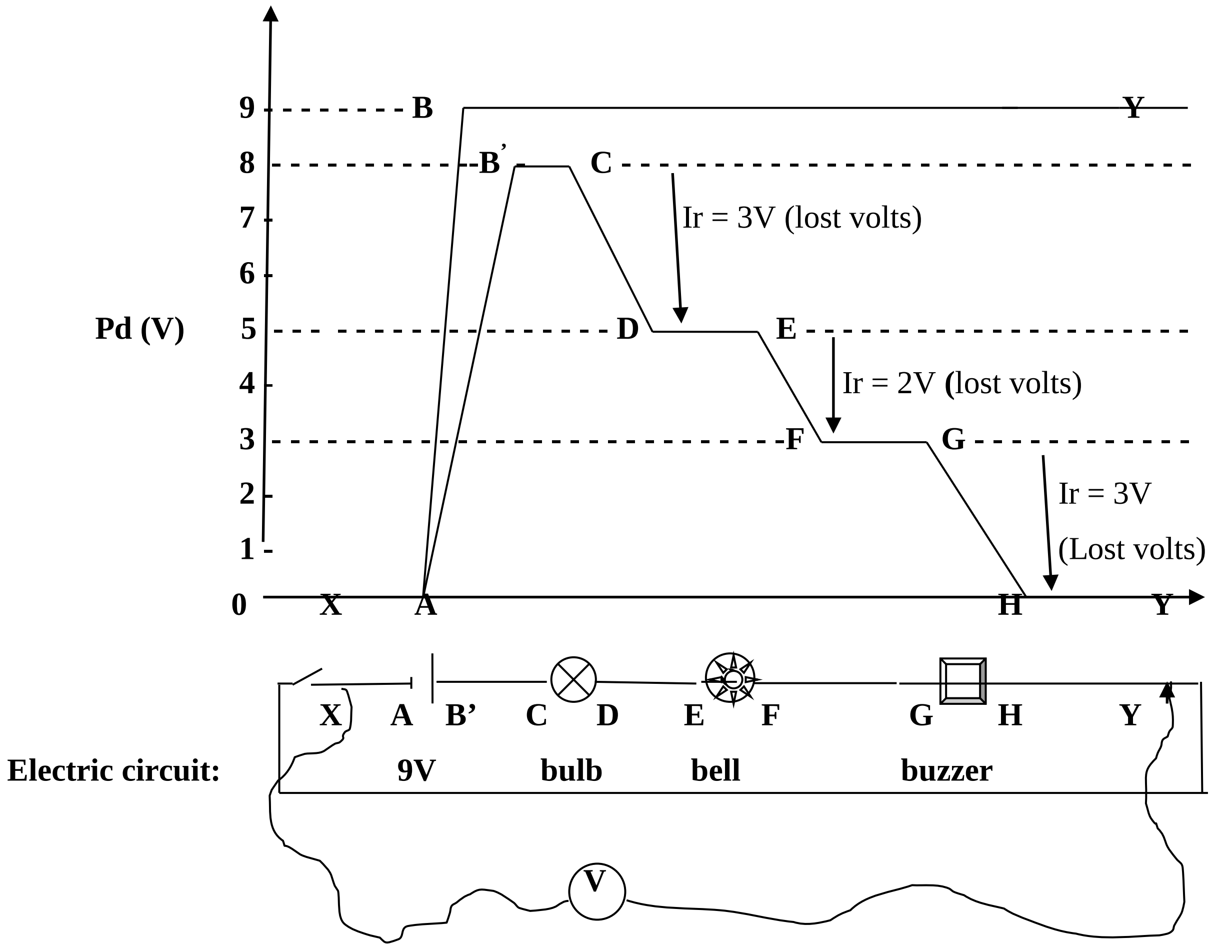


Figure 3.13: The potential rises and drops in the circuit (Young, 1992:726).

The mind-map below summarises this chapter. It shows how the electric circuits' concepts relate each other. One can clearly see from the diagram that the main physical quantities in the electric circuits are current and potential difference (Smith, Botha and De Beer, 2004:121).

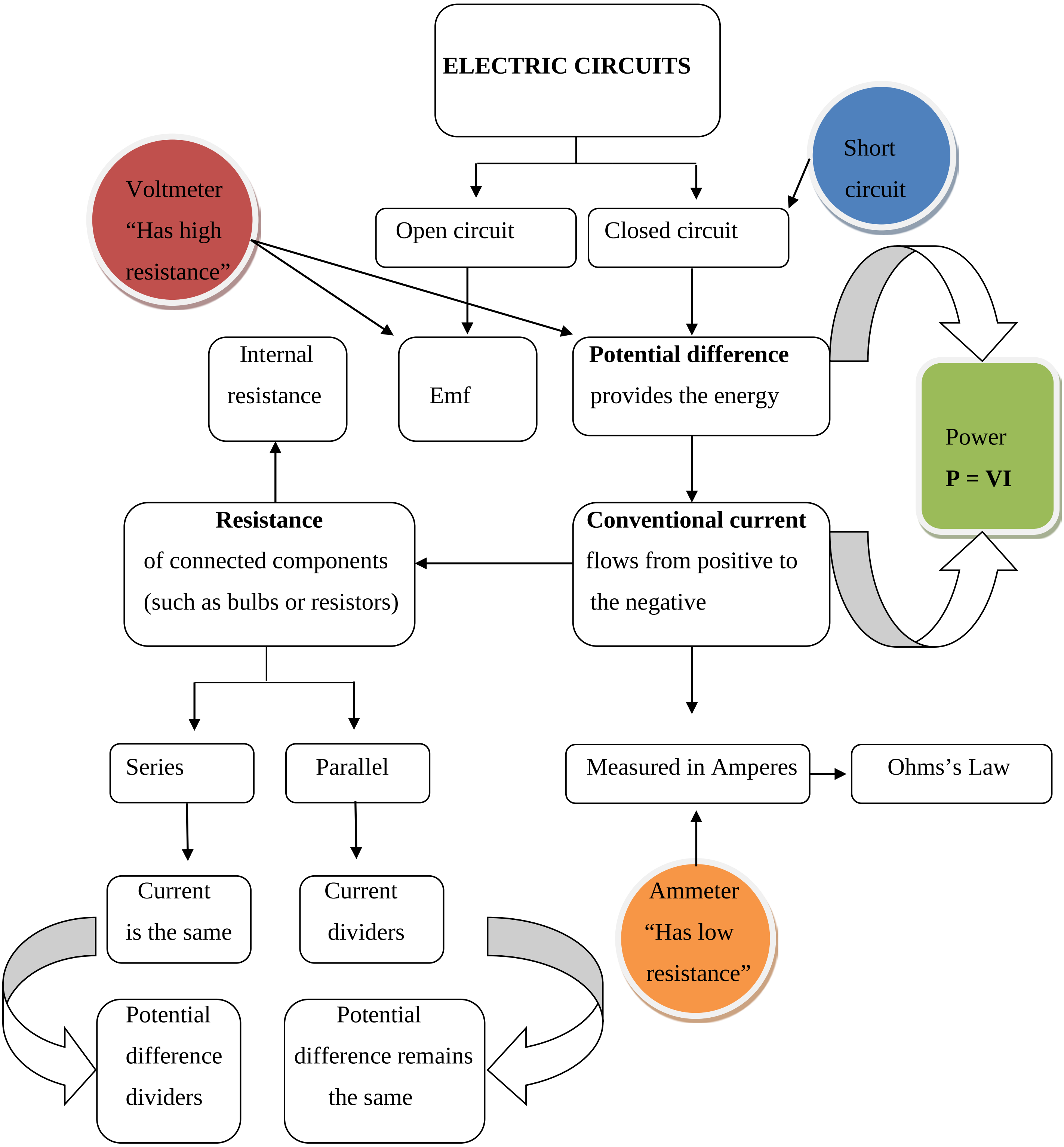


Diagram 3.2: Mind-map of the electric circuit’s concepts.

3.5. **Conclusion**

The following concepts can be classified as core concepts in simple electric circuit: charge, electric field, potential difference, emf, current strength and resistance. The concepts such as conductor and insulator are not core concepts, but are related to the resistance. Energy, work and power are general concepts in physics and are not regarded as core concepts in electricity (Wesi, 1998:44), hence they are not discussed in details. The knowledge of the core concepts and the literature review on learners' misconceptions shed more light on the research topic.

The next chapter outlines the research methodology.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

4.1. **Introduction**

The aim of this chapter is to discuss in detail the research design and methods used in this study. These dimensions are partly addressed in section 1.5.2 of chapter one. In chapter one the researcher presented the intention of conducting the study. Chapter two and three are based on the literature study which set the basis for the empirical study. Chapter two is focused on the Conceptual Change Model. In chapter three the core knowledge on simple electric circuit is discussion. This chapter presents in depth the research design and the research methods used in this study.

The chapter focuses on the problem statement, research aim and objectives, selection of participants, data collection instruments, data collection, data analysis and ethical considerations.

4.2. **Problem statement**

For the purpose of this study, the following primary and secondary research questions are formulated:

4.2.1. **Primary research question**

To what extend does the conceptual change model influence learner's academic performance in simple electric circuit?

4.2.2. **Secondary research questions**

(a) To what extend do learners demonstrate misconceptions in simple electric circuit?
(b) Will there be a significant difference in academic performance between experimental and

control group?

(b) Will there be a significant difference in academic performance between males and females (learners) taught using the new learning approach?

4.3. **Research Aim and Objectives**

4.3.1. **Research aim**

The aim of this study is to investigate the impact of CCM on learners ability to use simple electric circuits in class

4.3.2. **Research objectives**

The research aim was achieved by pursuing the following secondary objectives:

c) To develop learners' conceptual understanding with regard to concepts related to simple electric circuit.
d) To identify learners' misconceptions in the simple electric circuits and address them.
e) To improve learners' academic performance in simple electric circuits.

4.4. **Research design and methodology**

4.4.1. **Research design**

The study used both qualitative and quantitative designs (Onwauegbuzic *et al.*, 2004; McBurney, 2001; Wyse, 2011) to address the research question. The quantitative methods were mainly used to collect the appropriate statistical data. On the other hand, qualitative method was used to supplement the quantitative methods, particularly in analysing the explanations given by the respondents.

The study uses the experimental design with test (pre- and post-test) and questionnaire as tools for data gathering. An experimental design (Graziano and Raulin, 2004), with a strtified random sampling method for both the experimental and the control groups is used in the study because it had two benefits: It appropriately tested the effects or impact of the independent variable on the dependent variable. This means that the experimental design determined whether conceptual change model was responsible for the observed statistical change in the learners' academic performance in simple electric circuits. Secondly, the experimental design ensured internal validity (Graziano and Raulin, 2004:210).

William (2001) maintains that in an experimental research design the researcher endeavours to isolate and control every relevant condition which determine the event so as to observe the effects when the conditions are manipulated. Therefore the experimental design can be used to establish causality between variables. There are different types of experimental design, namely, pre-experimental, true experimental, quasi-experimental and correlation and ex post facto.

Clarke (2005) avers that the true experimental research emphasises a rigorous check of the identical nature of groups before testing the influence of a variable. This design includes pre-test/post-test control group design, Solomon Four-Group design and post-test only control group design.

In this study the true experimental, pre-test/post-test control group design (Alebiosu, 2005:112) is used. The pretest-posttest control group design is preferred method to compare participating groups and measured the degree of change occurring as results of treatment. It is regarded as the appropriate method to address the primary research question. The design controlled the assignment of subjects to experimental (treatment) and control groups through the use of a table of random numbers. Both groups experienced the same conditions, with the exception of the experimental group, which received the influence of the independent variable (new teaching and learning approach).

Table 4.1 below illustrates the research design.

Key: CCM = Conceptual Change Model and TPI = Traditional Physics Instruction

Scientific Random Assignment of Subjects to:	**1st measurement of the dependent variable O_1 = Pre-test**	**Exposure to the Treatment (independent variable)**	**2nd measurement of the dependent variable O_2 = Post-test**
Experimental group	Experimental group's average score on the dependent variable	CCM	Experimental group's average score on the dependent variable
Control group	Control group's average score on the dependent variable	TPI	Control group's average score on the dependent variable

Table 4.1: The pre-test/post test control group design.

Table 4.1 reflects that both groups (experimental and control) were subjected to the pre-test, thereafter they were exposed to the interventions. The control group was exposed to the Traditional Physics Instruction (TPI) while the experimental group was taught using CCM. The interventions were followed by the institution of the post test to the groups. The questionnaire and simple electric circuit conceptual test were the tools used to gather the information to answer the research questions.

4.4.2 **Research methodology**

There are distinguishable differences between the research methods and research methodology. Wisker (2008) maintains that methods are vehicles and processes used to obtain data. The research methods may be regarded as instruments or tools the researcher uses to accumulate the information. The examples of research methods include questionnaires, interviews and conceptual tests. The choices of the methods depend on the research paradigm adopted by the researcher.

On the other hand, the research methodology is the approach the researcher adopts to answer the research question. There are two main approaches used in social sciences, that is, qualitative and quantitative approaches. Most researchers use one approach in their studies (Alebiosu, 2005) because these approaches have distinguishable characteristics such as sampling methods, methods of data collection and data analysis. However, each approach has its benefits and detriments, and is more suitable to answering certain kinds of questions.

Ben-Eliyahu (2008) asserts that qualitative approach gathers information which focuses on describing a phenomenon in a deep comprehensive manner. Wyse (2011) maintains that qualitative research is exploratory research, which is used to gain understanding of underlying reasons, opinions, and motivations. It provides insights into the problem or helps to develop ideas or hypotheses for potential quantitative research. The methods for gathering qualitative data include interviews, open-ended questions, focus groups or observation schedules.

Even though qualitative research may be regarded as anecdotal, when instituted across a number of participants, it provides a conceptual understanding and evidence that certain phenomena are occurring with particular groups. Qualitative approach may also reveal information that would not be identified through pre-determined survey questions. Its limitations includes inability to generalize to the general population and it has difficulty in assessing relations between characteristics and challenges in applying statistical methods (Rubin and Barbie, 1998).

The quantitative approach on the other hand, is positivism in nature (Cohen, Manion and Morrison, 2011:7). Quantitative research uses measurable data to formulate facts and uncover patterns in research. This approach surveys a large number of individuals and applies statistical techniques to recognize overall patterns in the relations of processes (Ben-Eliyahu, 2008). Quantitative approach uses survey methods across a large group of individuals which enables generalization. It lends to statistical techniques that allow determining relations between variables. However, quantitative approach has difficulty in recognizing new and untouched phenomena as its main limitation (AIU, 2012; Wordpress, 2011).

The qualitative and quantitative approaches are sought to pursue the aim and objectives of this study. These approaches are highly informative, in the sense that the qualitative approach was employed to analyse learners' explanations in simple electric circuit conceptual test (SECCT). This method of analysing explanations per question required the definition of scientificaly complete response (nomothetic) and (ideographics) classification of explanations in certain categories (Küçüközer, 2004; Küçüközer & Kocakülah, 2007:105; Küçüközer & Demirci, 2008: 304; Kabapinar, 1998). The method was adopted becusase it is explanatory in nature and that made the reasearcher to undersdard the misconceptions learners had.

However, the study mainly uses the quantitative approach where the descriptive statistics involving means, standard deviations and frequency tables are employed to analyse the questionnaire. The ANOVA, t-test and ANCOVA are used to analyse the SECCT. The quantitative approach is used because it was suitable to examine constructs (academic performances) which were measurable. Furthermore it gave the researcher advantage to control threats to internal validity (McBurney, 2001).

4.4.3 **Study population and selection of participants**

4.4.3.1 Population

Population targeted for this study comprises of N = 1442 learners who were in grade 10 and enrolled for physical sciences in the academic year, 2011. The study was conducted in secondary schools in the rural area of Limpopo Province, Mankweng Cluster of Capricorn District. Mankweng cluster has five circuits and 65 secondary schools which offer physical sciences in grade 10.

A stratified random sampling technique (Welman and Kruger, 1999) was used to select learners per school (from four selected circuits). These schools were labelled school A, B, C and D. School A and D formed a control group while schools B and C formed experimental group. In each school, learners from grade 10 physical science class list were divided into two groups based on a single variable, sex, such that there were two strata (male and female).

From each stratum a random sample of 17 respondents was drawn to constitute a sample N = 136.

Using this sampling technique, two schools (one from Lebopo circuit and the other from Mankweng circuit) were selected to form a control group while another two schools from the other two circuits (one from Kgakotlou circiut and the other one from Mamabolo circuit) constituted an experimental group. The two groups were assigned in this manner to avoid "spillage". Spillage refers to the occurrence where the subject of the experimental group shares the intervention information with the subjects of the control group (Rapule, 2007:141).

A stratified random sample was preferred over other probability sampling techniques because it is representative of the population in the sense that it does not favour one unit of analysis over the another.

4.4.3.2. **Description of the sample**

In the sampled schools, the 34 learners in each school were selected to form a sample size n = 136. The current teacher to learner ratio in secondary schools as recommended by the Department of Education is 1:35 (DoE, 2003b). Therefore the class size for the intervention was adequate. The gender ratio was 1:1. This sample was selected in this fashion for the following reasons. First, it was easily accessible and secondly, the cost involved was fairly low. At the time of the study the learners' age ranges from 14 to 16 years, with mean age of 14.7.

4.4.4. **The data collection instruments**

The questionnaire and the simple electric conceptual test are used to gather relevant information needed to address the research questions. The next subsections discuss how these instruments are developed and validated.

4.4.4.1 **The development of the questionnaire and the SECCT**

(a) Questionnaire

This study uses the questionnaire developed by Rapule (2007:288) and modified it in order to pursue its objectives. The questionnaire consists of three sections, namely, biographical information of the respondents (9 items), the information on learning at school (6 items), information on simple electric circuit (16 items) and information on learning based on Conceptiual Change Model (16 items). The total number of items on the questionnaire are 47. Therefore the entire questionnaire included questions which entailed socio-demographic and personal information from the respondents (learners). Lastly, it encompasses items that seek information to ascertain what the respondents know about their learning.

In constructing the questionnaire, a 5-point Likert-scale was used (Norman, 2010). The 5-point Likert type scale was chosen because it offered a wide range of constructs on measurement (Rapule, 2007:145). Schnetler' study (as cited in Rapule, 2007) pointed out that a 5-point Likert-scale was flexible in terms of construction and administration.

The researcher opted for a 5-point Likert-scale because it is considered symmetric or "balanced" in the sense that there are equal amounts of positive and negative positions. In this scale five ordered response levels are used, even though other point Likert-scales used seven, nine or ten levels; recent studies (Burns and Burns, 2008; Norman, 2010) found that a 5-point scale produced slightly higher mean scores compared to those produced from other point Likert-scales. However, Dews (2008) maintains that there is very little difference among the scale formats in terms of variation about the mean, skewness or kurtosis. The format of a typical five-level Likert item used was:

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree

5. Strongly agree

The questionnaire is used to gather information in relation to the topic. It assists the researcher to understand how respondents learn physical sciences as a subject. Finally, it is used to evaluate lenears level of understanding of simple electric circuit. This tool is useful in helping the reseacher to identify the misconceptions learners had on electric circuits.

(b) Simple Electric Circuit Conceptual Test (SECCT)

The literature (Küçüközer, 2004; Küçüközer and Demirci, 2008; Jaakkola *et al*., 2011) is sought as a guide to construct the test items. A partially open-ended SECCT developed by Küçüközer's study (as cited in Küçüközer and Demirci (2008:310-311) is used. A test consisting of 8 multiple-choice type questions is partially open-ended because learners are asked to explain their choices. The test is adopted on the grounds that it had high reliability (r = 0.76) coefficient. This test is modified to pursue the aim and objectives of this study.

The respondents answered on the prepared question paper. They were instructed to put a cross in the box next to the option thought to be the most suitable answer, then they had to write motivation for their choice. They used codes rather than their real names when answering questions.

The same test items were used in the pre-testing and post-testing. The purpose was to determine whether the conceptual model improved learners' academic performance in simple electric circuits. Learners were not fore-warned about the date for the tests (Wesi, 1998). It was done to ensure that learners did not prepare for these tests through rote learning and memorization, as the study aimed at testing for an enduring change.

SECCT was used to ascertain if there were significant differences in learners' academic performance in electric circuits between the experimental and control groups. The design was also used to find out if there were any significant differences in male and female learners' achievements.

4.4.4.2 **Validity and the reliability of the questionnaire and the SECCT**

The validity of a measurement instrument refers to the extent to which the instrument measures what it is supposed to measure and performs as it is designed (Kumar, 2005:154; Graziano & Raulin, 2004:90). To establish the validity of these instruments, the researcher constantly asked himself the question: 'Am I measuring what I am suppose to measure?'. That is, the impact the Conceptual Change Model had on learners' academic achievement. The instruments used therefore gathered information on the learning gain or academic achievement.

According to Kumar (2005:90) the reliability of the instrument was ensured when the design was such that it consistently yields the same results when characteristics being measured has not changed. It is for this reason that the instruments used in this study are carefully chosen and designed to measure exactly what they are intended to measure.

This study adopts a test with the Cronbach's Alpha calculation ($\alpha = 0.76$) from (Küçüközer & Demirci, 2008). The high value ($\alpha > 0.7$) of the Cronbach's Alpha calculation indicated high test reliability. The test is modified to suit the research aim and objectives.

These instruments are given to the senior physical sciences senior teacher at our school to check for its validity and reliability. They were later given to my supervisor to re-examine their internal reliability and content validity. The instruments are also pilot tested with grade 10 learners of the school which was not in the sample. In addition, the controlled or true experimental design allowed the researcher to control for threats to the internal and external validity of the study. Threats to internal validity compromised the researcher's ability to say whether a relationship exists between the independent and dependent variables.

4.4.5 Data collection procedure

The first stage of data collection started two weeks prior the commencement of the study when instruments are piloted. Piloting is done to allow ample opportunity to ammend these instruments. After piloting the follwing chages were made to the questionnaire:

- Item 4 was modified to accommodate learners whose age were 13 and 14 years during the time of study.
- In order to be more specific, the word ‘controlled test’ (Quartely Provincial common test to all gade 10 physical science learners) was inserted to item 6.
- Item 13 was modified by inserting the word ‘concept’ so that it could read ‘science concepts’not just science.
- Item 37 alternative words were used in brackets to simplfy language, that is collaborate (work) and peers (friends). Learners are using English as their second language.

The test was modified by using converntional symbols for resistance (question 2). Item 8 was developed by the researcher and validated by his supervisor.

In the second stage, the first part of the questionnaire consisting of biographical information and information on the learning of physical sciences and information on simple electric circuit, is administered to the two groups a week before pretesting. The questionnaire was conducted on the same day, at the same time to both groups. The physical sciences educators responsible for grade 10 at respective schools, assisted the researcher to administer this instrument. This part was kept cofitential.

During the third stage, the pre-test was conducted on the specified day and time by the researcher with the help of respective physical sciences’ grade 10 educators. The purpose of the pretesting was to find out whether the two groups were on the same level of simple electric crcuits’ conceptual understanding.

Three weeks athereafter the two groups were subjected to the intervention sessions. Two experienced professional (physical sciences) educators offered lessons using Traditional Physics Instruction (TPI) to the control group while the reseacher offered lessons based on CCM to the experimental group. Schools' general time table was followed. This arrangement was made with an intention to reflect pricisely how science is learnt in the traditional learning and teaching as compared to the learning in the innovative approach.

The researcher did not want to influence traditional science learning and teaching, in favour of a fair comparison of the two instructional approaches on how science could be learnt. During Physical Science periods, the subject teachers (from schools in the experimental group) continued teaching those learners who were not in the study. The table below (table 4.2) shows the time table for the lesson presentation to the experimental group. This constituted the fourth stage of data collection.

The TPI involved teaching in which teaching-learning activities were teacher-centered. The leacture method dominates. Rote learning, without application of science concepts was encouraged. The teaching mainly dominated by talk-and-chalk.

On the other hand, the CCM was a learner-centered approach, where the teacher was the engineer, mediator and facillitator of the learning process. The teacher-researcher also arranged learning activities in which learners could explore, search, manipulate and investigate. Collaborative teaching stratergy employed aimed to foster conceptual change through discussions and debate. It was the learners' responsibility to actively participate in the meaning-making process.

Table 4.2: Intervention Time-Table.

Week	Day	Date	School B	School C
1	1	July 2011	08H00 – 09H00	15H00 – 16H00
	2	July 2011	09H00 – 10H00	15H00 – 16H00
	3	July 2011	08H00 – 09H00	14H00 – 15H00
	4	July 2011	09H00 – 10H00	15H00 – 16H00
	5	July 2011	08H00 – 09H00	12H30 – 13h30
2	1	July 2011	09H00 – 10H00	15H00 – 16H00
	2	July 2011	08H00 – 09H00	15H00 – 16H00
	3	July 2011	09H00 – 10H00	14H00 – 15H00
	4	July 2011	08H00 – 09H00	15H00 – 16H00
	5	July 2011	09H00 – 10H00	12H30 – 13h30
3	1	July 2011	08H00 – 09H00	15H00 – 16H00
	2	July 2011	09H00 – 10H00	15H00 – 16H00
	3	July 2011	08H00 – 09H00	14H00 – 15H00
	4	July 2011	09H00 – 10H00	15H00 – 16H00
	5	July 2011	08H00 – 09H00	12H30 – 13h30

The duration of the intervention lesson was 1 hour per conduct session. The treatment took 3 weeks. The post test was administered to two groups (at the same time by educators at repectives schools), two weeks after the intervention. Finally, a week thereafter, the researcher administered the last section of the questionnaire to the experimental group (learning based on Conceptual Change Model).

A copy of daily attentance register (DoE, 2003b) was used to monitor the participation of learners per school. The absenteeism during the intervention phase was minimal. The average of absentees for the intervention session (control group) was three, and this number is insignificant. No absenteeim was registered in the experimental group.

A summary of how the empirical survey was conducted (April 2011 – April 2014) is given in the table 4.3 below;

Table 4.3: Summary of empirical survey.

Activity	Control group	Experimental group
1. Administration of the questionnaire.	April 2011	April 2011
2. Pre-testing	May- June 2011	May – June 2011
3. Intervention Stratergy	July 2011	July 2011
4. Post testing	August 2011	August 2011
5. Administration of the questionnaire: Learning based on conceptual change model	-	August 2011
6. Data Analysis	September 2011	June 2013
7. Report Writing	June 2013	April 2014

In the fifth stage, two weeks after the intervention, the post test was administrated to the two groups (at the same day and time). A week thereafter, the researcher administered the last part of the questionnaire (learning based on Conceptual Change Model) to the experimental group only.

4.4.6 **Data analysis**

4.4.6.1 **Quantitative data analysis**

The tool to record the quantitative raw data was developed. The tool was developed in line with the survey instruments (questionnaire and SECCT). The participants were given participants unique numbers (1– 136) for confidetiality' sake (Appendix 5). Learner 1 to 68 were in the control group whereas learner 69 to 136 were in the experimental group. Schools were also asigned unique numbers. That is, schools in the control group were assigned number 1 and 4 whereas schools in the experimental group were allocated number 2 and 3. Gender was given specific number codes (male = 1 and female = 2).

For questionnaire part one, items 1 to 9 was inserted in the tool. Each learner's response was captured as a raw data. The same procedure was followed with part two (10-15 items), three (16-31 items) and four (16-47 items).

Learners reponses from the SECCT were also collected using the same tool. Question 1 to 8 were inserted in the tool and learners choices regardless of wrong or right were captured. The following making grid was used as a marking guide;

Table 4.4: Correct answers for SECCT.

Question	1	2(a)	2(b)	2(c)	2(d)	3	4(i)	4(ii)	5(a)	5(b)	6	7	8
Answer	**3**	**1**	**1**	2	2	4	1	6	3	5	2	4	4

The respondents' actual mark (for the correct answer) out of 13 and percentage were recorded in a separate tool. This tool contains learner, school, actual mark and percentage obtained. The researcher used this tool to generate tables 5.81 and table 5.82 on section 5.3 of this study.

The quantitative data obtained was analysed using the statistical services of North-West University (Potchefstroom campus). Descriptive statistics (Welmam, Kruger and Mitchill, 2005; Welman and Kruger, 1999) was used before the intervention to analyse the first part of the questionnaire.

Questions 1 to 9 were analyzed using frequency tables, while central tendency and Chi-square tests were used to analyze question 10 to 31. The information on learning assisted the researcher, before the intervention, to ensure that the groups started off with similar understanding of the topic. The second part of the questionnaire, question 32 to 47, was also analyzed descriptively.

On the other hand the inferential staststics (Baser, 2006) was used to analyze the respondents' responses on SECCT as follows;

- The ANOVA was performed on pre-test scores to determine if the results from different schools were comparable (section 5.4).
- The t-test between experimental group and control group was performed to determine if the pre-tests scores were comparable (section 5.4).
- The t-test was further performed (section 5.4) to determine whether there were no significant differences in learners' (males and females) academic performance in simple electric circuit taught using the new learning and teaching approach (CCM).

To compare the effect of intervention/natural schooling over time by means of paired t-tests; A paired t-tests within each school was performed. A paired t-test was further performed within experimental and control groups.

To compare post test scores by controlling the pre-test scores by means of ANCOVA's;

- Between schools
- Between experimental and control groups

ANCOVA test was performed (section 5.4) using the raw data collected. The generated tables for ANOVA, ANCOVA and t-tests were discussed.

4.4.6.2 **Qualitative data analysis**

The explanations on the SECCT were analysed using the procedure as outlined by Küçüközer and Demirci (2008:304) as follows:

- ➢ First, the participants' correct answer was determined for each question.
- ➢ Then, the explanation made, according to their open ended nature, are divided into two parts as being scientifically acepted or unacceptable.

➢ Then, the explanation of the scientically correct answer was classified into two parts, as being exactly correct or partially correct answer.

➢ Next, explanations of scientifically unacceptable anwers were similarly classified into ‘incorrect 1’ and ‘incorrect 2’ categories.

This procedure vividly determined the extent to which learners’ misconceptions were addressed. It pointed out areas where learners still shown signs of misconceptions and other related conceptual problems. Diagram 4.1 below, illustrates different levels used to code the responses.

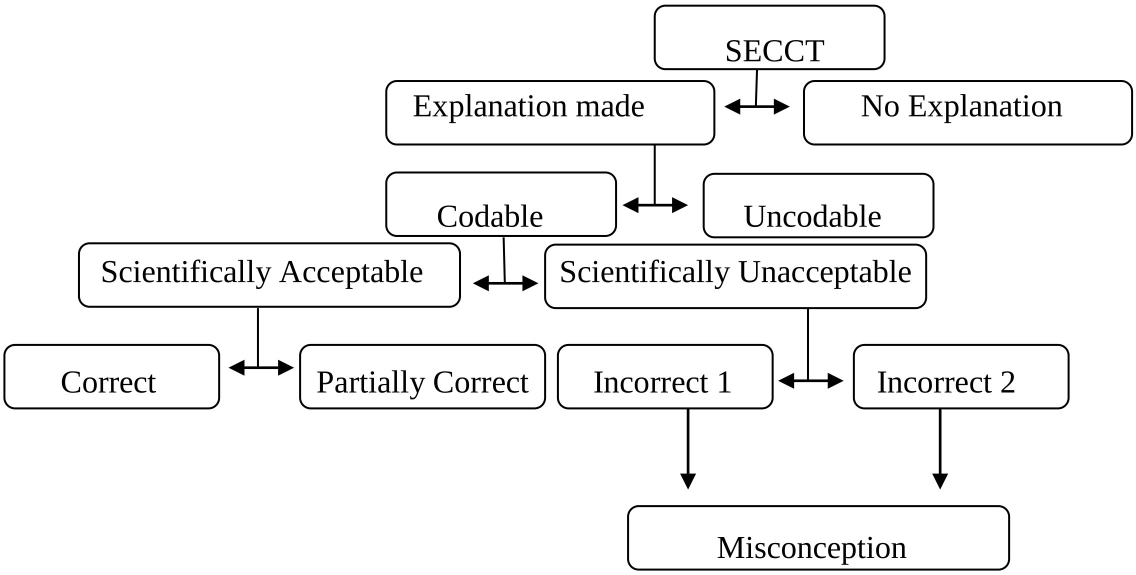


Diagram 4.1: Analyses of SECCT Explanations (Küçüközer & Kocakülah, 2007:105).

The above diagram indicates that where explanation was made, it was assessed whether it could be codable or uncodable. Uncodable explanations were difficult to understand what they imply (have no relation with the question). Codable were relevant or partly related to the question. These explanations were classified as scientifically acceptable or unacceptable. Scientifically acceptable explanations were further classified as correct or partially correct explanations. Scientifically unacceptable explanations were scrutinized and classified as ‘incorrect 1’ or ‘incorrect 2’.

Learners responses (ideas) classified under ‘correct 1’ include correct and incorrect explanation sentences. For example, bulb on the open switch is not lit and current is consumed in the circuit. On the other hand, explanations classified under ‘incorrect 2’ focused on minority or majority of any circuit component and the way the circuit is connected. For example, bulbs in parallel are always brighter than those in series or current decrease when passing through the bulb (Küçüközer & Kocakülah, 2007:106-109). All these type of explanations lead to misconceptions.

4.5 Ethical consideration

The permission to conduct the study was sought from various stake holders, including learners, parents, school principals, circuit managers and Limpopo Provincial Education Department (Appendix 1). Parents were reached through the informed concernt form (Struwig & Stead, 2004: 68). The confidentiality and the risks were at the heart of this form.

It was explaned in the concert form that:

- The data would be collected from respondents in a classroom setting (their classes), therefore risk associated with learners was minimal.
- Participation in the study was voluntarily and participants were free to withdrw any time should they felt like.
- The findigs of the study would be made available to the participants on request.
- The real names of participants, schools would never be mentioned.
- The puporse, aim and objectives of the study were explained to the respondents
- The respondents’ expectations (roles and responsibilities) were made explicit.
- Duration of involvement in the study was made clear.

Only learners who returned the concert form, signed by parent were allowed to participate in the study. These forms were kept for the entire study period.

4.6 Conclusion

The chapter illustrated the research design and methods used to collect the relevant data for the research question. The chapter discussed the validity and reliability of the instruments which were the pillars of every experimental survey.

In the next chapter the empirical results are presented.

CHAPTER 5

PRESENTATION OF THE EMPERICAL RESULTS

5.1. **Introduction**

The quantitative and qualitative results of data collected using the research design and methods outlined in chapter four are presented hereunder. The descriptive analysis and frequency tables were used to analyze data from the questionnaire.

One way ANOVA was used to analyse the data from the pre-test and post test. The ANOVA was employed because the data was collected from four schools and ANOVA could best compare the means scores from these groups. The Paired Samples t-test was performed to compare effect of intervention.

The ANCOVA was used to compare the effect of the two modes of instruction (that is, CCM and TPI). ANCOVA was also used to analyse the academic performance of males and female learners taught using CCM.

The explanation given from the open ended questionnaire was analysed qualitatively. The explanations provided by respondents on questionnaire part 1 and 2, were analysed using the content analysis procedure (Cohen, Manion and Morrison, 2011:563-569). Part 4 of the questionnaire was analysed using the definition of scientificaly complete response (nomothetic) and classification of explanations in certain categories (ideographics) as aserted by Küçüközer & Kocakülah (2007:105) and Kabapinar (1998).

5.2. **Presentation of the quantitative results**

5.2.1. **Presentation of results of Control Group**

The questionnaire was one of the research instruments. It was used to collect quantitative data from the respondents. The information was gathered from both control and experimental groups. The results are descriptively presented as follows;

5.2.1.1 **Biographical information of control group** (Questionnaire Part I, Question 1 to 9)

5.2.1.1.1. Name of the control group school

Table 5.1: Name of the control group school.

Schools	Frequency	Percentage
A	34	50.0
D	34	50.0
Total	68	100.0

Table 5.1 shows that the control group consisted of two schools, school A and school D. Each school had equal representation of participants. There were 68 participants who voluntary took part in the study.

5.2.1.1.2. Name of the circuit where control group schools are situated

Table 5.2: Name of the circuit where control group schools are situated.

Circuits	Frequency	Percentage
Mamabolo	34	50.0
Lebopo	34	50.0
Total	68	100.0

Schools in the control group were situated in two different circuits, that is, Mamabolo circuit and Lebopo circuit.

5. 2.1.1.3. Control group learners' (or participants') gender

Table 5.3: Gender composition for the control group learners.

Gender	Frequency	Percent
Male	34	50.0
Female	34	50.0
Total	68	100.0

The gender composition of the respondents in the control group was 1:1, that is, 50% male and 50% female.

5.2.1.1.4. Number of years a control group learner was in grade 10

Table 5.4: Years in grade for the control group.

Years in grade	Frequency	Percentage
Once	63	92.6
Twice	5	7.4
Total	68	100.0

Table 5.4 reflects that 92.6% of the sample were studying grade 10 for the first time while 7.4% were in the second year of study.

5.2.1.1.5. Control group learners' recent mark in physical sciences

Table 5.5: Recent marks in physical science examinations for the control group.

Mark in Physical Sciences	Frequency	Percentage
0 – 29	55	80.9
30 – 39	9	13.2
40 – 49	3	4.4
50 – 59	1	1.5
Total	68	100.0

The table illustrates the spread of marks obtained by respondents (learners) in physical sciences. It further indicates that 80.9% of learners obtained marks between 0 and 29 percent, the lowest academic achievement level, while only 1.5% got level 4 (marks between 50 and 59 percent).

To establish whether there is a relationship between the recent marks obtained and schools, a crosstabulation was computed. The results are presented in table 5.6 below.

Table 5.6: Control group schools' * Recent marks: Crosstabulation.

			Recent marks				Total
			0 - 29	30 – 39	40 - 49	50 - 59	
School	A	Frequency	23	7	3	1	34
		Percentage	67.6	20.6	8.8	2.9	100.0
	D	Frequency	32	2	0	0	34
		Percentage	94.1	5.9	0.0	0.0	100.0
Total		Frequency	55	9	3	1	68
		Percentage	80.9	13.2	4.4	1.5	100.0

Table 5.6 above shows that 67.6% of learners in control group school A had a recent mark between 0 and 29 while 94.1% of learners from control school D had the same level of recent mark in physical sciences. It is also observed from table 5.6 that no learner in control school D obtained a mark more than 39%.

5.2.1.1.6. Control group learners' visitation to science centre

Table 5.7: Control group learners' visit to science centre.

Responses	Frequency	Percentage
No	68	100.0
Yes	0	0.0
Total	68	100.0

The frequency table 5.7 above shows that no learner had ever visited a science centre.

5.2.1.1.7. Control group schools' participation in science road shows

Table 5.8: Control group schools' participation in science road shows.

Responses	Frequency	Percentage
No	68	100.0
Yes	0	0.0
Total	68	100.0

From table 5.8 it can be deduced that no learner from the sample (control group) had an opportunity to attend science road show.

5.2.1.1.8 Control group learners' attendance to science road shows

Table 5.9: Control group schools' attendance to science road shows.

Responses	Frequency	Percentage
No	68	100.0
Yes	0	0.0
Total	68	100.0

The results presented in table 5.9 reveal that learners from the control group never attended a science road show.

5.2.1.1.9 Control group learners' age per school

Table 5.10: Control group learners' age per school.

			Age				Total
			13	14	15	16	
School	A	Frequency	2	11	19	2	34
		Percentage	5.9	32.4	55.9	5.9	100.0
	D	Frequency	1	13	17	3	34
		Percentage	2.9	38.2	50.0	8.8	100.0
Total		Frequency	3	24	36	5	68
		Percentage	4.4	35.3	52.9	7.4	100.0

The table 5.10 above compares learners' age between two schools. It reflects that learners' age ranges from 13 years to 16 years. In school A 55.90% of learners were 15 years old whereas in school D 50% of learners had 15 years. In total 52% of learners in these schools had 15 years and 35% had 14 years. It was further observed that 7.4% of the sample had 16 years and 4.4% had 13 years.

5.2.1.1.10 **Summary of control group learners' response to bibliographical items**

The responses to this section indicate that

- 68 learners responded to this section.
- Learners are from different schools.
- Schools are situated in different circuits.
- The gender composition is 1:1.
- Most learners (92.6%) are studying grade 10 for the first time.
- Most learners (80.9%) performed poorly in physical sciences examinations.
- No learner visited a science centre.
- No learner attended or participated in the science road shows.

5.2.2. **Presentation of results of experimental group**

5.2.2.1 Biographical information of experimental group (Questionnaire Part I, Question 1 - 9)

5.2.2.1.1 Name of the experimental group school

Table 5.11: Name of the control group school.

Schools	Frequency	Percentage
B	34	50.0
C	34	50.0
Total	68	100.0

Schools in the experimental group had equal representation of respondents (50% from each school). The total number of learners in this group was 68 (table 5.11).

5.2.2.1.2 Name of the circuit where experimental group schools are situated

Table 5.12: Name of the circuit where experimental group school are situated.

Circuits	Frequency	Percentage
Mankweng	34	50.0
Kgakotlou	34	50.0
Total	68	100.0

The participants were from two circuits, Mankweng and Kgakotlou circuits.

5.2.2.1.3 Experimental group learners' (or participants') gender

Table 5.13: Gender composition for the experimental group learners.

Gender	Frequency	Percentage
Male	34	50.0
Female	34	50.0
Total	68	100.0

There was equal representation of gender in this group. That is, 50% male and 50% female. In total the group had 68 respondents (table 5.13).

5.2.2.1.4 Number of years an experimental group learner was in grade 10

Table 5.14: Years in grade for the experimental group.

Years in grade	Frequency	Percentage
Once	58	85.3
Twice	10	14.7
Total	68	100.0

The results in table 5.14 above shows that 85.3% of participants in the experimental group were studying grade 10 for the first time. The table further reveals that only 14.7% of participants were in the second year of study in this grade.

5.2.2.1.5 Experimental group learners' recent mark in physical sciences

Table 5.15: Experimental group learners' recent mark in physical sciences examinations.

Mark in Physical Sciences	Frequency	Percentage
0 – 29	53	77.9
30 – 39	9	13.2
40 – 49	4	5.9
50 – 59	2	2.9
Total	68	100.0

According to table 5.15, 77.9% of learners in experimental group obtained the lowest level of academic achievement (DoE, 2003a: 61). The table shows that as academic achievement level rises, number of learners performing well decreases, that is, 5.9% of learners obtained marks between 40 and 49 percent whereas only 2.9% of the sample were in level four (50% - 59%).

To establish whether there is a relationship between the recent marks obtained and schools, a crosstabulation was computed. The results are presented in table 5.16 below.

Table 5.16: Experimental group schools' * Recent marks: Crosstabulation.

Schools		Recent marks				Total
		0 – 29	30 - 39	40 - 49	50 – 59	
A	Frequency	25	6	1	2	34
	Percentage	73.5	17.6	2.9	5.9	100.0
D	Frequency	28	3	3	0	34
	Percentage	82.4	8.8	8.8	0.0	100.0
Total	Frequency	53	9	4	2	68
	Percentage	77.9	13.3	5.9	2.9	100.0

Table 5.16 indicates that most learners in school D (82.4%) got a mark between 0 and 29 percent in the examination than learners in school A (73.5%). In total 77.9% of learners from both schools obtained lowest level. Only 5.9% of learners in the experimental group obtained marks in level 4 (50% - 59%).

5.2.2.1.6 Experimental group learners' visitation to science centre

Table 5.17: Experimental group learners' visit to science centre.

Responses	Frequency	Percentage
No	68	100.0
Yes	0	0.0
Total	68	100.0

The frequency table 5.7 above shows that no learner in the experimental group had ever visited a science centre.

5.2.2.1.7 Experimental group schools' participation in science road shows

Table 5.18: Experimental group schools' participation in science road shows.

Responses	Frequency	Percentage
No	68	100.0
Yes	0	0.0
Total	68	100.0

Table 5.18 shows that no learner in the experimental group had an opportunity to attend science road show.

5.2.2.1.8 Experimental group learners' attendance to science road shows

Table 5.19: Experimental group schools' attendance to science road shows.

Responses	Frequency	Percentage
No	68	100.0
Yes	0	0.0
Total	68	100.0

The results in table 5.19 above reveal that learners in the experimental group never attended a science road show.

5.2.2.1.9 Experimental group learners' age per school

Table 5.20: Experimental group learners' age per school.

Schools		Age 13	14	15	16	Total
A	Frequency	3	8	21	2	34
	Percentage	8.8	23.5	61.8	5.9	100.0
D	Frequency	1	13	17	3	34
	Percentage	2.9	38.3	50.0	8.8	100.0
Total	Frequency	4	21	38	5	68
	Percentage	5.9	30.9	55.8	7.4	100.0

Table 5.20 above compares learners' age in experimental group between schools. It reflects that learners' age ranges from 13 years to 16 years. In school A 61.8% of learners were 15 years old whereas in school D 50% of learners had 15 years. Most learners in these schools were between 14 years and 15 years old. In total 7.4% of the sample had 16 years and 4.4% were 13 years of age.

5.2.2.1.10 Summary of experimental group learners' response to bibliographical items

The responses to this section indicate that

- 68 learners responded to this section;
- Learners are from different schools;
- Schools are situated in different circuits;
- The gender composition is 1:1;
- Most learners (85.3%) are studying grade 10 for the first time;
- Most learners (77.9%) performed poorly in physical sciences examinations;
- No learner visited a science centre;

- No learner attended or participated in science road shows.

5.2.3. **Comparison between the control and experimental groups' Biographical information**

The paragraph below compares the biographical information of the participants relative to each group (Control and experimental):

- There is equal number of learners in both groups;
- Learners are from different schools and circuits;
- Gender composition for both groups is 1:1;
- Most learners of both groups are studying grade 10 for the first time;
- Most learners of both groups performed poorly in physical sciences examinations;
- No learner in either of the group visited a science centre, attended or participated in science road shows.

5.2.4. **Control group learners' response to the structured questions of the questionnaire Part II: Question 1 to 6**

The following tables present control learners' responses to the structural questions of the questionnaire. An asterisk (*) will be used to indicate the number of learners (if any) who did not respond to a particular question.

Table 5.21: At our school we, as learners, conduct experimental work regularly.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	0	3	2	61	2	68
Percentage	0.0	4.4	2.9	89.7	2.9	100.0

Table 5.21 above indicates that most learners (92.6%) “disagree and totally disagree” with the statement, at our school we, as learners do conduct experimental work regularly while 7.3% “agree and agree with reservations” with the statement.

Table 5.22: I am confident in carrying out experiments on my own.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	0	0	0	6	62	68
Percentage	0.0	0.0	0.0	8.8	91.2	100.0

According to table 5.22, almost all learners “disagree and totally disagree” that they are confident in carrying out experiments on their own.

Table 5.23: I can easily follow instructions stipulated on the block to carry out experiment at school.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	4	56	5	3	0	68
Percentage	5.9	82.3	7.4	4.4	0.0	100.0

The largest majority of the learners (88.2%) “agree and totally agree” with the statement that they can easily follow instructions stipulated on the block to carry out experiments at school.

Table 5.24: I understand the science concepts better when my teacher demonstrates on experiment to the class.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	1	3	9	43	12	68
Percentage	1.5	4.4	13.2	63.2	17.6	100.0

According to table 5.24, most of the learners (80.8%) "disagree and totally disagree" that they understand the science concepts better when their teachers demonstrate an experiment while the minority (17.6%) "agree and agree with reservations" to the statement.

Table 5.25: I can easily handle apparatus when conducting experiments.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	3	25	12	24	4	68
Percentage	4.4	36.8	17.6	35.3	5.9	100.0

Table 5.25 above indicates that almost half of the learners (54.4%) "agree and agree with reservations" that they can handle apparatus when conducting experiment while almost another half (41.2%) "disagree and totally disagree" with the statement.

Table 5.26: I consider the contribution of practical work/experiment in learning science.

Responses	Very important	Important	Not important	Total
Frequencies	23	38	7	68
Percentage	33.8	55.9	10.3	100.0

The largest majority of the learners (89.7%) considered the contribution of practical work/experiments in learning science to be "important and very important" as compared to 10.3% that considered it "not important".

Synthesis

Based on the learners' responses to statements on information on learning, the following can be deduced:

- Most learners disagree that at their schools they as learners do conduct experimental work regularly.
- All learners disagree that they are confident in carrying out experiments on their own.
- Most learners agree that they can easily follow instructions stipulated on the block to carry out experiments at school.
- The largest majority of learners disagree that they understand the science concepts better when their teachers demonstrate an experiment.
- Almost half of learners agree that they can handle apparatus when conducting experiment while almost another half disagrees.
- Most learners considered the contribution of practical work/experiments in learning science to be important.

5.2.5 **Experimental group learners' response to the structured questions of the questionnaire Part II: Question 1 to 6**

The tables below present experimental group learners' responses to the structural questions of the questionnaire.

Table 5.27: At our school we, as learners, conduct experimental work regularly.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	0	3	2	58	5	68
Percentage	0.0	4.4	2.9	85.3	7.4	100.0

According to table 5.27 above, most learners (92.7%) "disagree and totally disagree" with the statement, at our school we, as learners do conduct experimental work regularly while 7.3% "agree and agree with reservations" with the statement.

Table 5.28: I am confident in carrying out experiments on my own.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	0	0	0	8	60	68
Percentage	0.0	0.0	0.0	11.8	88.2	100.0

Table 5.28 above indicates that almost all learners "disagree and totally disagree" that they are confident in carrying out experiments on their own.

Table 5.29: I can easily follow instructions stipulated on the block to carry out experiment at school.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	2	58	5	3	0	68
Percentage	2.9	85.3	7.4	4.4	0.0	100.0

The frequency table 5.29 indicates that most of the learners (92.7%) "agree and agree with reservations" that they can easily follow instruction stipulated on the block to carry out experiment at school.

Table 5.30: I understand the science concepts better when my teacher demonstrates on experiment to the class.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	1	4	8	46	9	68
Percentage	1.5	5.9	11.8	67.6	13.2	100.0

According to table 5.30, most of the learners (80.8%) "disagree and totally disagree" that they understand the science concepts better when their teachers demonstrate an experiment while the minority (17.7%) "agree and agree with reservations" to the statement.

Table 5.31: I can easily handle apparatus when conducting experiments.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	5	26	13	20	4	68
Percentage	7.4	38.2	19.1	29.4	5.9	100.0

In table 5.31 above, almost half of learners (57.3%) “agree and agree with reservations” that they can handle apparatus when conducting experiment while 35.3% “disagree and totally disagree” with the statement.

Table 5.32: I consider the contribution of practical work/experiment in learning science.

Responses	Very important	Important	Not Important	Total
Frequencies	26	37	6	68
Percentage	38.2	54.4	7.4	100.0

Table 5.32 indicates that most learners (92.6%) considered the contribution of practical work/experiments in learning science to be “important and very important” as compared to 7.4% that considered it “not important”.

Synthesis

Based on the experimental group learners’ responses to statements on information on learning, the following can be deduced:

- Most learners disagree that they conduct experimental work regularly.
- All learners disagree that they are confident in carrying out experiments on their own.
- Most learners agree that they can follow instructions to perform experiments.
- Most learners disagree that they understand the science concepts when teacher demonstrates an experiment
- Almost three fifth of learners agree that they can handle apparatus when conducting experiment while almost two fifth disagree.
- Most learners considered the contribution of practical work in learning science to be important.

5.2.6 **Comparison between control and experimental groups' responses to the structured questions of the questionnaire**

The paragraph below compares the responses to the structured questions of the participants relative to each group (Control and experimental):

- Most learners of both groups disagree that at their schools they as learners, do conduct experimental work continuously;
- All learners of both groups disagree that they are confident in carrying out experiments on their own;
- Most learners of both groups agree that they can follow instructions to perform experiments;
- All learners of the control as compared to most learners of the experimental group agree that they can easily follow the instruction of stipulated on the block to carry out the experiments at school;
- Almost three fifth of learners of the experimental group as compared to almost half of learners of the control group agree that they can handle apparatus when conducting experiment;
- Most learners of both groups valued the contribution of practical work in learning science to be important.

5.2.7 **Control group learners' responses to information on simple electric circuit (Questionnaire Part III)**

The following tables present control learners' responses to the structural questions of the questionnaire. An asterisk (*) will be used to indicate the number of learners who did not respond to a particular question.

Table 5.33: I like to solve problems on simple electric circuit.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	14	33	19	2	0	68
Percentage	20.6	48.5	27.9	2.9	0.0	100.0

Table 5.33 indicates that 69.1% of learners “agree and totally agree” that they like to solve problems on simple electric circuits, while 27,9% “agree with reservations” to the statement.

Table 5.34: I can easily relate the work on simple electric circuit to my everyday life experiences.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	0	22	7	30	9	68
Percentage	0.0	32.4	10.3	44.1	18.2	100.0

According to table 5.34 more learners (62.3%) “disagree and totally disagree” that they can relate the work on simple electric circuit to their everyday life experiences. On the other hand 42.7% “agree and agree with reservations” to the statement.

Table 5.35: I like doing experiments on electric circuit.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	4	42	13	9	0	68
Percentage	5.9	61.8	19.1	13.2	0.0	100.0

Table 5.35 shows that majority of learners, 80.9% "agree and agree with reservations" that they like performing experiments on electric circuits while minority (13.2%) "disagree" to the statement.

Table 5.36: The work on electric circuits motivates me to pursue my studies in sciences after grade 12

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	17	38	11	2	0	68
Percentage	25.0	55.9	16.2	2.9	0.0	100.0

Table 5.36 above indicates that 80.9% of learners "agree and totally agree" that the work on electric circuits motivates them to pursue studies in sciences after passing grade 12 while 16.2% "agree with reservations" to the statement.

Table 5.37: The experiments on simple electric circuit develop my skill to handle apparatus.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	15	33	11	7	2	68
Percentage	22.1	48.5	16.2	10.3	2.9	100.0

The results in table 5.37 shows that 70.6% of learners "agree and totally agree" that the experiments on simple electric circuit develop their skill to handle apparatus while 16.2% "agree with reservations" and only 13.2% "disagree and totally disagree" to the statement.

Table 5.38: The study of simple electric circuits develops my understanding of science concepts.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	19	31	7	6	5	68
Percentage	27.9	45.6	10.3	8.8	7.4	100.0

Table 5.38 shows that 73.5% of learners "agree and totally agree" that the study of simple electric circuits develop their understanding in science while 10.3% "agree with reservations to the statement. However, only 16.2% "disagree and totally disagree" to the statement.

Table 5.39: The tasks based on simple electric circuits helped me to analyze problems.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	14	43	5	5	1	68
Percentage	20.6	63.2	7.4	7.4	1.5	100.0

The table 5.39 above indicates that 83.8% of learners "agree and totally agree" that the tasks based on simple electric circuits helped them to analyze problems. On the other hand, 8.9% "disagree and totally disagree" to the statement.

Table 5.40: Electric circuits give me the opportunity to learn by doing experiments on my own.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	14	49	4	1	0	68
Percentage	20.6	72.1	5.9	1.5	0.0	100.0

The results in table 5.40 shows that majority of learners, 92.8% "agree and totally agree" that electric circuits give them the opportunity to learn by doing experiments on their own while minority of learners, 1.5% "disagree" to the statement.

Table 5.41: The experiments involving simple electric circuits require/demand understanding.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	23	27	12	4	2	68
Percentage	33.8	39.7	17.6	5.9	2.9	100.0

Table 5.41 indicates that 73.5% "agree and totally agree" that the experiments involving simple electric circuits require understanding while only 8.8% "disagree and totally disagree" to the statement.

Table 5.42: In the electric circuit I learn to find answers to problems.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	23	27	8	6	4	68
Percentage	33.8	39.7	11.8	8.8	5.9	100.0

Table 5.42 indicates that 73.5% of learners "agree and totally agree" that in the electric circuit they learn to find answers to problems. This table further shows that 11.8% "agree with reservations" while 14.7% "disagree and totally disagree" to the statement.

Table 5.43: Experiments in simple electric circuits help me to become creative in science.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	12	39	7	9	1	68
Percentage	17.6	57.4	10.3	13.2	1.5	100.0

From table 5.43 we observe that 75.0% “agree and totally agree” that experiments in simple electric circuits help them to become creative in science while 14.7% “disagree and totally disagree” to the statement.

Table 5.44: I usually enjoy lessons based on simple electric circuits.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	18	45	3	1	1	68
Percentage	26.5	66.2	4.4	1.5	1.5	100.0

Table 5.44 shows that 92.7% “agree and totally agree” that they enjoy lessons based on simple electric circuits.

Table 5.45: I consider studying electric circuits because it offers me an opportunity for doing practical work on my own.

Responses	Very important	Important	Not important	Total
Frequencies	34	34	0	68
Percentage	50.0	50.0	0.0	100.0

Half of learners in table 5.45 consider studying electric circuits as “very important” while the other half consider the statement as “important.

Table 5.46: I intent doing more experiments on electric circuits because I gain scientific knowledge.

Responses	Very important	Important	Not important	Total
Frequencies	21	47	0	68
Percentage	30.9	69.1	0.0	100.0

Table 5.46 indicates that 69.1% consider doing more experiments on electric circuits as "important while 30.9% consider the statement to be "very important.

Table 5.47: I want to study more on electric circuits because I enjoy the way my misconceptions are addressed and changes.

Responses	Very important	Important	Not important	Total
Frequencies	20	48	0	68
Percentage	29.4	70.6	0.0	100.0

Table 5.47 shows that 70.6% of learners regard studying more on electric circuits to be "important" because they enjoy how misconceptions are addressed while 29.4% consider the statement to be "very important".

Table 5.48: I am forced to study electric circuits.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	0	0	2	49	17	68
Percentage	0.0	0.0	2.9	72.1	25.0	100.0

Table 5.48 shows that 97.1% "disagree and totally disagree" that they are not forced to study electric circuits.

Synthesis

Based on the control group learners' responses to statements on information on simple electric circuits, the following can be deduced;

- Almost all learners agree that they like to solve problems on simple electric circuits.
- Majority of learners disagree that they can relate the work on simple electric circuit to their everyday life experiences.
- Most learners agree that they like performing experiments on electric circuits.
- Most learners agree that the work on electric circuits motivate them to pursue studies in sciences.
- Majority of learners agree that the experiments on simple electric circuit develop their skill to handle apparatus.
- Most learners agree that the study of simple electric circuits develop their understanding of science concepts.
- Majority of learners agree that the tasks based on simple electric circuits helped them to analyze problems.
- Almost all learners agree that electric circuits give them the opportunity to learn by doing experiments on their own.
- Most learners do agree that the experiments involving simple electric circuits require understanding.
- Most learners agree that the study of electric circuits helped them to learn how to be creative and to find answers to problems.
- Almost all learners agree that they enjoy lessons based on simple electric circuits.
- All learners believe that studying and doing more experiments on electric circuits are important.
- Almost all learners disagree that they are forced to study electric circuits.

5.2.8 **Experimental group learners' responses to information on simple electric circuit (Questionnaire Part III)**

The following tables present experimental learners response to the structural questions of the questionnaire.

Table 5.49: I like to solve problems on simple electric circuit (SEC).

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	10	32	21	2	3	68
Percentage	14.7	47.1	30.9	2.9	4.4	100.0

Table 5.49 illustrates that 78.0% ‘agree and agree with reservations” that they like to solve problems on simple electric circuit. It further shows that only 7.3% “disagree and totally disagree” to the statement.

Table 5.50: I can easily relate the work on simple electric circuit to my everyday life experiences.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	0	24	6	32	6	68
Percentage	0.0	35.3	8.8	47.1	8.8	100.0

Table 5.50 shows that almost half of learners, 44.1% “agree and agree with reservations” that they can relate the work on simple electric circuit to their everyday life experiences, while almost another half, 55.9% “disagree and totally disagree” to the statement.

Table 5.51: I like doing experiments on electric circuit.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagre e	Total
Frequencies	5	40	15	8	0	68
Percentage	7.4	58.8	22.1	11.8	0.0	100.0

Table 5.51 indicates that majority of learners, 80.9% "agree and agree with reservations" that they like doing experiments on electric circuit while minority, 11.8% "disagree" to the statement.

Table 5.52: The work on electric circuits motivates me to pursue my studies in sciences after grade 12.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	15	40	8	5	0	68
Percentage	22.1	58.8	11.8	7.4	0.0	100.0

Table 5.52 shows that 80.9% "agree and totally agree" that the work on electric circuits motivates them to pursue their studies in sciences after grade 12 while only 7.4% "disagree" to the statement.

Table 5.53: The experiments on simple electric circuit develop my skill to handle apparatus.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	15	29	16	4	4	68
Percentage	22.1	42.6	23.5	5.9	5.9	100.0

Table 5.53 indicates that 66.1% "agree and agree with reservations" that the experiments on simple electric circuit develop my skill to handle apparatus. On the other hand, 11.8% "disagree and totally disagree" to the statement.

Table 5.54: The study of simple electric circuits develops my understanding in science.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	16	33	10	6	3	68
Percentage	23.5	48.5	14.7	8.8	4.4	100.0

Table 5.54 shows that 72.0% "agree and totally agree" that the study of simple electric circuits develop their understanding in science while 13.2% "disagree and totally disagree" to the statement.

Table 5.55: The tasks based on simple electric circuits helped me to analyze problems.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	12	50	3	3	0	68
Percentage	17.6	73.5	4.4	4.4	0.0	100.0

Table 5.55 points out that 91.1% "agree and totally agree" that the tasks based on simple electric circuits helped them to analyze problems.

Table 5.56: Electric circuits give me the opportunity to learn by doing experiments on my own.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	12	47	5	4	0	68
Percentage	17.8	69.1	7.4	5.9	0.0	100.0

Table 5.56 demonstrates that 86.9% “agree and totally agree” that electric circuits give them the opportunity to learn by doing experiments on their own while only 5.9% “disagree” to the statement.

Table 5.57: The experiments involving simple electric circuits require/demand understanding.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	19	30	10	5	4	68
Percentage	27.9	44.1	14.7	7.4	5.9	100.0

Table 5.57 shows that 72,0% “agree and totally agree” that the experiments involving simple electric circuits require understanding while 13.3% “disagree and totally disagree” to the statement.

Table 5.58: In the electric circuit I learn to find answers to problems.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	30	25	5	5	3	68
Percentage	44.1	36.8	7.4	7.4	4.4	100.0

Table 5.58 illustrates that 80.9% “agree and totally agree” that in the electric circuit they learn to find answers to problems while 11.8% “disagree and totally disagree” to the statement.

Table 5.59: Experiments in simple electric circuits help me to become creative in science.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	14	35	7	9	3	68
Percentage	20.6	51.5	10.3	13.2	4.4	100.0

Table 5.59 shows that 72.1% “agree and totally agree” that experiments in simple electric circuits help them to become creative in science while 17.6% “disagree and totally disagree” to the statement.

Table 5.60: I usually enjoy lessons based on simple electric circuits.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	19	47	1	0	1	68
Percentage	27.9	69.1	1.5	0.0	1.5	100.0

Table 5.60 indicates that 97.0% “agree and totally agree” that they usually enjoy lessons based on simple electric circuits.

Table 5.61: I consider studying electric circuits because it offers me an opportunity for doing practical work on my own.

Responses	Very important	Important	Not important	Total
Frequencies	34	33	1	68
Percentage	50.0	48.5	1.5	100.0

Table 5.61 shows that 98.5% consider studying electric circuits as "important and very important" because it offers them an opportunity for doing practical work on their own.

Table 5.62: I intent doing more experiments on electric circuits because I gain scientific knowledge.

Responses	Very important	Important	Not important	Total
Frequencies	24	44	0	68
Percentage	35.3	64.7	0.0	100.0

Table 5.62 indicates that all learners intent doing more experiments on electric circuits.

Table 5.63: I want to study more on electric circuits because I enjoy the way my misconceptions are addressed and changes.

Responses	Very important	Important	Not important	Total
Frequencies	21	47	0	68
Percentage	30.9	69.1	0.0	100.0

Table 5.63 illustrates that all learners enjoy the way their misconceptions are addressed.

Table 5.64: I am forced to study electric circuits.

Responses	Totally agree	Agree	Agree with Reservations	Disagree	Totally disagree	Total
Frequencies	0	2	0	51	15	68
Percentage	0.0	2.9	0.0	75.0	22.1	100.0

Table 5.64 shows that 97.1% "disagree and totally disagree" that they are forced to study electric circuits.

Synthesis

Based on the experimental group learners' responses to statements on information on simple electric circuits, the following can be deduced;

- Majority of learners agree that they like to solve problems on simple electric circuit;
- Almost half of learners agree while almost another half disagree that they can relate the work on simple electric circuit to their everyday life experiences;
- Most learners agree that they like doing experiments on electric circuit;
- Most learners agree that the work on electric circuits motivate them to pursue their studies in sciences;
- Majority of learners agree that the experiments on simple electric circuit develop their skill to handle apparatus;
- Most learners agree that the study of simple electric circuits develop their understanding of science concepts;
- Most learners agree that the designed tasks helped them to analyze problems;
- Most learners agree that electric circuits give them the opportunity to carry out experiments on their own;

- Most learners believe that the experiments involving simple electric circuits require understanding;
- Majority of learners agree that electric circuit assisted them to find answers to problems and to become creative in science.
- Almost all learners agree that they enjoy lessons based on simple electric circuit
- Almost all learners believe that studying electric circuit is important.
- All learners intent doing more experiments on electric circuits because they enjoy the way their misconceptions are addressed.
- All learners disagree that they are forced to study electric circuits.

5.2.9 **Comparison between control and experimental groups' responses to the information on simple electric circuit**

The paragraph below compares the responses to the information on simple electric circuit of the participants relative to each group (Control and experimental):

- All learners of the control group as compared to most learners of the experimental group agree that they like to solve problems on simple electric circuit;
- Most learners of the control group as compared to half of learners of the experimental group disagree that they can relate the work on simple electric circuit to their everyday life experiences;
- Most learners from both groups agree that they like doing experiments on simple electric circuit;
- Most learners from both groups agree that the work on electric circuits motivate them to pursue studies in sciences;
- Majority of learners from both groups agree that the experiments on simple electric circuit develop their skill to handle apparatus;
- Most learners from both groups agree that the study of simple electric circuits develop their understanding of science concepts;
- Majority of learners from both groups agree that the tasks based on simple electric circuits helped them to analyze problems;

- Most learners agree that electric circuits give them the opportunity to carry out experiments on their own;
- All learners of the control group as compared to most learners of experimental group agree that electric circuits give them the opportunity to learn by doing experiments on their own;
- Most learners from both groups believe that experiments involving simple electric circuits require understanding;
- Most learners from both groups agree that the study of electric circuits helped them to learn how to be creative and to find answers to problems;
- All learners from both groups agree that they enjoy lessons based on simple electric circuit;
- All learners from both groups believe that studying and doing more experiments on electric circuits are important;
- All learners from both groups disagree that they are forced to study electric circuits.

5.2.10 **Experimental group learners' responses to information on Conceptual Change Model** (**Questionnaire Part IV**)

The following tables present experimental learners' response to the structural questions of the questionnaire that deals with the Conceptual Change Model. An asterisk (*) will be used to indicate the number of learners who did not respond to a particular question. This section indicates what the experimental learners' responses are after they have been exposed to the CCM.

Table 5.65: It was my experience that after a series of lessons on simple electric circuit, I understood science concepts better (item 32).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	27	9	31	1	0	68
Percentage	39.7	13.2	45.6	1.5	0.0	100.0

The result in table 5.65 indicates that 85.3% "agree and totally agree" that after a series of lessons on simple electric circuit, they understood science concepts better.

Table 5.66: The atmosphere during lessons presentation stimulates or promotes. my scientific thinking (item 33)

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	22	3	43	0	0	68
Percentage	32.4	4.4	63.2	0.0	0.0	100.0

Table 5.66 demonstrates that 95.6% "agree and totally agree" that the atmosphere during lessons presentation stimulates their scientific thinking.

Table 5.67: I like Physical Sciences more after attending lessons based on electric circuits (item 34).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	45	5	16	2	0	68
Percentage	66.2	7.4	23.5	2.9	0.0	100.0

Table 5.67 indicates that 89.7% "agree and totally agree" that they like Physical Sciences more after attending the lessons based on electric circuits while 2.9% "disagree" to the statement.

Table 5.68: I learned new things in the electric circuit lessons (item 35).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	45	7	12	4	0	68
Percentage	66.2	10.3	17.6	5.9	0.0	100.0

The frequency table 5.68 illustrates that 83.8% "agree and totally agree" that they learned new things in the electric circuit lessons. Only 5.9% 'disagree" to the statement.

Table 5.69: I have learned how to investigate things in science (item 36).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	45	3	14	1	1	68
Percentage	72.1	4.4	20.6	1.5	1.5	100.0

The results displayed in table 5.69 indicates that 92.7% "agree and totally agree" that they have learned how to investigate things in science while 3.0% "disagree and totally disagree" to the statement.

Table 5.70: I could easily collaborate (work) with my peers/ friends (item 37).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	52	1	12	2	1	68
Percentage	76.5	1.5	17.6	2.9	1.5	100.0

Table 5.70 shows that 94.1% "agree and totally agree" that they could easily collaborate with their peers while 4.4% "disagree and totally disagree" to the statement.

Table 5.71: Because of the experiments conducted during lessons' presentation I developed a positive attitude towards physical sciences (item 38).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	19	8	38	2	1	68
Percentage	27.9	11.8	55.9	2.9	1.5	100.0

Table 5.71 shows that 83.8% "agree and totally agree" that they developed a positive attitude towards physical sciences while 4.4% "disagree and totally disagree" to the statement.

Table 5.72: Before the series of lessons on electric circuit I had problems to execute experiments on my own (item 39).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	10	27	28	1	2	68
Percentage	14.7	39.7	41.2	1.5	2.9	100.0

Table 5.72 indicates that 80.9% "agree and agree with reservations" that before the series of lessons on electric circuit they had problems to execute experiments on their own.

Table 5.73: The lesson presentation on electric circuit captured my interest for the entire session (item 40).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	48	5	12	1	2	68
Percentage	70.6	7.4	17.6	1.5	2.9	100.0

Table 5.73 illustrates that 88.2% "agree and totally agree" that lesson presentations on electric circuit captured their interest.

Table 5.74: Attending this session was worthwhile (item 41).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	55	2	11	0	0	68
Percentage	80.9	2.9	16.2	0	0	100.0

Table 5.74 indicates that 97.1% "agree and totally agree" that attending the session on lesson presented through the lens of CCM was worthwhile.

Table 5.75: I see electric circuit as the area in science where I can sharpen my handling skills of apparatus (item 42).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	12	5	47	4	0	68
Percentage	17.6	7.4	69.1	5.9	0	100.0

Table 5.75 shows that 86.7% “agree and totally agree” that electric circuit is the area in science where they can sharpen their handling skills (of apparatus) while 5.9% “disagree” to the statement.

Table 5.76: The practical investigations in electric circuits relate to my everyday experiences (item 43).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	11	5	48	3	1	68
Percentage	16.2	7.4	70.6	4.4	1.5	100.0

Table 5.76 illustrates that 86.8% “agree and totally agree” that the practical investigations in electric circuits relate to their everyday experiences while 5.9% ‘disagree and totally disagree” to the statement.

Table 5.77:I consider studying electric circuits again because it offers me an opportunity for doing practical work on my own (item 44).

Responses	Very important	Important	Not important	Total
Frequencies	38	27	3	68
Percentage	55.9	39.7	4.4	100.0

Table 5.77 shows that 95.6% considered studying electric circuits as “important and very important”.

Table 5.78: I intent doing more experiments on electric circuits again because I gain scientific knowledge (item 45).

Responses	Very important	Important	Not important	Total
Frequencies	43	24	1	68
Percentage	63.2	35.3	1.5	100.0

Table 5.78 indicates that 98.5% consider doing more experiments on electric circuits as "important and very important".

Table 5.79: I want to investigate more on electric circuits because I enjoy the way my misconceptions are addressed and changes (item 46).

Responses	Very important	Important	Not important	Total
Frequencies	27	39	2	68
Percentage	39.7	57.4	2.9	100.0

Table 5.79 indicates that 97.1% regarded performing more investigating on electric circuits as "important and very important" because they are offered an opportunity to challenge their misconceptions.

Table 5.80: I will not do investigations or study electric circuits again (item 47).

Responses	Totally agree	Agree with Reservations	Agree	Disagree	Totally disagree	Total
Frequencies	0	0	0	9	59	68
Percentage	0.0	0.0	0.0	13.2	86.8	100.0

Table 5.80 indicates that all learners “disagree and totally disagree” that they never carry out investigations or study electric circuits again.

Synthesis

Based on the experimental group learners’ responses to statements on information on Conceptual Change Model, the following can be deduced;

- Almost all learners agree that they understood science concepts better.
- All learners agree that the atmosphere during lessons stimulated their thinking.
- Most learners agree that presentation on electric circuit inspired them.
- Most learners agree that they have learnt new things (concepts).
- Most learners agree that they have learned how to investigate in science.
- Majority of learners agree that they could easily collaborate with their peers.
- Most learners agree that they developed a positive attitude towards physical sciences.
- Most learners agree that they had problems to carry out experiments on their won.
- Most learners agree that lesson on electric circuit captured their interest.
- All learners agree that attending the session on CCM was worthwhile.
- Most learners agree that electric circuit may develop their handling skills.
- Most learners agree that the practical investigations in electric circuits relate to their everyday experiences.
- Almost all learners believe that it is important to carry out more experiments on electric circuits.
- Almost all learners believe that investigations on electric circuits offer opportunity to challenge their misconceptions.
- All learners disagree that they will never conduct investigations on electric circuits again.

5.3 **Presentation of the control and experimental groups' responses to Simple Electric Circuit Conceptual Test (SECCT)**

The paragraphs and tables below present participants responses to SECCT (Appendix 3) questions. The questions were based on learners' conceptual understanding and application of simple electric circuit. Both groups wrote the test prior to and after the experimental group was exposed to the intervention.

5.3.1 **Pre-test responses to SECCT for control and experimental groups**

Table 5.81 below indicates control and experimental groups' responses to the pre-test responses to SECCT.

Table 5.81: Pre-test results to SECCT.

Group	Results	N=68	Q1	Q2(a)	Q2(b)	Q2(c)	Q2(d)	Q3	Q4(i)	Q4(ii)	Q5(a)	Q5(b)	Q6	Q7	Q8	Aver
Control	Correct	Total	21	15	12	15	13	12	9	10	10	9	13	19	11	19.1
		%	30.9	22.1	17.6	22.1	19.1	17.6	13.2	14.7	14.7	13.2	19.1	27.9	16.2	19.1
	Wrong	Total	47	53	56	53	55	56	59	58	58	59	55	49	57	80.9
		%	69.1	77.9	82.4	77.9	80.9	82.4	86.8	85.3	85.3	86.8	80.9	72.1	83.8	80.9
Experimental	Correct	Total	19	13	12	12	13	11	11	13	9	6	11	12	13	17.5
		%	27.9	19.1	17.6	17.6	19.1	16.2	16.2	19.1	13.2	8.8	16.2	17.6	19.1	17.5
	Wrong	Total	49	55	56	56	55	57	57	55	59	62	57	56	55	82.5
		%	72.1	80.9	82.4	82.4	80.9	83.8	83.8	80.9	86.8	91.2	83.8	82.4	80.9	82.5

5.3.1.1 Response to question 1

Table 5.81 indicates that of the control group, 21 learners (30.9%) got this question correct while the others got it wrong and on the other hand, only 19 learners (27.9%) of the experimental group got it correct. The reason for this performance to question 1 might be lack of exposure to practical work as indicated in paragraph 5.2.6. Based on the explanations given, most learners thought that increase in the number of batteries always increases the potential difference.

5.3.1.2 Response to question 2(a)

Table 5.81 shows that of the control group, 15 learners (22.1%) got this question correct while others got it wrong. Table 5.80 also indicates that 13 learners (19.1%) of the experimental group got the same question correct. The reason for this might be the dominance of teacher demonstration rather than learners carrying out experiments on their own as indicated in paragraph 5.2.6. Summarising the reasons provided one could deduce that learners have a thought of the brightness of the bulb as results of current path to be one way in the series circuits. The same ideology emerged when responding to question 2 (b-d).

5.3.1.3 Response to question 2(b)

Table 5.81 indicates that 12 learners (17.6%) of each group got the question correct while others (82.4%) of each group got it wrong. The reason for this might be that learners are unable to integrate theory on electric circuits and practice as shown in paragraph 5.2.9.

5.3.1.4 Response to question 2(c)

Table 5.81 indicates that of the control group, 15 learners (22.1%) got this question correct as compared to 12 learners (17.6%) of the experimental group who got the same question correct; others from each group got it wrong. The reason for this performance might be that the work on simple electric circuits requires understanding as indicated by paragraph 5.2.9.

5.3.1.5 Response to question 2(d)

Table 5.81 shows that 13 learners (19.1%) of both groups got the question correct while 55 learners (80.9%) from each group got it wrong. The reason for this performance might be that the works on simple electric circuits require understanding as indicated by paragraph 5.2.9.

5.3.1.6 Response to question 3

Table 5.81 indicates that 12 learners (17.6%) of the control group got the question correct as compared to 11 learners (16.2%) of the experimental group who got it correct while other learners from these groups got it wrong. The reason for this performance to question 3 might be lack of exposure to practical work as indicated in paragraph 5.2.6.

5.3.1.7 Response to question 4(i)

Table 5.81 indicates that of the experimental group, 11 learners (16.2%) got this question correct while the others got it wrong and on the other hand only 9 learners (13.2%) of the control group got it correct. The reason for this might be that learners are unable to integrate theory on electric circuits and practice as shown in paragraph 5.2.9.

5.3.1.8 Response to question 4(ii)

Table 5.81 indicates that of the experimental group, 13 learners (19.1%) got this question correct while the others (80.9%) got it wrong and on the other hand only 10 learners (14.7%) of the control group got it correct. The reason for this might be that learners are unable to integrate theory on electric circuits and practice as shown in paragraph 5.2.9.

5.3.1.9 Response to question 5(a)

Table 5.81 demonstrates that of the control group, 10 learners (14.7%) got it correct while others (85.3%) got it wrong. On the other hand, of the experimental group, 9 learners (13.2%) got it correct while others (86.8%) got it wrong. The reason for this performance to question 3 might be lack of exposure to practical work as indicated in paragraph 5.2.6.

5.3.1.10 Response to question 5(b)

Table 5.81 compares learners’ responses to this question from the two groups (control and experimental). The table shows that of the control group, 9 learners (13.2%) got it correct while others (86.8%) got it wrong. On the other hand only 6 learners (8.8%) of the experimental group got the same question correct, whereas others (91.2%) got it wrong. The reason for this performance to question 3 might be lack of exposure to practical work as indicated in paragraph 5.2.6.

5.3.1.11 Response to question 6

Table 5.81 shows that of the control group, 13 learners (19.1%) got it correct while others (80.9%) got it wrong. Table 5.80 also indicates that of the experimental group, 11 learners (16.2%) got the same question correct while others (83.8%) got it wrong. The reason for this performance might be that the work on simple electric circuits requires understanding as indicated by paragraph 5.2.9.

5.3.1.12 Response to question 7

Table 5.81 indicates that 19 learners (27.9%) of the control group got it correct while others got it wrong. The same table indicates that of the experimental group, 12 learners (17.6%) got it correct whereas others got (82.4%) it wrong. The reason for this performance to question 3 might be lack of exposure to practical work as indicated in paragraph 5.2.6.

5.3.1.13 Response to question 8

Table 5.81 shows that of the experimental group, 13 learners (19.1%) got it correct while others (80.9%) got it wrong. On the other hand, 11 learners (16.2%) of the experimental group got it correct whereas other (83.8%) got it wrong. The reason for this performance to question 3 might be lack of exposure to practical work as indicated in paragraph 5.2.6.

5.3.2 **Post test responses to SECCT for control and experimental groups**

Table 5.82 below indicates control and experimental groups' responses to the SECCT post test.

Table 5.82: Post test results to SECCT.

Group	Results	N=68	Q1	Q2(a)	Q2(b)	Q2(c)	Q2(d)	Q3	Q4(i)	Q4(ii)	Q5(a)	Q5(b)	Q6	Q7	Q8	Aver
Control	Correct	Total	27	21	23	17	19	16	19	16	17	12	15	18	22	27.4
		%	39.7	30.9	33.8	25.0	27.9	23.5	27.9	23.5	25.0	17.6	22.1	26.5	32.4	27.4
	Wrong	Total	41	47	45	51	49	52	49	52	51	56	53	50	46	72.6
		%	60.3	69.1	66.2	75.0	72.1	76.5	72.1	76.5	75.0	82.4	77.9	73.5	67.6	72.6
Experimental	Correct	Total	64	41	36	39	29	56	48	43	35	41	42	43	50	64.4
		%	94.1	60.3	52.9	57.4	42.6	82.4	70.6	63.2	51.5	60.3	61.8	63.2	73.5	64.4
	Wrong	Total	4	27	32	29	39	12	20	25	33	27	26	25	18	35.6
		%	5.9	39.7	47.1	42.6	57.4	17.6	29.4	36.8	48.5	39.7	38.2	36.8	26.5	35.6

5.3.2.1 Response to question 1

Table 5.82 indicates that 27 learners (30.7%) of the control group got it correct while others got it wrong. On the other hand, of the experimental group, 64 learners (94.1%) got it correct while others (5.9%) got it wrong. The reason might be that the experimental group was exposed to practical work as indicated by paragraph 5.2.10.

5.3.2.2 Response to question 2(a)

Table 5.82 shows that of the experimental group 41 learners (60.3%) got it correct while others got it wrong. This table further indicates that only 21 learners (30.9%) of the control group got it correct while others (69.1%) got it wrong. The reason might be the influence of teaching and learning of simple electric circuits using the Conceptual Change Model as indicated in paragraph 5.2.10.

5.3.2.3 Response to question 2(b)

Table 5.82 indicates that of the experimental group, 36 learners (57.4%) got this question correct while others got it wrong. On the other hand, 17 learners (33.8%) of the control group got it correct while others got it wrong. The reason could be that learners (in experimental group) developed positive attitude towards physical sciences as in paragraph 5.2.10.

5.3.2.4 Response to question 2(c)

Table 5.82 indicates that of the experimental group, 39 learners (52.9%) got this question correct while others got it wrong. On the other hand, 23 learners (25.0%) of the control group got it correct while others got it wrong. The reason might be that attending lessons based on CCM was worthwhile as indicated in paragraph 5.2.10.

5.3.2.5 Response to question 2(d)

Table 5.82 indicates that of the experimental group, 29 learners (42.6%) got this question correct while others got it wrong as compared to 23 learners (25.0%) of the control who group got it correct while others got it wrong. The reason could be that learners still lack observational, problem solving and creative thinking skills as in paragraph 5.2.9 and 5.2.10.

5.3.2.6 Response to question 3

Table 5.82 indicates that of the experimental group, 56 learners (82.4%) got this question correct while others got it wrong. On the other hand, 16 learners (23.5%) of the control group got the same question correct while others got it wrong. The reason might be that the experimental group was exposed to practical work as indicated by paragraph 5.2.10.

5.3.2.7 Response to question 4(i)

Table 5.82 shows that of the experimental group, 48 learners (70.6%) got it correct while others got it wrong. This table further indicates that 19 learners (27.9%) of the control group got it correct while others got it wrong. The reason might be that the experimental group was exposed to practical work as indicated by paragraph 5.2.10.

5.3.2.8 Response to question 4(ii)

Table 5.82 indicates that of the experimental group, 43 learners (63.2%) got this question correct while others got it wrong. On the other hand, 16 learners (23.5%) of the control group got the same question correct while others got it wrong. The reason might be that the experimental group was exposed to practical work as indicated by paragraph 5.2.10.

5.3.2.9 Response to question 5(a)

Table 5.82 indicates that of the experimental group, 35 learners (51.5%) got this question correct while others got it wrong. On the other hand, 17 learners (25.0%) of the control group got the same question correct while others got it wrong. The reason might be that the experimental group was exposed to practical work as indicated by paragraph 5.2.10.

5.3.2.10 Response to question 5(b)

Table 5.82 indicates that of the experimental group, 41 learners (60.3%) got this question correct while others got it wrong. On the other hand, 12 learners (17.6%) of the control group got the same question correct while others got it wrong. The reason might be that the experimental group was exposed to practical work as indicated by paragraph 5.2.10.

5.3.2.11 Response to question 6

Table 5.82 shows that of the experimental group, 43 learners (63.2%) got it correct while others got it wrong. This table further indicates that 15 learners (22.1%) of the control group got it correct while others got it wrong. The reason might be that learners in experimental group developed good interpretation skill as in paragraph 5.2.10.

5.3.2.12 Response to question 7

Table 5.82 indicates that of the experimental group, 35 learners (51.5%) got this question correct while others got it wrong. On the other hand, 18 learners (26.5%) of the control group got the same question correct while others got it wrong. The reason might be that learners in experimental group could easily relate their work on simple electric circuit to their everyday life experiences as in paragraph 5.2.10.

5.3.2.13 Response to question 8

Table 5.82 indicates that of the experimental group, 50 learners (73.5%) got this question correct while others got it wrong. On the other hand, 22 learners (32.4%) of the control group got the same question correct while others got it wrong. The reason might be that the experimental group was exposed to practical work as indicated by paragraph 5.2.10.

5.4 **The ANOVA results between groups**

ANOVA, a statistical method that yields values that can be tested to determine whether or not a significant relation exists between variables (Bailey, 2008) was performed hereunder to ascertain whether there was any statistical mean difference between scores in schools.

On the other hand, effect size (Becker, 2000; Rosnow *et al.*, 2000; Lee, 2000; Thalheiemer and Cook, 2002; Weinberg and Abramowitz, 2008) is used to compare the treatment effect of TPI and CCM Effect sizes (*d*) are important because they allow one to compare the magnitude of experimental treatments from one experiment to another.

This study incorporated both the statistical significance ($\alpha = 0.05$) to interpret the mean differences between variances and effect sizes (Cohen's *d*) to interpret the effect of an intervention strategy. Both statistics were used because the statistical significance on its own has unacceptable index of effect (Thomson, 2001, 2002; Wright, 2003; Kline, 2004). The ES were computed as Cohen's *d*, Cohen (cited in Pallat, 2007: 206). That is, "weak effect, $d = 0.2$", "medium effect, $d = 0.50$" and "strong effect, $d = 0.8$ and more".

Table 5.83: Descriptive statistics for analysis of variances.

Descriptives

Pre-score

	N	**Mean**	**Std. Deviation**	**Effect Sizes** School A with	School B with	School C with
A	34	2.62	1.181			
B	34	2.24	1.327	.29		
C	34	2.41	1.234	.16	.1	
D	34	2.38	1.436	.16	.1	.02
Total	136	2.41	1.291			

The descriptive statistic in table 5.83 illustrates the number of respondents wrote the test per school, their mean mark, standard deviation and effect sizes. Schools had different mean values in the pre-test scores. School A had more mean while school B had least mean value. Table 5.80 further shows the variation in effect sizes among schools. It is observed that the effect sizes of school A with school C and D, school B with school C and D, and school C with school D were weak ($d < 0.2$). There was a slightly moderate effect size of school A with B. Therefore the effect of instruction prior the study was weak.

The Levene's test (Montgomery, 2004) is conducted to test whether or not the variances of the groups are statistically different. If the Levene's test shows a "Sig. Value" less than 0.05, then the variances are significantly different. The Levene statistic's 'Sig.' value of 0.664 shows $p > 0.05$. Therefore the test of homogeneity of variances indicates that mean differences among schools were not significantly different. That is, these means were almost similar. The validity of the above results is strengthened by the ANOVA output that gave the p (0.683) > 0.05.

The Turkey test conducted compare pre-test means of each school with the other three schools. This information assisted the researcher to compare the means of pre-scores for groups in homogeneous subset.

It could therefore be concluded that all groups had the same knowledge of the topic before intervention.

5.4.1 **Presentation of t-test results on pre-test and post-test scores.**

The t-test between experimental group and control group was performed to determine whether the pre-test scores were comparable.

Table 5.84: A t-test for control and experimental group.

Group Descriptive Statistics: Pre-scores

	Group	N	Mean	Std. Deviation	Std. Error Mean	Effect Sizes
Pre-score	Control	68	2.50	1.310	.159	
	Experimental	68	2.32	1.275	.155	.132

The group descriptive test in table 5.84 reveals that both groups had N = 68. The control group had a mean value of 2.50 whereas that of experimental group was 2.32. These mean score values differ slightly, however, table 5.85 would inform us if the observed mean difference is statistically significant or not. There was a weak effect size ($d < 0.132$) in these groups.

The Levene's test for equality of variances and the t-test for equality of means show the p value (0.427) > 0.05. This tells us that the mean difference between pre-scores of the two groups was not statistically significant. To compare the effect of intervention (natural schooling over time), the paired t-test was performed.

Table 5.85: Means and standard deviations in a Paired Samples t-test.

Paired Sample Statistics

Group			Mean	N	Std. Deviation	Std. Error Mean	Effect Size
Control	Pair 1	Pre-score	2.50	68	1.310	.159	.9
		Post score	3.71	68	1.052	.128	
Experimental	Pair 2	Pre-score	2.32	68	1.275	.155	4.2
		Post score	7.72	68	1.674	.203	

The computer output in table 5.85 showed that there were a mean differences between the pre-test and post test scores in the control group. Similar situation was observation in the experimental group. The experimental group post score mean was more than the post score mean of the control group. Effect sizes of both groups were more than 0.8. However, the control group had an effect size ($d = 0.9$) less than that of the experimental group (4.2).

Paired sample test and sample correlation were conducted. Correlation was carried out to measure the strength of a linear relationship between two variables. According to Cohen *at al*., (2011: 614) the correlation coefficient is always between -1 and +1. The closer the correlation is to +1 or -1, the closer it is to a perfect linear relationship, then the stronger is the association.

Weinberg and Abramowitz (2008: 131) maintain that the sign of the correlation value indicates the nature (negative or positive association) of the association between the two variables while the correlation magnitude shows the strength (weak or strong association) of the association.

In this study the correlation value is interpreted based on the following criteria:

- -1.0 to -0.7 strong negative association.
- -0.7 to -0.3 weak negative association.
- -0.3 to +0.3 little or (0 no association).
- +0.3 to +0.7 weak positive association.
- +0.7 to +1.0 strong positive association

The statistical analysis in table 5.86 indicates that the control group ($r = 0.520$) had $p < 0.05$. The r-value showed a weak positive association between the pre-test and post test scores, while *p*-value showed that there was a less than 0.05 probability that a correlation coefficient would have occurred by chance in a sample of $N = 68$ (Field, 2003:88). The significance (*p*) value tells us that the probability of these correlations were low.

For experimental group, $r = -0.041$ and $p > 0.05$. The negative nature of this correlation is an indicative of the fact that there were respondents who obtained low scores in the pre-test while in the post test the same respondents obtained high scores or vice versa. According to the criteria stated above, this group gave little negative association.

Table 5.86: The Paired Sample t-test.

Paired sample Test and sample correlation

Group			Paired Differences					T	Df	Sig. (2-tailed)	r-value	p-value
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference						
						Lower	Upper					
Control	Pair 1	Pre-score – Post score	-1.206	1.179	.143	-1.491	-.921	-8.435	67	.000	.520	.000
Experimental	Pair 2	Pre-score – Post score	-5.397	2.145	.260	-5.916	-4.878	-20.748	67	.000	-.041	0.740

The paired sample test in table 5.86 reflects the $p < 0.05$ for pre-score and post score of the control group. The *p*-value indicates that mean differences between the pre-test and post test scores in the control group are statistically significant. On other hand the mean differences between the pre-test and post test scores in the experimental group are not statistically significant ($p > 0.05$). The magnitude of these effects would be explored using analysis of covariance (ANCOVA).

5.4.2 **Presentation of ANCOVA results**

5.4.2.1 **The ANCOVA results between schools**

The researcher compared the post test scores by controlling for pre-test scores by means of ANCOVA. The ANCOVA using pretest score as a covariate measures was conducted to measure the effect of instructions on learners' academic achievement. According to Langin (1993) the analysis of covariance can be defined as the procedure for comparing mean values of a response variable between groups when the response variable covaries with other continuous variables (covariates). The inclusion of covariates in this model would reduce unexplained variation and thus increase power of the ANCOVA.

Table 5.87 indicates the Effect Sizes. School A had stronger effect with school B, and school C (*d* > 0.8) and had weaker effect with School D (d =0.20). The ES of school B and school C with school D is the same and strong (d > 0.8). It is observed that the ES of schools within the group (A with D and B with C) is weak.

Table 5.87: The Means and Effect Sizes: ANCOVA.

Estimates

Dependent Variable: Post score					
School			Effect Sizes		
		Mean	A with	B with	C with
	A	3.549			
	B	7.622	2.94		
	C	7.853	3.11	0.17	
	D	3.829	0.20	2.90	2.90

a. Covariates appearing in the model are evaluated at the following values: Pre-score = 2.41.

Table 5.88 shows estimated marginal means, after applying pre-scores as a covariate. The results in this table indicate that the estimated marginal mean has increased.

The ANCOVA assisted the researcher to ascertain whether the groups were significantly different in terms of their scores on the dependent variable (post score). The 'Sig.' value corresponding to the independent variable 'school' is less than 0.05, then it can be concluded that the groups differ significantly.

The other information we can get from ANCOVA concerns the influence of our covariate (pre-score). The information will indicate whether there is a practical significant relationship between the covariate and the dependant variable, while controlling for the independent variable (school). The *p*-value corresponding to 'pre-score' is also less than 0.05, meaning that the covariate is significant.

5.4.2.2 **The ANCOVA results between groups**

Table 5.88: The Means and Effect Sizes in ANCOVA.

Estimates

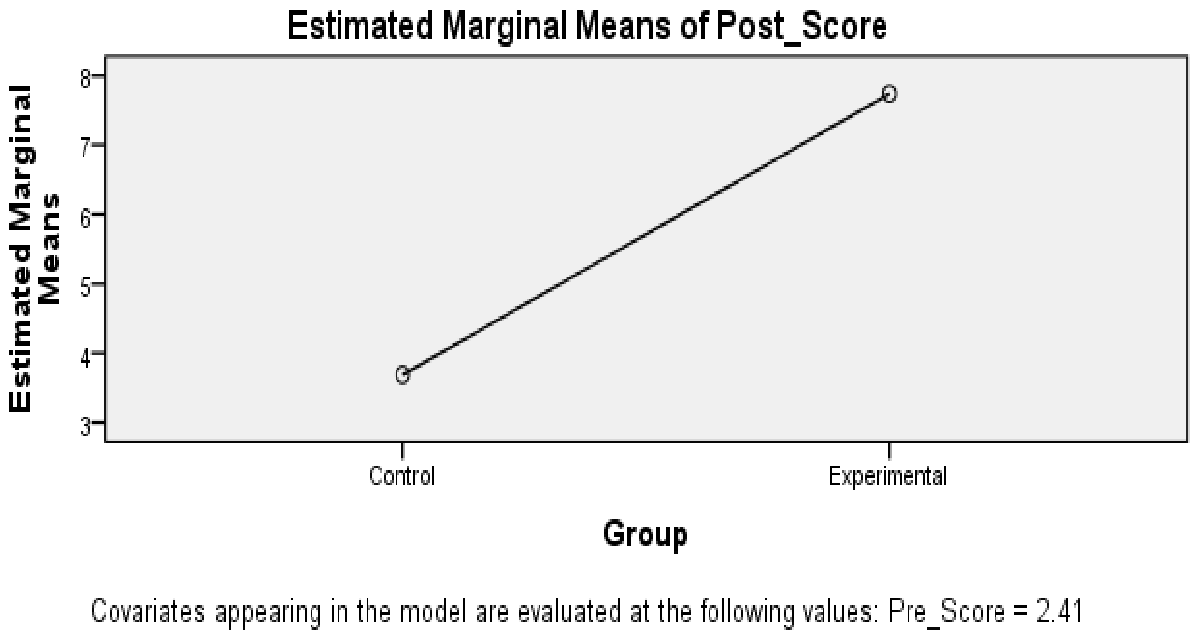
Dependent Variable: Post score

Group	Mean	Effect Size
Control	3.689	2.93
Experimental	7.737	

a. Covariates appearing in the model are evaluated at the following values: Pre-score = 2.41.

The estimated marginal means in table 5.88 shows that the mean scores were different. The experimental group had greater mean score value than the control group. There was a practical effect size ($d > 0.8$) between these groups.

: **Figure 5.1: The graph depicting the estimated marginal means between groups.**



From the graph above, the post test score mean differences between the two groups was clearly shown. The results of F-test and ANCOVA indicate that *p*-value < 0.05. This shows that the difference between the estimated marginal means were statistically significant, meaning that these means were different.

Table 5.89: Case Summary.

Between-Subjects Factors

		Value Label	N
Group	1	Control	68
	2	Experimental	68

Table 5.90: Between-Subject effects in ANCOVA.

ANCOVA
Tests of Between-Subjects Effects

Dependent Variable: Post score					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	555.942[a]	2	277.971	145.624	.000
Intercept	829.772	1	829.772	434.702	.000
Pre_Score	7.934	1	7.934	4.157	.043
Group	554.492	1	554.492	290.488	.000
Error	253.874	133	1.909		
Total	5249.000	136			
Corrected Total	809.816	135			

a. R Squared = .687 (Adjusted R Squared = .682)

The respondents who wrote the post test in each group were N = 68 (Table 5.89). The main ANCOVA results in table 5.90 compare the post test scores between groups. The *p* value corresponding to the independent variable (school) is less than 0.05. This indicates that the groups' mode of instructions differ significantly. It could also be observed that the *p* value corresponding to 'pre-score' was also less than 0.05, meaning that the covariate was also significant.

5.5 **Presentation of the analysis of results on the academic achievement of males and females learners in the experimental group**

The analysis was performed to determine whether there would be no significant differences in learners' (males and females) academic achievement in simple electric circuit taught using the Conceptual Change Model (hypothesis b).

Table 5.91: Descriptive statistics for UNIANOVA.

Descriptives

Dependent Variable: Post score

Gender	Mean	Std. Deviation	N
Male	7.47	1.562	34
Female	7.97	1.766	34
Total	7.72	1.674	68

Table 5.91 shows that there was equal gender representation in the experimental group. The means for males and females learners differ.

It can be observed from table 5.92 that pre-score is not a significant predictor of post score ($p = 0.804$). It can further be observed that there is no statistically significant mean difference between males and females (Gender) when adjusted for the covariate ($p = 0.232$).

Table 5.92: Means and Effect Sizes.

Estimates

Dependent Variable: Post score

Gender	Mean	Effect Size	Sig.
Male	7.474	.294	.232
Female	7.967		.232
a. Covariates appearing in the model are evaluated at the following values: Pre-score = 2.32.			

The Effect Sizes due to CCM was moderate ($d = 0.294$).

Summary of results on the academic achievement of learners (males and females) in the experimental group

- Report on ANOVA based on pre test scores

Analysis of variance found that there was no statistically significant difference between schools in the experimental and control groups ($p > 0.05$) on pre-test scores.

- Report on t-test for the pre-test between experimental and control groups

The t-test performed revealed that the p value (0.427) > 0.05, tells us that the mean difference between pre-scores of the two groups was not statistically significant. There was a weak effect size ($d < 0.2$) in these groups. Therefore the two groups were had the same level of understanding the topic before the intervention.

- Report on the Paired Sample t-test for pre-test and post test scores

Effect sizes of both groups were more than 0.8. The control group had an effect size of, $d = 0.9$ while that of the experimental group was $d = 4.2$. Therefore, both treatments had strong effect, even though the intervention strategy used in experimental group had more positive impact on learners learning than the one employed in the control group.

- Report on ANCOVA

The one-way between-groups analysis of covariance was conducted to compare the effectiveness of two different interventions designed to enhance effective teaching and learning of simple electric circuit on grade 10 learners. The participants' pre-scores on simple electric circuit were used as the covariate. Preliminary checks were conducted to ensure that there was no violation of the assumption of homogeneity of variances. After adjusting for pre-intervention scores, it was found that there was a significant difference between the two interventions groups on post intervention scores. The effect size, $d > 0.8$ showed that CCM had more impact during intervention than TPI.

- Report on gender performance in the experimental group

The Pairwise Comparison Test indicated that there was no statistically significant difference between males and females (Gender) when adjusted for the covariate ($p = 0.232$). This was supported by an Effect Size = 0.294, indicating a moderate effect of the conceptual Change Model on gender in the experimental group.

The gender performance in this study is in line with some of the research findings which had the opinion that gender difference in science achievement has disappeared (Agbolor, 1993; Bilesanmi-Awoderu, 2006; Balogum, 1994; Erinosho, 2000; Erinosho, 2005; Faulkner and Lie, 2006). However, the findings of this study contradict the findings of Aguele and Agwugah (2007) and Kolawole (2007) who found in their studies that male students achieved significantly better than female students in science subjects.

5.6 **Categories and analysis of qualitative results of the questionnaire**

5.6.1 **Questionnaire part 1**

No explanation was given to item 7, 8, and 9 of the biographical information. The absence of explanations to these items corresponds with learners' responses.

5.6.2 **Questionnaire part 2**

The content analysis was used to analyse the explanation respondents gave as probed by the open ended questionnaire. The data analysis procedure involved making sense of data in terms of the participants' explanation of the situation, noting patterns that emerged.

The analytical coding was employed because it is descriptive and more interpretive in nature. Mayring (2004:206) asserts that analytical coding accurately defines the process of determining or reporting written data. Therefore each item had its own code in order to address its content adequately.

5.6.2.1 **At our school we (as learners) conduct experimental work regularly. State how frequently do you conduct experiments.**

The following paragraph will give the categories and reasons for learners to responding in the way the responded.

5.6.2.1.1 **Categories**

Learners' statements to how frequent do they conduct experiments were categorised as follows:

Category A: Once
Category B: Twice
Category C: Irrelevant
Category D: No response

5.6.2.1.2 **Reasons**

- Learners who responded by saying 'once' was because they were once given a project. In the project learners were expected to construct a torch. These learners could not differentiate between project and experiment.
- Learners who responded by saying 'twice' explained that the tasks were for the continuous assessment (CASS). The assessment package for grade 10 includes two formal practical tasks. Teachers tend to focus only on those two practical tasks.
- Learners who responded irrelevantly said they did not conduct experiments regularly. They did not mention how often.
- There were learners who did not respond. These learners did not provide any explanation.
-

5.6.2.2 **I am confident in carrying experiments on my own. Briefly give details of the experiment you conducted on your won.**

The following paragraph will give the categories and reasons for learners to responding in the way the responded.

5.6.2.2.1 **Categories**

Category A: None
Category B: No response

5.6.2.2.2 **Reasons**

- Learners who responded by saying “none” did not give any reason.
- Other learners did not respond. They did not write anything.

5.6.2.3. **I can easily follow instructions stipulated on the block to carry out experiments at school. Provide explanation of such experiments.**

The following paragraph will give the categories and reasons for learners to responding in the way the responded.

5.6.2.3.1 **Categories**

Category A: Physics
Category B: Chemistry
Category C: Life Sciences
Category D: No response
Category E: Uncodable

5.6.2.3.2 **Reasons**

- Learners who responded by mentioning experiment in physics, indicated that they have done the experiment on electric circuits.
- Learners who responded by outlining experiments in chemistry, mention the investigation of heating and cooling curves using ice cubes. Other learners explained the experiment on testing of ions.
- Learners who responded by giving an account of experiments in Life Sciences, mention experiment on bisecting ox liver while some give details of experiment on transpiration and testing starch.
- Other learners did not write anything.
- Other learners responded by providing explanations which were difficulty to be classified, for example, "a practical on how to draw apparatus".

5.6.2.4. **I understand science concepts better when my teacher demonstrates an experiment to the class. Motivate your answer.**

The following paragraph will give the categories and reasons for learners to responding in the way the responded.

5.6.2.4.1 **Categories**

Category A: Disagree
Category B: Totally disagree
Category C: Sometimes
Category D: No response

5.6.2.4.2 **Reasons**

- Learners, who responded by saying they 'disagree' with the statement, advanced a reason that the teacher demonstrates the experiment fast.

- Learners who responded by saying they ‘totally disagree’ with the statement, motivated their response by saying that the class become noisy and they can hardly follow the demonstration.
- Learners who responded by saying “sometimes” they understand science concepts through demonstration, complain about the visibility of apparatus and the visibility of the contents of the test tubes and beakers.
- Other learners did not respond, nothing was written.

5.6.2.5 **I can easily handle apparatus when conducting experiments. List apparatus you have recently handled in experiments at your school.**

The following paragraph will give the categories and reasons for learners to responding in the way the responded.

5.6.2.5.1 **Categories**

Category A: Physics
Category B: Chemistry
Category C: Life Sciences
Category D: No response

5.6.2.5.2 **Reasons**

- Learners who responded by mentioning physics apparatus included circuit board, batteries, resistors, bulbs, ammeter, rheostat voltmeter, switch and connectors.
- Learners who responded by mentioning physics apparatus included test tubes, beakers, thermometer, spatula, medicine dropper, burner, spirit lamp, tripod stand.
- Learners who responded by mentioning physics apparatus included bell jar, dissecting needles, Test tubes, beakers, knife.
- Other learners did not write anything.

5.6.2.6 **Summary of analysis of explanations provided by learners on the questionnaire**

The content analysis above showed that learners at schools did not conduct experiments regularly. The situation made learners to be not confident in carrying out experiments on their own. Learners were positive that they could follow instructions in order to perform experiments. The situation at schools was that teachers often demonstrate experiments. Even though teachers allowed learners to handle apparatus during demonstration, learners did not learn much from those demonstrations.

5.7 **Analysis of explanations provided by the Experimental Group on the SECCT**

The following paragraphs seek to analyse the qualitative data (explanations) provided by learners to SECCT (Appendix 4).

5.7.1 **Analysis of explanations provided to question 1**

In this question, learners were tested on the sub-concept 'the effect of increasing the number of batteries in simple electric circuit'. The concept of increasing number of batteries in an electric circuit seemed to be understood by most learners. It was surprising to discover that other learners marked the correct answer but could not provide any explanation. Response to this question revealed that other learners still have misconception that increasing the number of batteries always result in an increase in the potential difference. These learners never thought of increasing number of batteries in parallel.

5.7.2 **Analysis of explanations given to question 2 (a -d)**

Question 2 (a - d) sought to ascertain whether respondents experiences no problem with the sequential reasoning. This type of reasoning arises when learners have a thought of the brightness of the bulb as results of current path to be one way in the series circuits. According to the sequential reasoning, some changes before or in front of the bulb, affect the brightness of the bulb, but some changes after the bulb does not affect its brightness (Küçüközer and Demirci, 2008:305).

Most learners assumed that the current and the brightness of the bulb are proportional to each other. These learners fail to relate the brightness of the bulb with the power of the bulb. One may conclude that learners could not apply Ohms law correctly. According to Ohms' law, decrease in resistance cause increase of current (V=IR), but increase in current is proportional to the power and the brightness of the bulb ($P=I^2R$). This led to misconception of 'sequential reasoning' model.

5.7.3 **Analysis of explanations given to question 3: Question 3 aimed to investigate respondents' thoughts about "batteries as stationary current source".**

The analysis of the information given by learners on this question indicates that some learners did not understand the power-potential difference relationship and power-resistance relationship, that is ($P = V^2/R$). Simply put, the brightness of the bulb is proportional to the power of the bulb. The difficulty experienced by Some learners to respond correctly to this question can be attributed to their inability to relate the brightness of the bulb and the power of the bulb.

5.7.4 **Analysis of explanations given to question 4 (i)**

Question 4 sought the knowledge of closed circuit, the series and parallel connection of light bulbs. Learners seemed to have good interpretation of circuits with only series or parallel connection of bulbs. Once the two types of connections are combined in a single circuit, then other learners start to have interpretation problems.

Other learners believed that as current passed through the circuit, it is consumed by circuit components. Even though most learners did well in this question, some still hold misconception that bulb in parallel are always brighter than bulbs in series.

5.7.5 **Analysis of explanations given to question 4 (ii)**

The respondents were tested if they have mastered the purpose of a switch (open and closed) in the circuit.

These learners have observed that the switch is open, therefore current wouldn't pass through bulb C, but they failed to comprehend that the remaining bulbs made a series connection. Few (6%) learners had wrong interpretation about an open switch. These learners might have a language problem as a result of everyday language (Küçüközer and Kocakülah, 2007: 106).

5.7.6 **Analysis of explanations given to question 5 (a -b)**

Question 5 tests learners' understanding of the potential difference. This concepts was taught through POE using ladder analogy for the potential drop (in mechanics) as alluded by Baser (2006: 7). The analysis revealed that some learners confuse the 'potential difference' concept and current concept. The analysis has shown that the concept of "potential difference" is difficult to be assimilated and accommodated.

5.7.7 **Analysis of explanations given to question 6**

Question 6 was included in the SECCT to test whether learners understood current flow in a circuit. The current concept was learnt through the grain bean model (Dekkers, 2005) during the treatment phase and the analogy of bicycle peddling system (Küçüközer and Kocakülah, 2007). The comparison between the game and the real electric circuit, the bicycle paddling system and the real circuit were made.

Most learners gave scientifically exact correct explanations. The analysis indicated that learning science through play might benefit learners. However, some (3%) demonstrated two types of misconceptions, that is, clashing currents misconception (current flows from both terminals of the battery and clashes at the bulb, hence it lights), while others showed misconception of current consumption model (current is consumed by the circuit component, such as a bulb and diminished as it goes to the other side of that component).

5.7.8 **Analysis of explanations given to question 7**

Question 6 and 7 were almost similar in that point 1 and point 2 in question 6 were replaced by two identical bulbs and current direction was reversed. Both questions tested current concept.

Most learners got the correct answer. This result did not come as a surprise because learners were offered an opportunity to play the maize grain game during breaks and even at home. The game assisted them to confront their existing ideas. The current concept was adequately accommodated each time they related the game with the real circuit through debates and discussions. The debates spiralled into intelligible and fruitful current concept. It can be concluded that the Conceptual Change Model assisted learners to conger the current concept.

5.7.9 **Analysis of explanations given to question 8**

The question intended to ascertain whether learners could easily and correctly construct a simple electric circuit, consisting of a battery, ammeter, voltmeter and resistor. During treatment phase learners made to construct many different circuits, such as the circuit from a torch, a circuit for a car roof, wiring two roomed house made from hardboards, a circuits to measure the current strength and voltage, drawing a circuit diagram when a real circuit was given, and constructing a circuit when a circuit diagram is given. The question gave respondents opportunities to show their skill of assembling a circuit.

Most learners gave exactly correct scientifically acceptable explanations. However, other learners (4%) still confuse the connection of ammeter and voltmeter. These learners lacked hands-on activities. One may deduced that these learners might have been not given enough chance of handling apparatus as expected by the CCM.

5.7.10 **Summary of explanations provided by the Experimental Group on the SECCT**

The aim of analysing this section was to evaluate the impact made by the Conceptual Change Model in learning science concepts, particularly those concepts related to the simple electric circuits. It can be said that findings from the analysis of learners' explanations based on question 1, 2(c), 3, 5(a), 5(b), 6, 7, and 8 lead to the conclusion that the CCM did improve learners understanding of science concepts. The results indicated that the responses given were relevant. The analysis further showed remarkable scientific responses learners gave to question 6, 7 and 8.

However, there were some questions (2a, 2b, 2d and 4 ii) in which learners responses were not satisfactory. These were questions in which most learners demonstrated deep rooted misconceptions. Some of the misconceptions found in the literature were in line with those that were reported in the findings section (section 5.5.3) of this study. A summary of such misconceptions are outlined below.

- Increase in the number of batteries always increases the potential difference (question 1). The same finding was reported by Lee and Law (2001) and Küçüközer & Kocakülah (2007:110).

- Sequential reasoning: A change before the bulb in a series circuit affects the bulb's brightness but some changes after the same bulb does not affect the brightness of the bulb (question 2(a), 2(b) and 2(d)). This misconception was also reported in the studies by McDermott and Shaffer (1992), Küçüközer & Kocakülah (2007:110) and Küçüközer & Demirci (2008:306).

- Consumption of current: Current is consumed its circuit electrical components (such as bulbs, resisters, etc.), therefore the current diminishes when it returns to the battery (questions 4(ii) and 7). Such misconception was also reported by Baser and Durmus (2010), Küçüközer and Kocakülah (2008:66), Küçüközer and Demirci (2008:308), Alebious (2005) and Lee and Law (2001).

- Batteries are constant current source (question 3). The same misconception was encountered in the study of Küçüközer & Kocakülah (2007:110) and Küçüközer & Kocakülah (2008:66).

- Clashing currents: Current (with the same value) flows to the bulb from both terminals of the battery, when colliding on the bulb, the bulb gives light (question 6). This misconception was also documented in the studies of Küçüközer and Kocakülah (2008:66).

The analysis of question 8 (section 5.7.9) indicated that some learners still had problems of using ammeter and voltmeter correctly. When a comparison was made among question 1, 5 and 8, it was further revealed that the findings of this study shown similarities with other studies (Küçüközer and Kocakülah, 2008:66; Küçüközer and Kocakülah, 2007:110; Wesi, 2003; Engelhart and Beichner, 2004; Lee and Law 2001; Borges and Gilbert, 1999) in that learners used the concepts of voltage, current and energy interchangeably as if these concepts are the same.

5.8 **Conclusion**

The analysis of respondents on biographical information indicated that the sample consisted of N = 136 respondents. There were 68 participants in each group. The participants were learners who were in grade 10 during the time of study. These learners came from four secondary schools (A, B, C and D). Schools were situated in different circuits. School A and school D were in the control group while school B and school C were in the experimental group.

The gender composition was 1:1. The control group had only 7.4% of learners in the second year of study while the experimental group had 14.7%. These figures were not significant and did not affect the study negatively. During the time of study, 80.9 % of learners in control group were obtaining marks in the lowest academic achievement level while experimental group had 77.9% of learners in the same academic achievement level. It was established that School D and school C contributed more learners (94.1% and 82.4% respectively) to the lowest level of academic achievement.

Learners in these schools never visited science centre. They did not attend any science road show. These learners did not have an opportunity to attend science exhibition. Learners' age ranged between 13 to 16 years old. In total, only 14.8% of learners were 16 years old. This number was not statistically significant. Therefore learners' age did not influence the study.

The analysis of the questionnaire (learning at school) revealed that experiments were not conducted regularly, and that did not motivate learners to carry out experiments on their own. Teachers were comfortable with demonstrations whereas learners did not learn much. However, learners agreed that they could follow instructions to conduct experiment when given the opportunity. Learners further indicated that they could easily handle apparatus. These learners valued practical work (experiments).

The analysis of the information gathered from simple electric circuit indicated that learners like to perform experiments on simple electric circuits (SEC). Learners acknowledged that experiments on SEC helped them to develop skills of handling apparatus. The study of SEC might develop their understanding of science concepts. Tasked based on SEC could assist them to analyse problems and, experiments on SEC would assist them to gain scientific knowledge. The work on simple electric circuits motivates them to pursue their studies in sciences after passing grade 12. Learners enjoyed lessons based on SEC.

On the other hand, learners raised their concern that they could not relate their study in SEC with their daily life experiences, but what was encouraging was that they were not forced to study the work on simple electric circuits.

Learners responded positively on a number of items which were gathering information on learning of electric circuit based on the Conceptual Change Model. The questionnaire was given to them after the intervention. Learners' response showed that the CCM made impact on their learning of simple electric circuits. It became clear when the explanations for their choices were analysed. During intervention some of learners' misconceptions were addressed whereas some were rooted. The CCM succeeded in changing learners' perception and attitude towards the study of electric circuits hence they were able to relate the work on electric circuit with their daily experiences.

Analysis of variance (on pre-test) found that there was no statistically significant difference between schools in the experimental and control groups ($p > 0.05$). Therefore learners in these schools had the same understanding of the topic (simple electric circuits). The t-test performed after grouping schools into control and experimental groups, indicated that the mean difference between pre-scores of the two groups was not statistically significant. There was a weak Effect Size ($d < 0.2$) in these groups. The groups were on the same level academically.

Analysis of Paired Sample t-test for pre-test and post test scores revealed that the Effect sizes of both groups were more than 0.8. The control group had an effect size of, $d = 0.9$ while that of the experimental group was $d = 4.2$. Therefore, both treatments had strong effect, even though the intervention strategy used in experimental group had more positive impact on learners learning than the one employed in the control group.

The one-way between-groups analysis of covariance (ANCOVA) was conducted to compare the effectiveness of two different interventions designed to enhance effective teaching and learning of simple electric circuit on grade 10 learners. The participants' pre-scores on simple electric circuit were used as the covariate. Preliminary checks were conducted to ensure that there was no violation of the assumption of homogeneity of variances. After adjusting for pre-intervention scores, it was found that there was a significant difference between the two interventions groups on post intervention scores ($F(3,131) = 290.49$, $p = 0.001$, effect size = 2.93). The effect size, $d > 0.8$ showed that CCM had more impact during intervention than TPI.

The Pairwise Comparison Test indicated that there was no statistically significant difference between males and females (Gender) when adjusted for the covariate (p = 0.232). This was supported by the Effect Size = 0.294, indicating a moderate effect of the conceptual Change Model on gender in the experimental group. Therefore male and female learners had the same academic achievement level.

The quantitative findings emerging from statistical analyses (t-test, ANOVA and ANCOVA) indicate that there was statistically significant differences between the two groups (control group and experimental group) with the experimental group indicative a positive impact of CCM on learners' conceptual understandings of fundamental concepts of electric circuits as assessed by SCCT.

The next chapter presents the conclusions and recommendations.

CHAPTER 6

CONCLUSION AND RECOMMENDATIOONS

6.1. **Introduction**

This chapter presents the concluding remarks and recommendations of the study based on the literature study (chapter 1, 2, 3, 4 and 5). Chapter 1 focused on the orriantative introduction which includes background to the problem, a brief problem analysis, statement of the problem, significance of the study, hypotheses, theoretical framework, the ehical aspects, study outline and chapter division.

Chapter 2 reviewed liturature on the theoretical framework on Conceptual Change Model, learners' misconceptions, learning theories and intervention stratergy.

Chapter 3 discussed liturature on core knowledge of simple electric circuits. The discussions encampass the circuit componets such as battery, bulb, switch, resistor, etc. Other concepts such as charge, emf, current, potential difference and resistance were outlined.

Chapter 4 outlined the research design and methodology. The chapter entails the reasearch quections (primary and secondary), research aim and objectives, hypothesis, description of population and sample, the development of instruments, the discusion on how data was collected and how would it be analysed. The ethical considerations were also presented.

Chapter 5 presented and disscused the emperical findings. The findings were presented under two categories, that is, as quantitative and qualitative. The quantitative findings involved frequency tables, t-tests, ANOVA and ANCOVA test statistics. On the other hand qualitative approach was also used to analyse the explation given on open-ended questions.

This chapter focuses on the results of the empirical survey and thereafter proposes recommendations for further research in this field. The envisaged conclusions and recommendations address the research hypotheses and the objectives of the study (section 4 and 5, chapter 1), namely:

Objectives

(a) To develop learners' conceptual understanding with regard to concepts related to simple electric circuit.
(b) To identify learners' misconceptions in the simple electric circuits and address them.

Hypotheses

(a) When teaching the simple electric circuits using Conceptual Change Model, the experimental group will perform academically better than the control group.
(b) There will be no significant differences in learners' (males and females) academic achievement in simple electric circuit taught using the Conceptual Change Model.

The conclusions and recommendations finally address the aim of the study: Investigating the impact of the Conceptual Change Model on learners' academic achievement using simple electric circuit.

6.2. **Statistical results and analysis**

It was observed from learning of simple electric circuits at respective schools that learners were not assisted to relate what they learnt at school with their daly life experiences. However, learners appreciated the benefits brought by the Conceptual Change Model in terms of the new approach of learning science.

The control and experimental groups were subjected to the pre- and post tests. The academic performance (achievement) of the two groups was measured before the treatment phases.

Thereafter, groups were exposed to the interventions. The Conceptual Change Model (CCM) was used in the experimental group while Traditional Physics Instruction (TPI) was used in the control group. The post test was instituted to measure the academic achievent after the intervention. The results proved that the experimental group performed better than the control group, after it was exposed to the CCM. The result provided evidance to accept the reaseach hypothesis (a), (section 6.1).

It was further observed from the analysis of the tests that there was no significant difference in learners' (males and females) academic achievement in simple electric circuit taught using the Conceptual Change Model, hence the hypothesis (b) was also accepted.

The experimental group was subjected to part 4 of the questionnaire to evaluate the impact of CCM on science learning. It was observed that learners confessed to have been understood science better, they had even acknowledged that they learnt new concepts and gain scientific knowledge (section 5.2.6).

It was further obseved from the analysis on questionnaire that learners' handling skills were sharpened and learners could easily relate science they were learning with their daily life experiences. Therefore CCM served as one of the agent for life-long learning. From this observation one can conclude that the Conceptual Change Model succeeded in developing learners' conceptual understanding with regard to concepts related to simple electric circuit.

Lastly, the explanation given by the experimental group on post test was qualitatively analysed. It was done to ascertain the existance of misconception after they were identified in the pre-testing and addrssed during the treatement phase. The observation made was that CCM did improve learners' understanding of science concepts. However, there were some deep rooted misconceptions learners could still demonstrate after exposed to the CCM (section 5.5.3).

6.3. **Learning problems associated with CCM**

There were shortcomings of learing simple electric circuits; concepts using the conceptual change model. The learning model is activity based approach, therefore it became not worthwile to older learners in the class because these learners were shy to play with young classmates.

The conceptual change model encompasses POE and collaboration as its corner stones. The POE based activities require a learner who can express himself, in order to explain his predictions and observations. It was observed that language problem (use of English) inhibited learners full participation.

The Conceptual Change Model does not encourage individual learning, it propagates that learning is unfolded and comprehended easily when learners are engaged in a debate and discussion, in order to interrogate the exsisting misconceptions. It is through this actions that the new concept is accommodated, become fruitful and interlligible to the learner. Therfore, to those learners who found it difficult to associate with others, might have not benefited maximally from the CCM.

The above shortcomings of CCM provide a clear picture that the CCM is not a panancia, that is, it cannot provide all the answers needed for the effective science learning and dispelling of all misconceptions learners have. These facts suggest recommendations to further studies.

6.4. **The recommendations**

The recommendations are divided into two categories, namely, the recommendations for the effetive ways of implementing the CCM and for the future research studies.

6.4.1. **Recommendations: Effective ways of exercuting the CCM**

During the treatment phase of the experimental group, it was observed that guidelines for the efficient and effective implementation of the Conceptual Change Model were not clearly defined. Based on the results of the emperical study, the researcher proposes the following guielines.

- Designing of group work within the class

In the introductory phase of the lesson, the facillitator should divide learners into small groups of not more than five members. It was observed that when learners work in large group, some members of a group become spectators and that reduces the level of engagement. The same observartion was also repoted by Rapule (2007:239) who noted that the greatest challenge with large groups was control. The responsibilities must be rotated within the group members.

- Incorporate guided discovery activities

The guided discovery activities enhance effective science learning through the lens of the CCM. In guided discovery activities the teacher must avoid direct instruction, instead lead the learners through questions and activities to discover, discuss, appreciate and verbalize the new knowledge. Simply put, the teacher's role should be that of prompting and facilitating discussion that would lead learners to develop their own conclusions on the subject.

- The POE and collaboration

Predict-Observe-Explain (POE) is a teaching strategy that probes understanding by requiring students to carry out three tasks. First the students must predict the outcome of some event and must justify their prediction, then they describe what they see happening (observe); and finally they must reconcile any conflict between prediction and observation (explain). It is recommended that for CCM to be more effective, the facilitator should endeavour to design the learning activities in POE version. The POE tenants encompass the collaboration towards a common goal.

Rapule (2005, 2007:241) maintained that POE model of practical work is based on the classical model of research, in that learners are given an opportunity to state a hypothesis and give reasons to support their predictions. The POE increased learners' engagement and improved learning from practical work (Crouch *et al.*, 2004:836; Kearney *et al*., 2003:589). Therefore the Conceptual Change Model must never be divorced from POE.

- Reflection phase

The reflection comes towards the end of the lesson. It is done to engage learners in the discussion where they formalize issues. Reflection phase is a clarity seeking session in the sense that, it assists learners to consolidate and modify thier scientific knowledge structure. This phase help to sustain the new learning approch (CCM) as it is assessed by its own beneficiarias.

- The Conceptual Change Model tenants

The learning programme should be aligned as far as possible to the tenants of the CCM as discussed hereunder.

- Commit to an out come: Introduce the lesson by comminting learners to the lesson's outcomes.
- Expose beliefs: The facillitator should create a classroom environment where learners may freely share, discuss their ideas, predictions and reasoning before testing phase.
- Confront beliefs: Learners are given space and time to confront their existing ideas through collaborative experiences that chalenges their preconceptions.
- Accommodate the concept: Individual learner accommodate a new concept or skill through discussion and debate.

- Extent the concept: Learners apply and make connections between the new concept and other situations (relate to their daily life experiences).
- Go beyond: Learners make use of the concepts in different situations, in attempt to solve their own problems.

Accommodating the new concept is a transition step which a learners should become aware of. The question “What will happen if ...... ?” improves the acceptance of the scientific concepts. Accommodation of the new concept is a crucial step of CCM, becuase a leaner must find the new concept fruitful and intelligible.

The researcher was prompted by the findings of the study to propose recommendations for further research based as an outcome of this study.

6.4.2. **Recommendations: Further research**

Lack of learners’ participation in science related activities scuch as road shows, vistation to science centre and engage in career exhibitions, is a major concern. This problem need to be addressed through a research project because if it remains unsolved, it may culminate into a situation where learners lose interest in sciences.

This study focused on the FET-Band, therefore it is recommended that the similar study be undertaken to expose learners in the GET-Band (senior phase) to the innovative stratergy of learning science. Learners in the GET-Band are ideal for similar study becuase they choose subject groupng in grade 10.

The emperical study revealed that practical work is not conducted regularly at schools, particularly in grade 10. This problem calls for the conduction of the research study becuase practical work is essential for science learning. It is through the practical work that learners develop the scientific skills (make hypothesis, collect data, analyse data, draw conclusion based on the analysed data and give recommendations).

It was observed during data collection that schools were under resourced, that is, there was no laboratories, chemicals and apparatus. Therefore there is a need to conduct a study to investigate whether or not science may be taught and learnt maximally without hands-on (experiments) activities.

The Conceptual Change Model did not erradicate all misconceptions which were identified during the pre-testing. Baser and Durmus (2010:56) mainatined that not all misconceptions related to direct current electricity could be challeged and changed through experimentation. Therefore some other pedagogical means of physics should be utilized. This debate opens a room for future research.

6.5. **Conclusion**

The outcomes of the study as reported in this thesis, provide evidence that the Conceptual Change Model is a valuable resorce for effective science learning. If science learners, educators, curriculum advisors and designers can positively buy this learning stratergy, then learners' understanding of science concepts' status will increase and yields high academic achievement in physical sciences. It can therefore be concluded that the emperical results obtained from this study proved that the Conceptual Change Model could be used as an agent to develop science learners.

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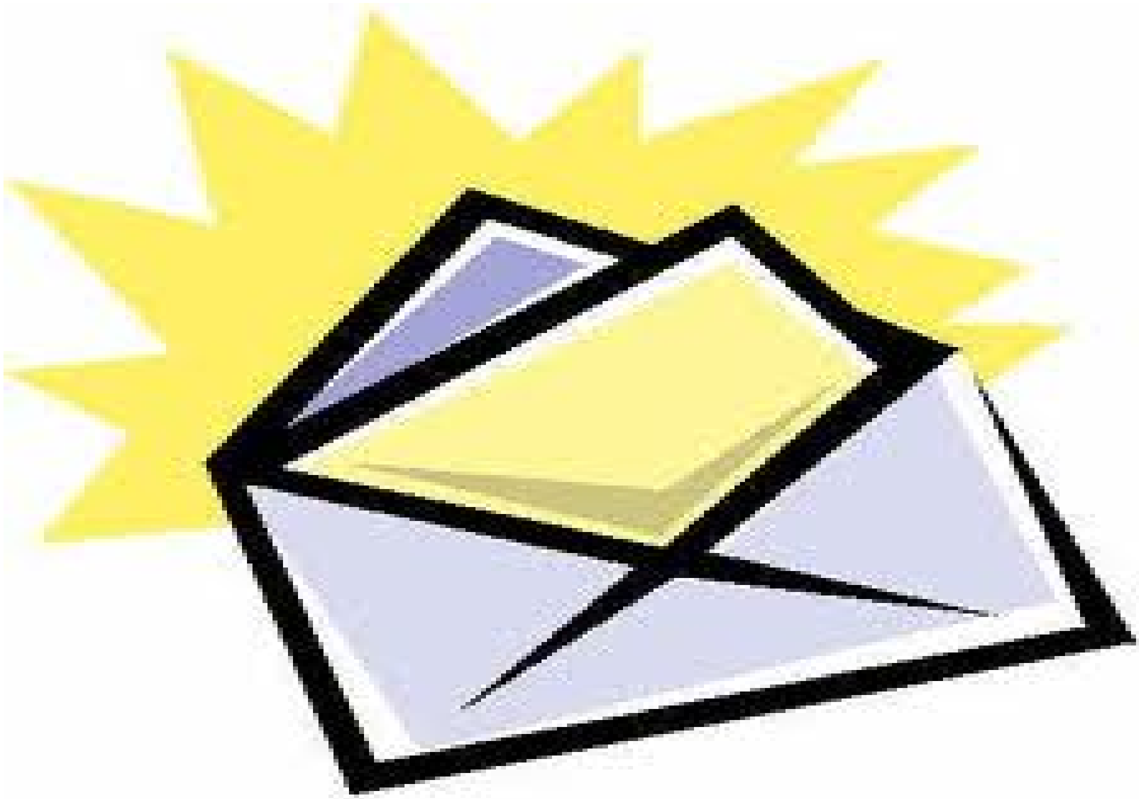
APPENDICES

Appendix 1:

Acceptance letter from Department of education: Limpopo.



LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF EDUCATION

Enquires: Dr Makola MC ,Telephone: 015-290 9448 ,Fax: 015 2970134 ,E-mail:MakolaMC@edu.limpopo.gov.za

LIMPOPO PROVINCE
DEPARTMENT OF EDUCATION
2012 -05- 0?
H.O.D'S OFFICE
PRIVATE BAG X9489 POLOKWANE 0700

462 SUID STREET
Florapark
Polokwane
0699

Attention: Manabile MP

Re: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct a research has been approved- **THE IMPACT OF CONCEPTUAL CHANGE MODEL ON GRADE 10 LEARNERS ACADEMIC ACHIEVEMENT USING SIMPLE ELECTRIC CIRCUIT** i.e. Mankweng Cluster

3. The following conditions should be considered:

   3.1 The research should not have any financial implications for Limpopo Department of Education.

   3.2 Arrangements should be made with both the Circuit Offices and the schools concerned.

   3.3 The conduct of research should not anyhow disrupt the academic programs at the schools.

   3.4 The research should not be conducted during the time of Examinations especially the forth term.

   3.5 During the study, the research ethics should be practiced, in particular the principle of voluntary participation (the people involved should be respected).

1

3.6 Upon completion of research study, the researcher shall share the final product of the research with the Department.

4. Furthermore, you are expected to produce this letter at Schools/ Offices where you intend conducting your research as an evidence that you are permitted to conduct the research.

5. The department appreciates the contribution that you wish to make and wishes you success in your investigation.

Best wishes.

---------------------- ----------------------

Thamaga MJ **Date** 2018/02/29

Head of Department

2

Appendix 2: Learners' Research Participant Consent Form A (Experimental Group)

Research title: The impact of conceptual change model to grade 10 learners using simple electric circuit.
Project leader: Manabile Mmaletsegetla Paulus
Address: Residential: 462 Suid street, Florapark, Polokwane, 0699
Postal: P. O Box 578, Faunapark, Polokwane, 0787
Cell number: 079 510 7352
Supervisor: Dr Morabe ON, North-West University Pochefstroom Campus

You are being asked to participate in this research project. Please note the following;

- Your involvement in this study is voluntary, you are not obliged to divulge information you would prefer to remain private, and you may withdraw from the study at any time.
- The project leader will treat the information you provide as confidential. You will not be identified in any document (including the research report) by surname, first name, school or by any other information. No one, other than the project leader and your parent or guardian, will be informed that you participated in this research.
- Every effort will be made to minimise possible risks. All activities are similar to normal classroom procedures, and all performances are anonymous.
- The research findings will be made available to you, should you request them.
- You will not incur any costs as a result of your participation in this study.
- Should you have any queries about this study, now or in the future, you are welcome to contact the project leader or his supervisor at the above contact details.

If you agree to participate, then

- You will be asked to complete a questionnaire consisting of three sections, namely, biographical information of the respondents, the information on learning at school and information on simple electric circuit.
- You will be expected to attend physical sciences electric circuit's lessons.
- You will also be asked to write a partial open-ended simple electric circuit conceptual test, consisting of 8 multiple choice-type questions.
- You will finally be asked to complete a questionnaire part IV, learning based on Conceptual Change Model.

Authorization

- ***Learner:*** I have read and understood the contents of this document. I therefore agree to participate in this research.

  Participant's signature: ____________________________ Date: ___________________

- ***Parent or guardian:*** I have read and understood the contents of this document. I give my child a permission to participate in this study.

  Parent's or guardian's signature: ______________________ Date: ____________________

- ***Researcher :*** signature: _________ Date: __________ Respondent Unique number: _______

Appendix 2: Learners' Research Participant Consent Form B (Control Group)

Research title: The impact of conceptual change model to grade 10 learners using simple electric circuit.

Project leader: Manabile Mmaletsegetla Paulus

Address: Residential: 462 Suid street, Florapark, Polokwane, 0699
Postal: P. O Box 578 Faunapark, Polokwane, 0787

Cell number : 079 510 7352

Supervisor: Dr Morabe ON, North-West University Pochefstroom Campus

You are being asked to participate in this research project. Please note the following;

- Your involvement in this study is voluntary, you are not obliged to divulge information you would prefer to remain private, and you may withdraw from the study at any time.
- The project leader will treat the information you provide as confidential. You will not be identified in any document (including the research report) by surname, first name, school or by any other information. No one, other than the project leader and your parent or guardian, will be informed that you participated in this research.
- Every effort will be made to minimise possible risks. All activities are similar to normal classroom procedures, and all performances are anonymous.
- The research findings will be made available to you, should you request them.
- You will not incur any costs as a result of your participation in this study.
- Should you have any queries about this study, now or in the future, you are welcome to contact the project leader or his supervisor at the above contact details.

If you agree to participate, then

- You will be asked to complete a questionnaire consisting of three sections, namely, biographical information of the respondents, the information on learning at school and information on simple electric circuit.
- You will be expected to attend physical sciences electric circuit's lessons based on conceptual change model.
- You will also be asked to write a partial open-ended simple electric circuit conceptual test, consisting of 8 multiple choice-type questions.

Authorization

- ***Learner:*** I have read and understood the contents of this document. I therefore agree to participate in this research.

  Participant's signature: ______________________ Date: ____________

- ***Parent or guardian:*** I have read and understood the contents of this document. I give my child a permission to participate in this study.

  Parent's or guardian's signature: ______________________ Date: ____________

- ***Researcher:*** signature: __________ Date: ________ Respondent Unique Number: ______

Appendix 3: QUESTIONNAIRE TO LEARNERS

PART 1: BIOGRAPHICAL INFORMATION ON LEARNERS

Respondent Unique number: ………

Read the following statements and give answers as accurate as you possibly can. It is vital to give your own response rather than your friends. The answers to the questionnaire are confidential and will be administered as such.

MAKE A CROSS ON THE APPROPRIATE BLOCK

1. Name of your school:

1	2	3	4
A	B	C	D

2. Name of the circuit where your school is situated:

1	2	3	4
Dimamo	Mankweng	Kgakotlou	Lebopo

3. Gender:

1	2
Male	Female

4. Age in years

1	2	3	4	5
13	14	15	16	17

5. Number of years in the grade

1	2	3
1st	2nd	3rd

6. What is your recent mark/level in the Physical Sciences controlled test?

	1	2	3	4	5	6	7
Level	1	2	3	4	5	6	7
%	0 - 29	30 - 39	40 - 49	50 - 59	60 - 69	70 -79	80 - 100

7. I have been to other science centre(s) before

1	2
YES	NO

If yes, name the science centre(s) you have visited

____

____

8. I have attended a science road show conducted at my area before

1	2
YES	NO

If yes, name the person(s) who conducted the science show at your area

____

____

9. I have attended a science career exhibition(s)

1	2
YES	NO

If yes, name the place(s) where science career exhibition took place

____

____

PART 2: INFORMATION ON LEARNING AT SCHOOL

Respond to the items of the questionnaire by marking with an x on the appropriate block. Remember there is no right or wrong answers to the statements; choose the block that best describes your situation.

KEY: *Choose 1: If you totally agree with the statement.*

Choose 2: If you agree with reservations

Choose 3: If you agree.

Choose 4: If you disagree with the statement, or

Choose 5: If you totally disagree with the statement.

Please motivate your answers in the space provided.

10. At our school we, as learners, conduct experimental work regularly

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

State how frequently (if applicable)

____

____

11. I am confident in carrying out experiments on my own.

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Briefly give details of the experiment you conducted on your own

____

____

12. I can easily follow instructions stipulated on the block to carry out experiments at school

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Explanation of such experiments:

____

____

13. I understand the science concepts better when my teacher demonstrates an experiment to the class.

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Motivate your answer

____

____

14. I can easily handle apparatus when conducting experiments

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

List the apparatus you have recently handled in experiments at your school:

____

____

Choose a suitable option

15. I consider the contribution of practical work/experiments in learning science as

Very important	1
Important	2
Not important	3

PART 3: INFORMATION ON SIMPLE ELECTRIC CIRCUIT

Respond to the items of the questionnaire by marking with an x on the appropriate block. Remember there is no right or wrong answers to the statements; choose the block that best describes your situation.

16. I like to solve problems on simple electric circuit

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

17. I can easily relate the work on simple electric circuit my everyday life experiences

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

18. I like doing experiments on electric circuit

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

19. The work on electric circuits motivates me to pursue my studies in sciences after grade 12.

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

20. The experiments on simple electric circuit develop my skill to handle apparatus

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

21. The study of simple electric circuits develop my understanding in science

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

22. The tasks based on simple electric circuits helped me to analyze problems

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

23. Electric circuits give me the opportunity to learn by doing experiments on my own

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

24. The experiments involving simple electric circuits require/demand understanding

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

25. In the electric circuit I learn to find answers to problems

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

26. Experiments in simple electric circuits help me to become creative in science

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

27. I usually enjoy lessons based on simple electric circuits

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Relate the following (Question 13 – 15) in order of importance.

28. I consider studying electric circuits because

	1	2	3
It offers me an opportunity for doing practical work on my own	Very important	Important	Not important

29. I intent doing more experiments on electric circuits because

	1	2	3
I gain scientific knowledge	Very important	Important	Not important

30. I want to study more on electric circuits because

	1	2	3
I enjoy/love the way my unscientific misconceptions are addressed and changes.	Very important	Important	Not important

31. I am forced to study electric circuits

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Why?

____

____

PART 4: INFORMATION ON SIMPLE ELECTRIC CIRCUIT
(LEARNING BASED ON CCM)

Respond to the items of the questionnaire by marking with an x on the appropriate block. Remember there is no right or wrong answers to the statements; choose the block that best describes your situation.

32. It was my experience that after a series of lessons on simple electric circuit, I understood science better

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Give an example of the experiment you understood better after the conduct session

____

____

33. The atmosphere during lessons presentation stimulates or promotes my scientific thinking

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Which lesson/experiment did stimulate you most?

____

____

34. I like Physical Sciences more after the lessons presentation based on electric circuits

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Motivate your answer

35. I learned new things in the electric circuit lessons

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Which things have you learnt? Explain:

36. I have learned how to investigate things in science

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Give an example of something you have investigated:

37. I could easily collaborate (work) with my peers/ friends

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Motivate your answer

____

____

38. Because of the experiments conducted during lessons' presentation I developed a positive attitude towards physical Sciences

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Explain your choice

____

____

39. Before the series of lessons on electric circuit I had problems to execute experiments on my own

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Motivate your answer

____

____

40. The lesson presentation on electric circuit captured my interest for the entire session

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Which experiment/activity kept your attention during this session?

____

____

41. Attending this session was worthwhile

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Why do you say so?

____

____

42. I see electric circuit as the area in science where I can sharpen my handling skills in Apparatus

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Which other skills have you gained by attending these lessons?

____

____

43. The practical investigations in electric circuits relate to my everyday experiences

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Supply an example of experiment that you have performed/seen that relates to your everyday life.

____

____

Rank the following (13 -16) in order of importance

44. I consider studying electric circuits again because

	1	2	3
it offers me an opportunity for doing practical work on my own	**Very important**	**Important**	**Not important**

45. I intent doing more experiments on electric circuits again because

	1	2	3
I gain scientific knowledge	**Very important**	**Important**	**Not important**

46. I want to investigate more on electric circuits because

	1	2	3
I enjoy/love the way my unscientific misconceptions are addressed and changes.	**Very important**	**Important**	**Not important**

47. I will not do investigations or study electric circuits again

1	2	3	4	5
Totally agree	**Agree**	**Agree with reservations**	**Disagree**	**Totally disagree**

Why?

____

____

Appendix 4. Simple Electric Circuit Conceptual Test

Simple Electric Circuit Conceptual Test

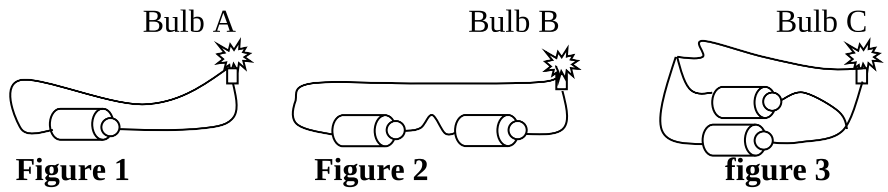
Respondent unique number: ....

Instructions to the respondent:

- Clearly write your unique tracking number. Always use this umber when completing a task related to this research project. Your number is always available from your educator.
- Answer all the questions. Each question has an open option which may be used to write the answer that is (according to you) not among the given options.
- Put an X into the box next to the alternative which you think is the correct answer. If according to your opinion, there is no correct answer, cross the last option and then write your answer.
- Briefly explain your choice.
- **<u>Do not</u>** write your name, surname or your school's name.
- This test consists only of **4 pages, 8 questions** and **13 sub questions**.

Simple Electric Circuit Conceptual Test (SECCT)

1. Batteries and bulbs are identical in the figures below. Put an X into the box next to the statement which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.



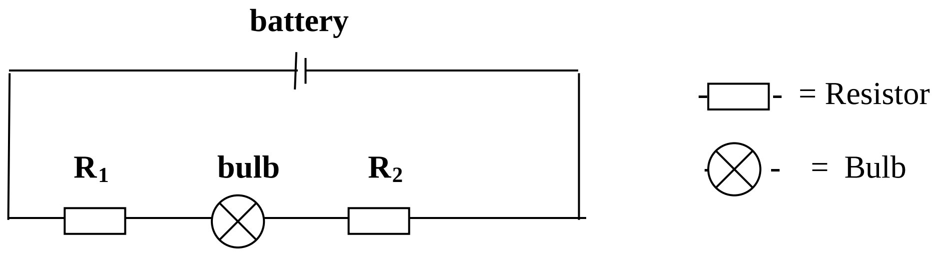
☐1 A > B > C ☐2 B > A > C ☐3 B > A = C ☐4 A = B = C ☐5 B = C > A ☐6 .....

Your explanation:

____

____

2. The following basic circuit is given below



The question involves the changes made in a simple circuit. Please put an X in the box next to the response you choose and explain why you choose that alternative.

(a) If the value of R_1 decreases, the brightness of bulb will ....

☐1 Increase ☐2 Decrease ☐3 Stays the same ☐4 ....

Your explanation:

____

____

(b) If the value of R_2 decreases, the brightness of bulb will ....

[1] Increase [2] Decrease [3] Stay the same [4] ....

Your explanation:

____

____

(c) If the value of R_1 increases, the brightness of bulb will.............

[1] Increase [2] Decrease [3] Stay the same [4] ....

Your explanation:

____

____

(d) If the value of R_2 decreases, the brightness of bulb will.............

[1] Increase [2] Decrease [3] Stay the same [4] ....

Your explanation:

____

____

3. In the figures below, the bulbs and batteries are identical.

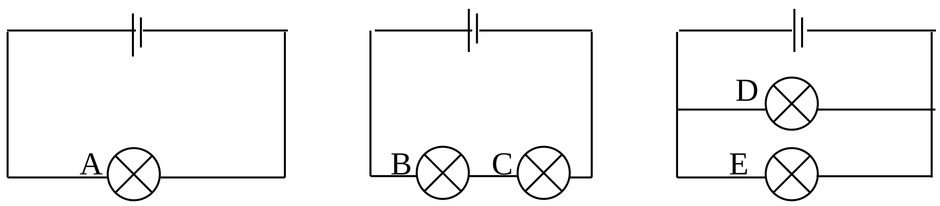


Figure 1 **Figure 2** **Figure 3**

Put an X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

[1] A > B = C = D = E [2] A = B = C > D = E [3] A > B = C > D = E
[4] A = D = E > B = C [5] A = B > C > D > E [6] ....

Your explanation:

____

____

4. All bulbs (A, B, C and D) are identical in the circuits shown in figure 1 and figure 2.

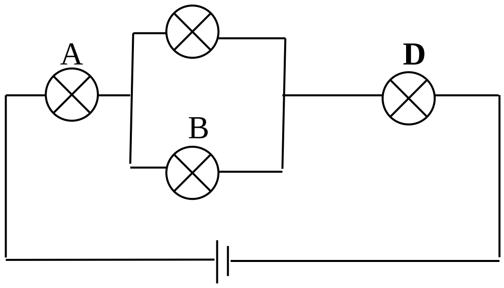


Figure 1

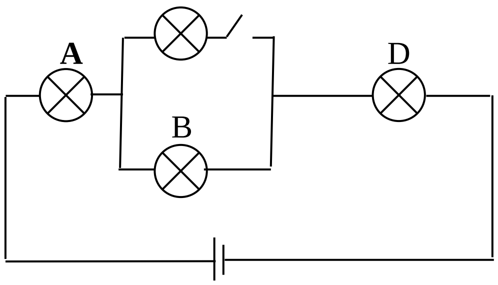


Figure 2

Use this information to answer the questions below.

(i) In figure 1, the switch is closed. Put X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

☐1 A = D > B = C ☐2 A > B = C > D ☐3 C > A = D > B

☐4 A = B = C = D ☐5 None of bulbs are lit when switch is closed ☐6 ....

Your explanation:

____

____

(ii) Switch is open in figure 2. Put an X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

☐1 A > B = C > D ☐2 A > B = D, C isn't lit ☐3 A = D > B = C

☐4 A > B > D, C isn't lit ☐5 None of bulbs are lit when switch is opened ☐6 ....

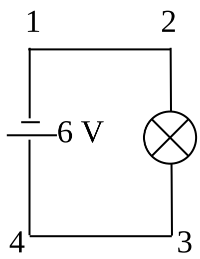
Your explanation:

____

____

5. Bulbs are identical in two circuits given below. Put an X into the box next to the alternative which you think is the correct answer about the potential difference between two specified points of each circuit. Explain your reasoning briefly.

5(a) Figure 1



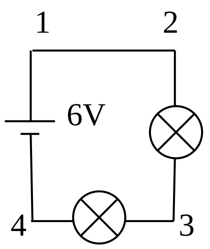
- [1] Between 1 and 2 = **6 Volts.** 2 and 3 = **6 Volts.** 3 and 4 = **6 Volts**.
- [2] Between 1 and 2 = **6 Volts**. 2 and 3 = **3 Volts**. 3 and 4 = **3 Volts.**
- [3] Between 1 and 2 = **0 Volt**. 2 and 3 = **6 Volts**. 3 and 4 = **0 Volt.**
- [4] Between 1 and 2 = **2 Volts**. 2 and 3 = **2 Volts**. 3 and 4 = **2 Volts**
- [5] ....

Your explanation:

____

____

5(b) Figure 2



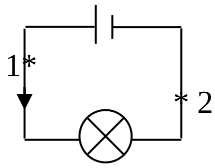
- [1] Between 1 and 2 = **6 Volts**. 2 and 3 = **6 Volts**. 3 and 4 = **6 Volts**.
- [2] Between 1 and 2 = **6 Volts**. 2 and 3 = **3 Volts**. 3 and 4 = **0 Volt**.
- [3] Between 1 and 2 = **0 Volt**. 2 and 3 = **3 Volts**. 3 and 4 = **0 Volt**.
- [4] Between 1 and 2 = **2 Volts**. 2 and 3 = **2 Volts**. 3 and 4 = **2 Volts**.
- [5] Between 1 and 2 = **0 Volt**. 2 and 3 = **3 Volts**. 3 and 4 = **3 Volts**.
- [6] ....

Your explanation:

____

____

6.



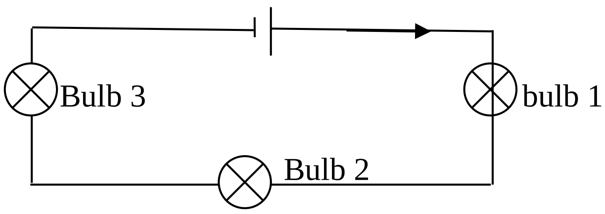
☐	1	1 > 2	Put an X into the box next to the alternative which you think is the correct answer about the magnitude of the current in points 1 and 2 circuit besides. Explain your your reasoning briefly.
☐	2	1 = 2	
☐	3	1 < 2	
☐	4	....	

Your explanation:

____

____

7. The arrow shows the direction of the current in the connecting wire. Put an X into the box next to the alternative which you think is the correct answer about the statement that best describes the situation as demonstrated by the circuit below. Explain your reasoning briefly.



☐ 1 Bulb 1 is brightest, bulb 2 glows dim red and bulb 3 not lit at all.

☐ 2 Bulb1 is brightest, bulb 2 glows dim red and bulb 3 glows dim red.

☐ 3 Bulb 1 is brightest, bulb 2 and bulb 3 will not light at all.

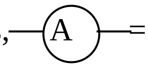
☐ 4 Bulb 1, bulb 2 and bulb 3 have the same brightness.

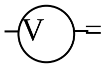
☐ 5 ....

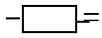
Your explanation:

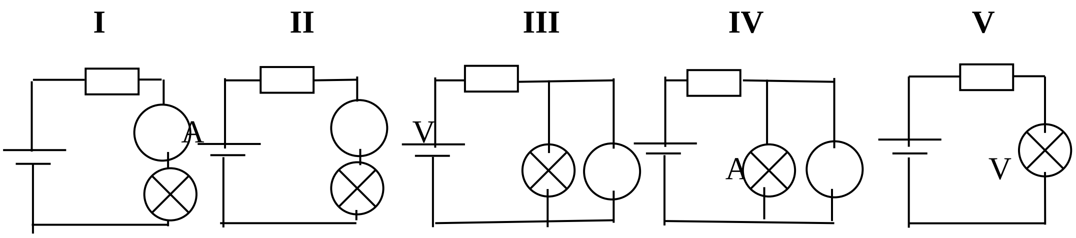
____

____

8. Resistors, bulbs and batteries are identical in all five circuits. Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulb in each circuits, 

= ammeter; 

= voltmeter and  = resistor. Explain your reasoning briefly.



[1] I = II = V > III = IV	[2] I = II = V > III = IV	[3] V > I = II > III = IV
[4] I = IV = V, II and III aren't lit	[5] I = II = III = IV = V	[6] ....

Your explanation:

___

___

Appendix 5: Grade 10 Electric Circuit Learning Programme

The lesson presentation will be guided by the following aspects

1. **Principles**

- Social transformation: To ensure that the educational imbalances of the past are readdressed, and that equal educational opportunities are provided for all learners irrespective of their sex.
- Outcome-based education: To enable all learners to attain their maximum learning potential by outlining the learning outcomes to be achieved by the end of the learning process. This principle and skills will be incorporated to encourage a learner-centred and activity-based approached to all lesson presentations.
- High knowledge and skills: To develop a high level of knowledge and competent skills in learners concerning electric circuit concepts.
- Integration and applied competencies: To provide an opportunity for learners to acquire integrated learning of theory, practice and reflection.
- Human rights, exclusivity, environment and social justice, lesson presentation will be sensitivity to issues of diversity.

2. **List of critical outcomes** (CO).

The designing and planning of lessons on electric circuit will be based on the following critical outcomes as proposed by the National Curriculum Statement (DOE 2003:14).

- CO 1: Identify and solve problems and make decision using critical and creative thinking.
- CO 2: Work effectively with others as members of a team, group, class, organization (school) and community.
- CO 3: Organize and manage themselves (learners) and their activities responsibly and effectively.

- CO 4: Collect, analyze, organize and critically evaluate information.
- CO 5: communicate effectively using visual, symbolic and/or language skills in various modes
- CO 6: Use science and technology effectively and critically showing responsibility towards the environment and the health of others.

3. **List of the developmental outcomes** (DO).

It is the undertaking of the lesson and its learning activities to instigate learners to be able to;

- DO 1: reflect on and explore a variety of strategies to learn more effectively.
- DO 2: participate as responsible citizens in the life of local, national and global community
- DO 3: be culturally and aesthetically sensitive across a range of social contexts.
- DO 4: explore education and career opportunities
- DO 5: develop entrepreneurial opportunistic

4. **Electric circuit module framework for grade 10**

4.1. List of the learning outcomes and assessment standards for physical sciences

Learning activities based on simple electric circuit will aim to achieve the following learning outcomes through the stipulated assessment standards.

Learning outcome	Assessment standards
LO 1: Practical scientific inquiry and problem solving skills.	AS 1: Conduct an investigation
	AS 2: Interpreting data to draw conclusions
	AS 3: Solving problems
	AS 4: Communicating and presenting information and scientific arguments
LO 2: Constructing and applying scientific knowledge.	AS 1: Recalling and stating scientific concepts.
	AS 2: Indicating and explaining relationships.
	AS 3: Applying scientific knowledge.
LO 3: The nature of science and its relation to technology, society and the environment.	AS 1: Evaluating knowledge claims and science's inability to stand in isolation from other fields.
	AS 2: Evaluating the impact of science on human development.
	AS 3: Evaluating science's impact on the environment and sustainable development.

4.2. Core knowledge area of electric circuits grade 10

LO'S and AS'S	Content
LO 1: AS 1 - 4 **LO 2**: AS 1 - 3 **LO 3**: AS 1 & 2	▪ Need for a closed circuit for charges to flow. ▪ Electrical potential difference (voltage). ▪ Current (DC and AC). ▪ Resistance (of bulbs and resistors). ▪ Principles and instruments of measurement of voltage (p.d), current and resistance.

5. **Work Schedule for Grade 10 – Electric Circuits.**

5.1. **Week 1**

Day	Core knowledge area and concepts in the NCS for Physical sciences 2008-2013	Core knowledge area and concepts proposed for this study in 2011	LO'S and AS'S	Resources
1	Need for a closed circuit for charges to flow; Principles and instruments of measurement of voltage, current and resistance.	Give evidence for why a closed circuit is needed for charges to flow. Identify and draw symbols for a: resistor, battery, bulb, switch, voltmeter ammeter, and connecting wires	LO 1: AS 3 & 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Learners, torch, and car. Resistors, torch battery, PM 9 battery, switches, voltmeter, ammeter and connecting wire
2		Draw simple electric circuit diagram using symbols. Indicate the direction of the current. Show how ammeter and voltmeter are connected. For a given circuit diagram, draw a picture of one or more physical circuits.	LO 1: AS 3 & 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Batteries, connecting wire bulbs, bulb holders, switches, ammeter, voltmeter, and A1size chart of a circuit diagram
3		For a given picture, draw one or more circuit diagrams.	LO 1: AS 1, 3, 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	A1 size chart with a picture of electrical circuit
4		Given a circuit diagram, set up a circuit.	LO 1: AS 1, 2, 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Batteries, connecting wire bulbs, bulb holders, switches, ammeter, voltmeter, and A1size chart of a circuit diagram
5		Given a real circuit, draw the circuit diagram.	LO 1: AS 1 - 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Batteries, connecting wire bulbs, bulb

				holders, switches, ammeter, circuit boards and voltmeter.

5.2. **Week 2**

Day	Core knowledge area and concepts in the NCS for Physical sciences 2008-2011	Core knowledge area and concepts proposed for this study in 2010	LO'S and AS'S	Resources
6	Electric potential difference (voltage);	Define electric potential difference and emf. Discuss the similarities and differences between electric potential difference (p.d) and emf Explain through practical activity why the voltage across the resistors arranged in parallel is the same. Explain why the voltage across the resistors connected in series is the sum of the voltages across each resistor	LO 1: AS 3 & 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Batteries, connecting wire bulbs, bulb holders, switches, ammeter, circuit boards and voltmeter.
7		Use the fact that voltage is proportional to resistance to calculate what proportion of the total voltage of a circuit will be found across each circuit element (across the bulb and battery).	LO 1: AS 1, 3, 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Batteries, connecting wire bulbs, bulb holders, switches, ammeter, circuit boards and voltmeter.
8		Solve problems in which the voltages across elements in a circuit add up to the emf.	LO 1: AS 3 & 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Batteries, connecting wire bulbs, bulb holders, switches, ammeter, circuit boards and voltmeter.

9		Define current Calculate the current flowing in the circuit using the equation $I = Q \div \Delta t$	LO 1: AS 1 - 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Learners, coloured wool string, maize grains, A4 charts with symbols of battery, charge, bulb, ammeter and game rules. Circuit boards, battery bulbs, ammeter and stop watch
10	Current;	Determine the current through the battery in a circuit with several resistors in series relative to a circuit with a single resistor. Determine the current through the battery in a circuit with several resistors connected in parallel in series relative to a circuit with a single resistor.	LO 1: AS 1 - 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Circuit boards, resistors (bulbs), ammeters and connectors. A1 chart with circuit diagram depicting one resistor

5.3. **Week 3**

Day	Core knowledge area and concepts in the NCS for Physical sciences 2008-2011	Core knowledge area and concepts proposed for this study in 2010	LO'S and AS'S	Resources
11		Give a microscopic description of resistance in terms of electrons moving through a conductor and transferring its kinetic energy.	LO 1: AS 1 - 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Learners, coloured wool string, maize grains, A4 charts with symbols of battery, charge, bulb, ammeter and game rules. Circuit boards, battery bulbs, ammeter and stop watch. Electric wire heater and nichrome wires with different thickness and lengths
12	Resistance;	Define the unit of resistance Explain why the battery in a circuit goes flat- refer to the energy transformation (battery and resistor).	LO 1: AS 1 - 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Photograph of George Ohms. Flat battery and the one which is not flat. Different resistors, Chart with colour coding and resistance
13		Explain why adding resistors in series in a circuit increase the resistance of the circuit.	LO 1: AS 1, 3, 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Circuit boards, resistors (bulbs), ammeters and connectors. A1 chart with circuit diagrams, one with one resistor, two resistors in

				series and three resistors in series
14		Explain why adding resistors in parallel in a circuit decrease the resistance of the circuit.	LO 1: AS 1, 3, 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Circuit boards, resistors (bulbs), ammeters and connectors. A1 chart with circuit diagrams, one with one resistor, two or three resistors in parallel
15		Draw a diagrams to show a short circuit	LO 1: AS 1, 3, 4 LO 2: AS 1 – 3 LO3: AS 1 & 2	Circuit boards, resistors (bulbs), ammeters and connectors. A1 chart with circuit diagrams, one with one resistor showing short circuit.

6. Lesson Plans

6.1. Lesson 1: Six lesson activities

Lesson 1: Simple Electric Circuit (Week 1, Day 1) **Educator: Manabile MP** **Year: July 2011** **School: A and C**

<table>
<tr><td colspan="3">Subject: Physical Sciences</td><td colspan="4">Grade: 10</td><td colspan="2">Duration: 1 hour</td></tr>
<tr><td colspan="3">Core Knowledge Area: Electricity & magnetism
Theme: Electric circuits
Context: Electric circuits in the house, radio, car, power generation, etc</td><td colspan="4">LO 1 LO 2 LO 3
AS 1-4 AS: 1-3 AS: 1& 2
Integration : Mathematics LO: 2
Languages LO: 2
Eng Graphics LO: 1</td><td colspan="2">CO: 1- 6

DO: 1- 5</td></tr>
<tr><td colspan="3">Link with previous knowledge: Electrostatics</td><td colspan="6">Link with the next knowledge: Matter and materials- electrical conductors, insulators and semiconductors.</td></tr>
<tr><th rowspan="2">Concepts</th><th rowspan="2">Educator Activity</th><th rowspan="2">Learner Activity</th><th rowspan="2">Resources</th><th colspan="3">Assessment Strategy</th><th rowspan="2">Evidence of achievements</th><th rowspan="2">Time frame</th></tr>
<tr><th>Forms</th><th>Methods</th><th>Tools</th></tr>
<tr><td>Electric circuit,

open circuit,

and closed circuit.</td><td>Activity 1.1

Invite 10 learners to make a circle, assist them to make a closed circuit with their hands and arms stretched.

The teacher asks the class to predict and explain their hypothesis, what</td><td>Activity 1.1

Boys and girls voluntarily make a closed circuit with their hands and arms stretched.

One learner leaves the circle to demonstrate the open circuit.</td><td>Learners</td><td>Group class activity</td><td>Peer</td><td>Checklist</td><td>Learners must be able to make a circuit model.</td><td>15 min</td></tr>
</table>

	would happen to the circle if one learner leaves the circle. The teacher asks one learner to leave the circle. The class is asked to compare the two setups. **Activity 1.2** The teacher groups learners in groups of not more than five members. The teacher asks each group to predict (with reasons) what would happen if the torch's switch is pushed forward. A learner is asked	**Activity 1.2** Learners in groups of not more than five members predict what will happen when the torch's switch is pushed forward. Each group forwards its hypotheses to the class. Learners are then	torch with battery and bulb	Group class activity	Peers and educator	Checklist	Learners must be able to differentiate between closed and open circuit.	15 min

	to push the switch forward. **Activity 1.3** The teacher takes the class to the car. The car door and hooter are used to demonstrate open and closed circuit.	asked to observe what happens. Thereafter they are given an opportunity to compare their prediction and observations, explain and discuss their observations. **Activity 1.3** Learners are once more instructed to predict what will happen to the car's roof light when the car door is opened and also when the hooter is pressed. They are given opportunity to compare their prediction with what they observe and discuss their	Car door and car hooter	Group class activity	Peers	Checklist	Learners must be able to differentiate between closed and open circuit.	10 min

	Activity 1.4 The teacher will then explain the concepts; electric circuit, open circuit and closed circuit	discrepancies. **Activity 1.4** Learners write down concepts' definitions and descriptions in their dairy books.	chalk board, chalk and learners' dairy book	Class work	Educator	Memo	Learners must be able to explain and discuss concepts such as electric circuit, open circuit, closed circuit.	20 min

Expanded Opportunities:

Learners are given various circuit diagrams showing simple electric circuits, closed circuits and open circuits to identify.

Reflection:

Learners showed interest in the learning activities, a car activity was most exciting and made learners to ask encouraging questions. Most groups correctly identified closed and open circuit. The model assisted them to comprehend the concepts.

Special Needs:

Even slow learning learners showed significant improvement in learning science concepts.

Enrichment/Applications:

Learners were tasked to observe TV screen at home, after pushing the switch on. They should write their observations in their dairy.

Homework/Activities from LSM:

Smith, U., Botha, A., De Beer, J. & Phuwe, N. 2004. Physical Sciences for all: Learners' (NCS) book. MacMillan publisher. Page 136 – 137.

Question 1.

1. Use the circuit diagram components, bulb, battery, switch and the wire to draw the circuit diagrams

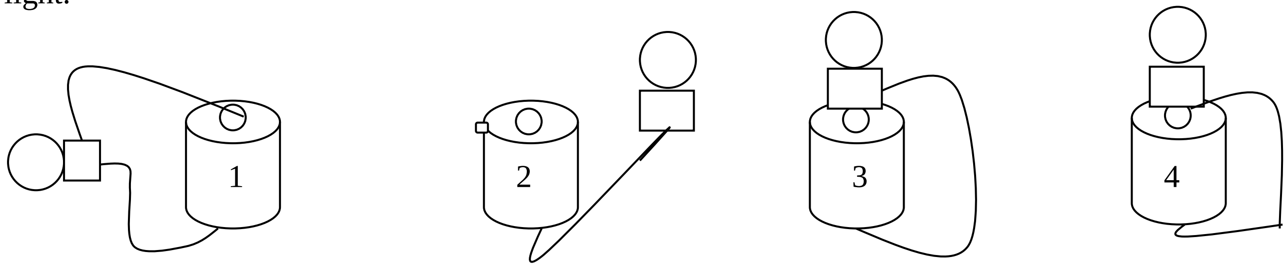
1.1 Open circuit

1.2 Closed circuit

Question 2

2.1. Delete the incorrect word in the following statement: To get the bulb lights we need a **closed/open** circuit.

2.2. For each of the following four circuits, determine whether the bulb will give light and make the corrections such that they all give light.



Lesson 2: Simple Electric Circuit (Week 1, Day 2) Educator: Manabile MP Year: 2011 July School: A and C

<table>
<tr><td colspan="3">Subject: Physical Sciences</td><td colspan="4">Grade: 10</td><td colspan="2">Duration: 1 Hour</td></tr>
<tr><td colspan="3">Core Knowledge Area: Electricity & magnetism
Theme: Electric circuits
Context: Electric circuits in the house, radio, car, power generation, etc</td><td colspan="4">LO 1 LO 2 LO 3
AS 1-4 AS: 1-3 AS: 1& 2
Integration : Mathematics LO: 2
Languages LO: 1
Elect Tech LO: 2</td><td colspan="2">CO: 1- 6

DO: 1- 5</td></tr>
<tr><td colspan="3">Link with previous knowledge: Electrostatics</td><td colspan="6">Link with the next knowledge: Matter and materials- electrical conductors, insulators and semiconductors.</td></tr>
<tr><td rowspan="2">Concepts</td><td rowspan="2">Educator Activity</td><td rowspan="2">Learner Activity</td><td rowspan="2">Resources</td><td colspan="3">Assessment Strategy</td><td rowspan="2">Evidence of achievements</td><td rowspan="2">Time frame</td></tr>
<tr><td>Forms</td><td>Methods</td><td>Tools</td></tr>
<tr><td>Draw simple electrical circuit diagram.</td><td>Activity 2.1

The teacher gives learners in groups a cell, connecting wire and a bulb.

Learners are then instructed to make an electrical circuit that would make the bulb to light.</td><td>Activity 2.1

Learners in groups are asked to make an electrical circuit that would make a bulb to light, given a cell, bulb, and connecting wire.

Each group has to present its working circuit to class.</td><td>Bulbs, cells and connecting wires.</td><td>Practical Task</td><td>Educator</td><td>Checklist</td><td>Learners must be able to construct a simple electric circuit</td><td>15 min</td></tr>
</table>

	Activity 2.2 The teacher asks each group to draw the circuit diagram for the electrical circuit they have constructed in activity 1 and label each electrical component.	**Activity 2.2** Learners draw the diagram for the electrical circuit they have constructed in activity 1 and label the electrical components.	A4 white sheet of papers, pencils, rubbers,	Group Activity	Peer	Checklist	Learners should be able to draw the circuit diagram from the real circuit set-up.	15 min
Given electrical circuit diagram, draw a picture	**Activity 2.3** The teacher Displays A1 size chart with a circuit diagram consisting of the cell, open switch and bulb on the circuit board.	**Activity 2.3** Learners draw the picture of a given circuit diagram Each group has to present its work to the class.	Circuit board, bulb, cell, switch, A3 size plain sheets, pencils, and rubbers.	Group Activity	Peer	Checklist	Learner must be able to draw a picture from the given circuit diagram.	10 min
Connecti on of ammeter	**Activity 2.4**	**Activity 2.4**						

and voltmeter .	The teacher assists learners to connect ammeter and voltmeter in the circuit. The teacher asked learners to predict what will happen to the ammeter if the switch is closed. Close the switch, observe and discuss their observations against their predictions The teacher further assists learners to read measurements reflected on ammeter and voltmeter The teacher writes down important	Learners are instructed to construct a circuit with a cell, bulb and open switch and ammeter (to be connected in series with other circuit components. They are once more requested to open the switch and connect the voltmeter across the bulb (that is, in parallel with the bulb). They are to make prediction, close the switch and observe. Thereafter discuss their findings. Learners write important notes in	Circuit boards, bulbs, cells, switches, ammeters and voltmeters	Practical task	Teacher	Checklist	Learners should be able to connect ammeter and voltmeter, and be able to read meter readings correctly.	20 min

	facts on the chalk board to summarise all the activities.	their dairy books.						

Expanded Opportunities:
Learners are given various circuit (pictures and diagrams) with circuit components connected in different positions to learn.

Reflection:
Learners showed interest in the learning activities, a car activity was most exciting and made learners to ask encouraging questions. Most groups correctly identified closed and open circuit. The model assisted them to comprehend the concepts.

Special Needs:
Even slow learning learners showed significant improvement in learning science concepts.

Enrichment/Applications:

Learners were tasked to observe at home to the TV screen after pushing the switch on. They should write their observations in their dairy.

Homework/Activities from LSM:

Smith, U., Botha, A., De Beer, J. & Phuwe, N. 2004. Physical Sciences for all: Learners' (NCS) book. MacMillan publisher. Page 136 – 137. Question 3.

Lesson 3: (Week 1, Day 3) Electric Circuit   Educator: Manabile MP   Year: July 2011   School: A and C

Subject: Physical Sciences	**Grade**: 10	**Duration**: **1 hour**
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO: 1 Life Sciences LO: 3 Mechanical Tech LO: 3	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy** **Forms**	 **Methods**	 **Tools**	**Evidence of achievements**	**Time frame**
For a given picture, draw one or more circuit diagrams. An extension of	**Activity 3.1** The teacher brought to class a circuit board with two cells, bulb, open switch, ammeter and voltmeter across the cells. Learners are asked to predict what would happen if the	**Activity 3.1** Learners should study the circuit and hypothesize what would happen if the switch is closed. One learner voluntarily is given an opportunity to	Circuit board, two cells, bulb, switch, ammeter, voltmeter. Connecting wires.	Class work	Peer and Educator	Memo	Learners should be able to draw a circuit from a given picture	25 min

activity 2.2 of lesson 2	switch is closed. Their prediction should include the direction of current flow. **Activity 3.2** The teacher displays A1 chart with the picture showing the same set-up as in activity 1. Learners are requested to draw the diagram representing the picture. **Activity 3.3** The teacher gives learners five A4 charts, one with electrical circuit	close the switch for the other learners to observe and discuss their observation in relation to their predictions. **Activity 3.2** Learners in groups draw the circuit diagram for the given picture; they have to label the circuit's components. Each group will have to present its work **Activity 3.3** Learners in groups (Group members changes in each lesson) matches the	A1 size chart with the picture of the electrical circuit Charts with pictures and electrical circuit	Class group activity Class group activity	Group Peer Educator	Checklist Observation sheet	Learners should be able to draw a circuit from a given picture Learners should be able to match the picture with the corresponding	15 min 20 min

<table>
<tr><td></td><td>picture while the other four has different electrical diagrams..</td><td>picture to its diagram. Each group presents its choice with reasons</td><td>diagrams.</td><td></td><td></td><td></td><td>circuit diagram</td><td></td></tr>
<tr><td colspan="9">Expanded Opportunities:

Learners are given various pictures depicting different electrical components, such as door bell, buzzer, car roof light, DC electric motor, etc to draw their circuit diagrams.</td></tr>
<tr><td colspan="9">Reflection:

It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.</td></tr>
<tr><td colspan="9">Special Needs:

A special afternoon class were arranged for learners with special needs such as slow learning,</td></tr>
<tr><td colspan="9">Enrichment/Applications: Homework/Activities

Learners are give a picture of LED to draw.</td></tr>
</table>

Lesson 4: Electric Circuit (Week 1, Day 4) Educator: Manabile MP Year: 2011 July School: A and C

Subject: Physical Sciences			**Grade**: 10				**Duration**: 3 weeks (**15 hrs**)	
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc			LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO: 3 Languages LO: 1 Information Tech LO: 4				CO: 1- 6 DO: 1- 5	
Link with previous knowledge: Electrostatics			**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.					
Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy**			**Evidence of achievements**	**Time frame**
				Forms	**Methods**	**Tools**		
Given a circuit diagram, set up (construct) a real circuit. Extension of	**Activity 4.1** The teacher displays A1 chart with a diagram of electric circuit consisting of three cells connected in series (one after the other facing one direction) switch, bulb, ammeter and voltmeter across the	**Activity 4.1** Learners are instructed to set-up a circuit. Test if their set up works.	Circuit boards, cells, bulbs, switches, ammeters, voltmeters, and Connecting wires.	Practical task	Educator	Checklist	Learners should be able to set-up a real electric circuit when a picture of such circuit is presented.	30 min

activity 2.3 of lesson 2	bulb. **Activity 4.2** The teacher displays the diagram for the torch. The teacher instructs learners in groups to assemble it until it works.	**Activity 4.2** Learners in groups assemble the torch components until it works.	Torches' components	Practical Activity	Peer and Educator	Checklist	Learners should be able to set-up a real electric circuit when a picture of such circuit is presented.	30 min

Expanded Opportunities:

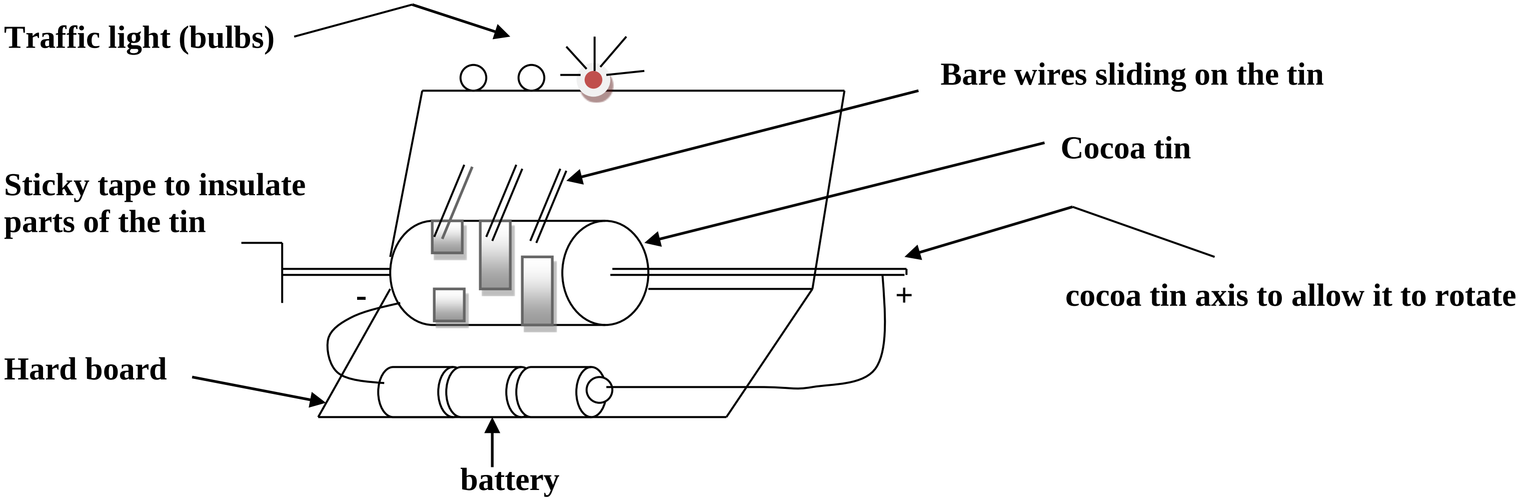
Learners are given door bell electrical circuit diagram, DC door bell, batteries, wire and switch. The teacher requests learners to construct a real circuit for the DC door bell.

Reflection:
It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.

Special Needs:
All learners were actively engaged in the class room activities. No sign of special attention.

Enrichment/Applications: Homework/Activities

Learners were given a circuit diagram for a DC traffic light (robot). They were asked to construct that traffic light. Rotating the axile will make the light flush on and off.



Lesson 5: Electric circuit (Week 1, Day 5) Educator: MP Manabile Year: 2011 July School: A and C

<table>
<tr><td colspan="3">Subject: Physical Sciences</td><td colspan="4">Grade: 10</td><td colspan="2">Duration: 3 weeks (15 hrs)</td></tr>
<tr><td colspan="3">Core Knowledge Area: Electricity & magnetism
Theme: Electric circuits
Context: Electric circuits in the house, radio, car, power generation, etc</td><td colspan="4">LO 1 LO 2 LO 3
AS 1-4 AS: 1-3 AS: 1& 2
Integration : Mathematics LO: 1
Geography LO: 2
Information Tech LO: 4</td><td colspan="2">CO: 1- 6

DO: 1- 5</td></tr>
<tr><td colspan="3">Link with previous knowledge: Electrostatics</td><td colspan="6">Link with the next knowledge: Matter and materials- electrical conductors, insulators and semiconductors.</td></tr>
<tr><td rowspan="2">Concepts</td><td rowspan="2">Educator Activity</td><td rowspan="2">Learner Activity</td><td rowspan="2">Resources</td><td colspan="3">Assessment Strategy</td><td rowspan="2">Evidence of achievements</td><td rowspan="2">Time frame</td></tr>
<tr><td>Forms</td><td>Methods</td><td>Tools</td></tr>
<tr><td>Given a real circuit, draw the circuit diagram.

Extension of activity</td><td>Activity 5.1

The teacher takes learners to the car, when the car driver’s door is opened, the roof bulb lights. The teacher instructs learners to draw the circuit diagram for this circuit.</td><td>Activity 5.1

Learners are instructed to draw the circuit diagram for to show how the car roof bulb has to light when the car driver’s door is opened.</td><td>Car and its roof bulb</td><td>Group Activity</td><td>Educator</td><td>Checklist</td><td>Learners must be able to draw a real circuit from the circuit diagram</td><td>20 min</td></tr>
</table>

2.2	**Activity 5.2** The teacher presses the car hooter and it produces a loud sound. The teacher asks learners to draw the circuit diagram that will make the hooter to sound.	**Activity 5.2** Learners in groups draw the circuit diagram that will make the hooter to sound when pressed.	Car and its hooter.	Group Work	Peer and educator	Checklist	Learners should be able to draw a circuit diagram	10 min
	Activity 5.3 The teacher gives learners in groups different circuits, each group has to draw the diagram (label the electrical components) for the given circuits	**Activity 5.3** Learners in groups draw the circuit diagram (label the electrical components) for different real electrical circuits pre-constructed by the teacher.	Electrical circuits pre constructed by the teacher on the circuit boards. A3 white sheets, rubbers and pencils	Group Work	Educator	Checklist	Learners must be able to draw the circuit diagram and label the circuit components	15 min

	Activity 5.4 The teacher bought the bicycle with a dynamo and the bicycle head light connected to the bicycle. The teacher ask learners in groups to write their prediction , of what would happen if the bicycle wheel is turned. The teacher asked one learner to turn the wheel and ask learners to observe and explain their observation. Then compare their predictions with their observations.	**Activity 5.4** Learners write their predictions regarding what would actually happen when the bicycle wheel is turned. A learner is given an opportunity to turn the wheel, the other learners observe what happens They write their observations and compare them with their predictions. They draw the circuit that makes the light bulb to light.	Bicycle with dynamo and light bulb	Group work	Peer	Checklist	Learners must be able to draw the circuit diagram and label the circuit components	15 min

Expanded Opportunities: Learners are taken to the car and observe how a cigarette lighter get hot and asked to draw its circuit diagram.
Reflection: It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.
Special Needs: All learners were actively engaged in the class room activities. No sign of special attention.
Enrichment/Applications: Homework/Activities Learners were asked to draw the circuit diagram for the brake lights, when the brake paddle is pressed

Lesson 6: **Electric circuit (Week 2, Day 1)** **Educator: MP Manabile** **Year: 2011 July** **School: A and C**

Subject: Physical Sciences	**Grade**: 10	**Duration**: 1 Hour
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO: 2 English LO: 2 Life Sciences LO: 3	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy**			**Evidence of achievements**	**Time frame**
				Forms	**Methods**	**Tools**		
Electrical potential difference and emf	**Activity 6.1** The teacher assists learners to learn how the electrical circuit works through the maize grain game (play). The teacher hands out the game's rules to learners. The volunteers are asked to play, while	**Activity 6.1** Learners read the game's rules and volunteer to partake.	A4 sheets with game rules. 10 liters of Maize gain, coloured string of wool, A4 white sheets with diagrams of	Role play	Peer assessment	Rubric	Learners are able to play the game as instructed	15 min

	the teacher guides them. While the play is on, the teacher guides learners to relate the game with the real electrical circuit.		cell, heat, light, sound, resistor, ammeter, and voltmeter					
	Activity 6.2 The teacher instructs learners to set up an electrical circuit according to the game's circuit. The teacher facilitates and mediates the lesson.	**Activity 6.2** Learners (in groups) set-up the real electrical circuit simulating the circuit played in the game (activity 6.1).	Circuit boards, bulbs, resistors, switches, cells, ammeters and voltmeters.	Practical task	Educator assessment	Checklist	Learners are able to set up electrical circuit	10 min
	Activity 6.3 The teacher request learners to predict the behaviour of	**Activity 6.3** Learners in groups make predictions about ammeter and	Circuit boards, bulbs,	Investigation	Group assessment	Rubric	Learners are able to use the ammeter and	5 min

	ammeter and voltmeter if they have to be connected in circuit with the switch open. They are given an opportunity to connect these meters and make observations and discuss their findings against their predictions. The teacher instigate learners to predict what would happen to the ammeter and voltmeter readings (in activity 6.3) when the switch is closed. The teacher explains the	voltmeter readings when the switch is open. They connect ammeter in series and voltmeter in parallel with the cells and make observations. They discuss their findings against their hypotheses Learners make predictions, close the switch and make observations thereafter they discuss their findings. Learners write notes in their dairy	switches, cells, resistor, ammeters and voltmeters				voltmeter	

	concepts and writes important facts on the board.	books						
Cells connected in series and in parallel	**Activity 6.5** The teacher gives learners two circuit diagrams on A1 chart with Three cells connected in series, while the other has three cells connected in parallel.. The teacher instructs learners to make a prediction regarding the	**Activity 6.5** Learners construct a circuit as prescribed on the chart. They predict what would happen if the switch is closed. Close the switch and make observations thereafter they discuss their findings.	Circuit boards, bulbs, switches, cells,	Practical task	Peer assessment	Rubric	Learners are able to explain the effect of cells in parallel and also in series	10 min

	brightness of the bulb for parallel and series connection of cells. Thereafter they close the switch and make observations. **Activity 6.6** The teacher guides learners to play the maize grain game with two resistors in series and also in parallel. The teacher asks learners to predict number of maize grains that would be in both resistors when the game is stopped. The game is related to the real electrical circuit. The teacher writes	**Activity 6.6** Learners volunteer to play the game with series circuit. Another set of volunteers are asked to play the game for parallel circuit. Each time learners predict the number of maize grains to be registered by the resistors. Learners write the	A4 sheets with game rules. 10 liters of Maize gain, coloured string of wool, A4 white sheets with diagrams of cell, heat, light, sound, resistor, ammeter, and voltmeter	Role play	Peer assess	Rubric	Learners are able to explain why resistors in series increases the resistance of the circuit while in parallel decreases the circuit's resistance.	10 min

Resistors connected in series and resistors connected in parallel	the key points of the lesson on the board. **Activity 6.7** To accommodate the concept of series and parallel connection of the circuit components, the teacher gives learners scenario to analyze. **Activity 6.8** To extend the concepts of series and parallel electrical circuits, the teacher gives learners 12 volts DC light bulbs, car battery, switches and connecting wire. The teacher instructs them to	lesson summary in their dairy books. **Activity 6.7** Learners in groups analyze the given scenario. Each group presents its work to the class. **Activity 6.8** Learners wire their toilets using DC.	Hand out with scenario Car batteries, 12 volts DC light bulbs, connecting wires and switches	Class work Project	Educator assesses Educator assesses	Memora ndum Rubric	Learners are able to analyze the scenario using the concept of series and parallel resistors Learners are able to use the concept of parallel and series connection.	5 min 5 min

	wire boys and girls toilets. Light bulbs are to be connected in parallel, each with its own switch. Boys should wire boys' toilet while girls wire girls' toilet. The teacher supervises.							

Expanded Opportunities:

Learners were asked to visit electricians at their area, particularly those who wire houses ask them how do they connect bulbs in the house and why does she follow that wiring theory. Extra lesson was conducted to play the game and work on POE activities thereafter.

Reflection:

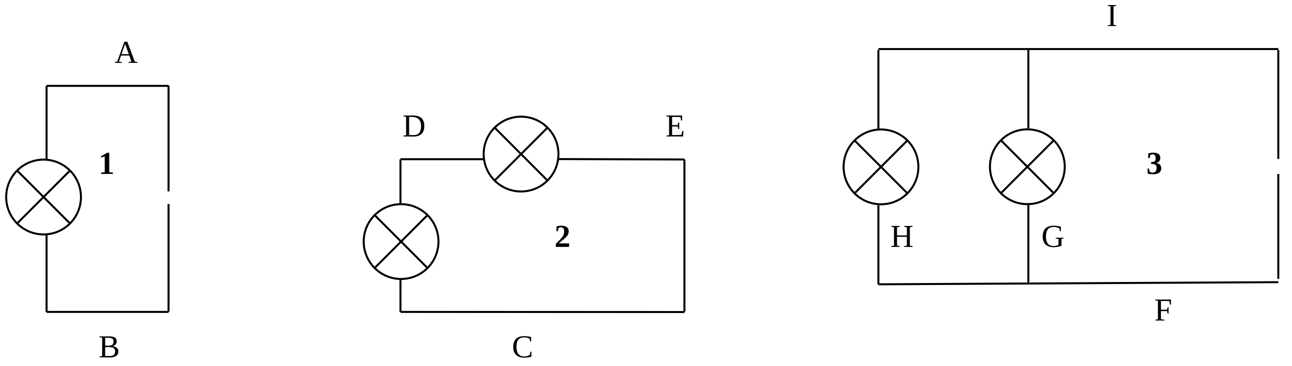
It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.

Special Needs:

All learners were actively engaged in the class room activities. No sign of special attention.

Enrichment/Applications: After school (extra lesson) activities

1.Activity 1 (in group of six members), predict what would happen , write your prediction, then construct these circuits, measure the current as indicated by the letter in the diagram and observe then write down your observations then discuss and write down what actually did you learn from this activity



Prediction table

Before constructing the circuit, complete prediction part for circuit 1, 2 and 3 by filling in **: >, <. or =.**

Circuit 1		**Circuit 2**		**Circuit 3**	
Predicted	Measured	Predicted	Measured	Predicted	Measured
I_A I_B	I_A I_B	I_C I_D	I_C I_D	I_F I_G	I_F I_G
		I_D I_E	I_D I_E	I_F I_H	I_F I_H
		I_C I_E	I_C I_E	I_G I_H	I_G I_H
				I_F I_I	I_F I_I

Measure and fill the table and compare your predictions and measured columns then draw conclusion.

For accurate measurements

Circuit 1: $I_A = I_B$

Circuit 2: $I_C = I_D = I_E$

Circuit 3: $I_G + I_H = I_F$

2.Learners were asked to get more information about the series and parallel connections of bulbs and batteries and their effect on the entire circuit.

Maize Grain Game
(suitable for guided discovery and conceptual change lessons)

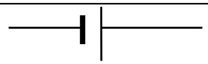
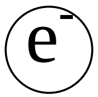
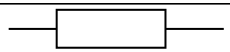
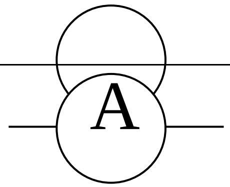
The Maize Grain Game (GBG) has been designed to model what happens in a simple electric circuit. Its main purpose is to clarify a number of concepts related to electric circuits. The activity has been used with reasonable success with teachers and learners in South Africa (Dekkers, 2005: 24).

Needed:

20 participants, 15kg bag of dried beans, 10 cups (for bean collectors and distributions), 20m string (it may be coloured wool string), 2 stopwatches, 25 A4 blank sheets (to draw symbols on), A marker pen (for drawing), Sellotape (to stick symbols on participants).

Rules;

There are various roles for participants. To confirm your role, wear the appropriate sign (use the sticky tape). Participants wear the signs and thereafter their roles are spelled out.

Player	Symbol	Role
Bean source		Provide maize carriers with maize grains
Maize grains carrier		Carry maize grains from the source to the collectors
Maize grains collector		Collect maize grains from the maize grain carriers
Carrier-counter		Count how many carries pass in one minute

Movement controller		Open/close the circuit, to start and end the movement of maize grain carrier.

Educator’s role:

Hand out the signs, bag of maize grains, stopwatches, string and sticky tape. Discuss the rule of the game to learners. Guide learners on how to arrange themselves before they can play. Discuss the role each player should play. The educator remains the facilitator, mediator and engineer of the learning activity. The educator tries to answer the question ‘What to do?’.

What to do ?

Step 1. Maize grains source: Give each passing maize grains carrier 6 maize grains, no more, no less.

Step 2. Bean carrier:

a. Follow the string, do not stop unless the string ends.
b. Whenever you pass the source, accept 6 maize grains.
c. Whenever you pass the collector, give him/her some beans, circle around him/her and then follow the string.
d. Make sure that after completing each full circuit, you have no maize grains left.

Step 3. Maize Grains Collector:

a. From every carrier, collect some maize grains. Make sure the carrier circles around you.

b. Change collected maize grains into something else (choose whether you make light, heat, movement, light or sound, write it in your sign).

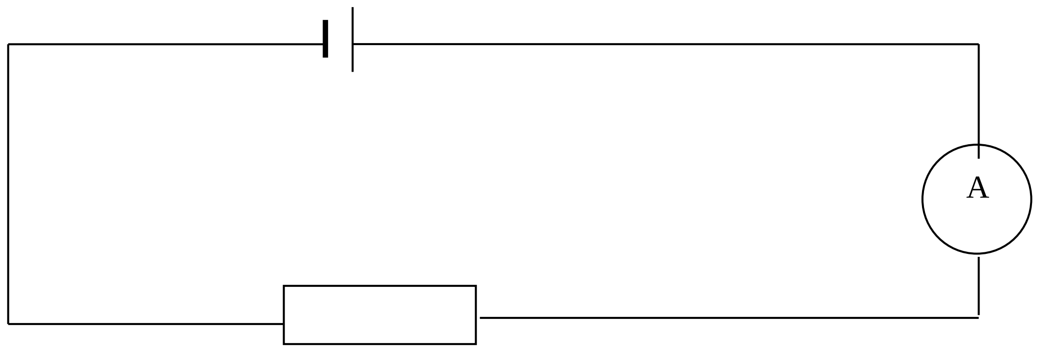
Final rules in summary form:

- maize grains carrier must go around the circuit and follow the string.
- maize grains carrier must deposit all maize grains each time they go around the circuit,
- maize grains carrier must distribute their beans fairly over the maize grain collectors in the circuit, that is, identical maize grains collectors receive identical amounts of maize grains.
- Whenever an educator gives instruction to start or stop the game, the movement controller does the role.

The game can start now ! (Start with one bean source, one maize grain collector and about 10 grain carriers)

Game 1

Using the learning materials, learners build a circuit, similar to this.



Circuit 1: Allow the carriers move a while (about 3 minutes), then stop and answer the following questions.

Q1.1:

In a real electric circuit there is no transport of maize grains, instead of maize grains, what is transported and transformed into light, heat, motion or sound?

Q1.2:

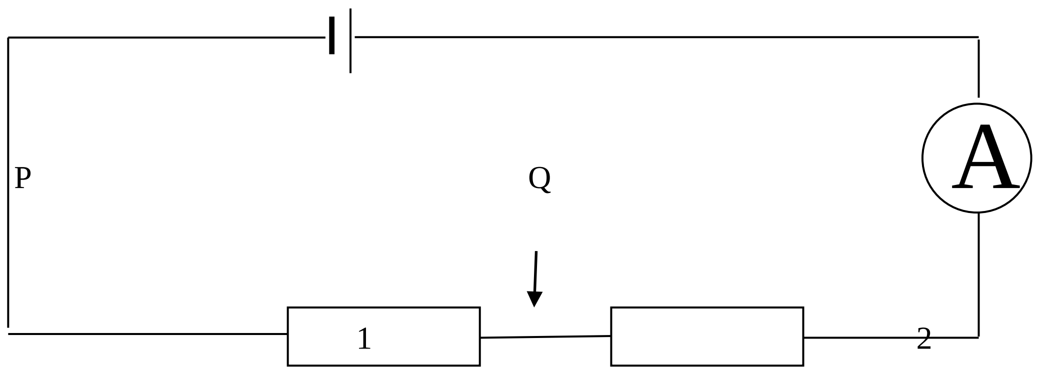
a. How can we make the carriers stop moving ?,
b. What does this tell you about current in an electric circuit ?

Q1.3:

a. Does it matter where we place the counter ?,
b. What can we say about the number of maize carriers at the start and the end of the game ?

Game 2

Set up game 2 as below. Allow the carriers move a while (about 3 minutes), then stop and answer the following questions.



Circuit 2

The following questions are based on circuit 1 and 2.

Q2.1: What changes does the carrier-counter observe, as compared to circuit 1 ? (More, less or the same amount of carriers passing per minutes)

Q2.2: What changes does been collector 1 observe, as compared to circuit 1 ?

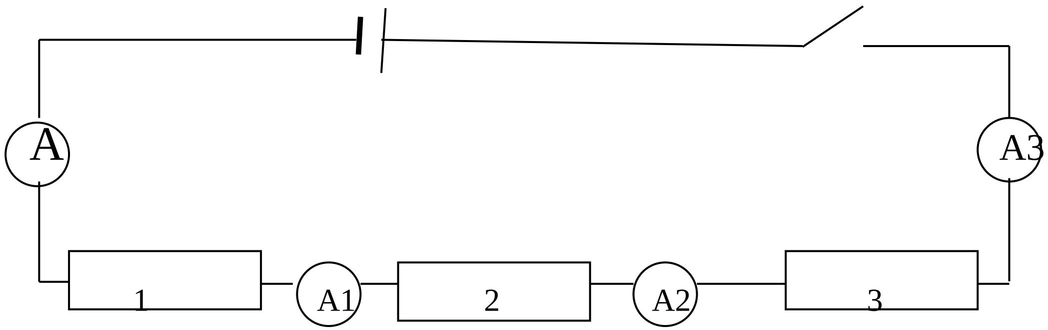
Q2.3: Suppose we change the position of the counter to P or Q. Does that make the difference for the number of carriers passing per minute ?

Q2.4: The text below describes an electric circuit. Each of the term written in bold ***italics*** has a counterpart in our model (game). List all terms written in italics and attach to each, its counterpart.

There is an ***electric current*** if there are ***electric*** charges moving around in a circuit. The electric charges travel through the ***connecting wires*** of the circuit from the ***power source*** to the ***resistors***. The electric charges transport ***electric*** energy from the source to resistors. Resistors collect the energy and transform it into other forms of energy such as heat, light, movement, sound, etc. The electric charge that returns to the source has lost all the energy that was given to it. It is ready to collect (pick) up new energy from the source.

Game 3

Allow the carriers move a while (about 3 minutes), then stop and answer the following questions. The questions compare circuit 1, 2 and 3.



Circuit 3

Q3.1: What charges does the carrier-counter A observe, as compared to circuit 1 and 2?
Q3.2: What changes does grain collector 1 observe, as compared to circuit 1 and 2?
Q3.3: Compare the counts of carrier-counters A. A1, A2. And A3.

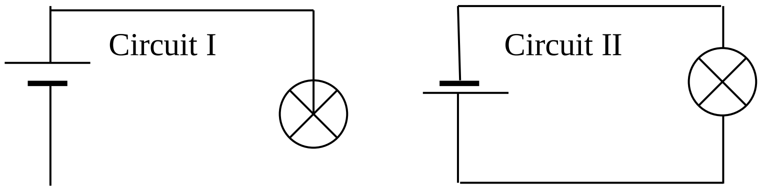
Answers:

Q1.1: Energy, **Q1.2**: Break the string, **Q1.3**:No, it counts the same number/ Number of maize grains remain the same
Q2.1: Less, **Q2.2**: Less carrier, each depositing less maize grains, **Q2.3**: No, **Q2.4**: Electric charge - Flow of maize grains carrier; electric charges – maize grains carrier; connecting wires – the string; power source – maize grains distributor; resistors – maize grains collectors
Q3.1: Less, **Q3.2**: Less carriers, each depositing less maize grains, **Q3.3**: All count the same number.

POE activity is designed to consolidate what has been leant through the maize grains game.

POE Activities 1

Assume that all batteries, wires and bulbs used in the circuits are identical.



Prediction

Compare the brightness of the bulb in circuit I with the bulb in circuit II

a. The bulb of circuit I will be the brighter one
b. The bulb will be equally bright
c. The bulb in circuit II will be the brighter one

Your explanation

Your observation

Build the circuits and do observations to test your prediction.

Observation

____

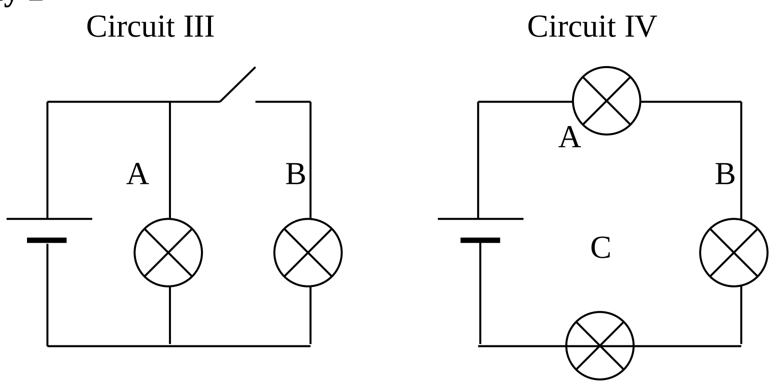
____

Do you want to change your prediction and explanation (yes/no), if yes write below

____

____

POE Activity 2



Assume that all batteries, wires and bulbs used in the circuits are identical.

Activity 2.1 Circuit III

Prediction

In circuit III bulb A is lit. If we close the switch the other bulb will also light. What will happen to bulb A when we close the switch?

a. Bulb A will light brighter than before
b. Bulb A will be equally bright
c. Bulb A will be dimmest, B bright
d. Your explanation

____

____

Your observation

Build the circuit III and do observations to test your prediction.

Observation

____

____

Do you want to change your prediction and explanation (yes/no), if yes write below

____

____

Activity 2.2 Circuit IV

Assume that all batteries, wires and bulbs used in the circuits are identical.

Prediction

a. Bulb A will be brightest, B less bright, C will be dimmer
b. All bulbs will be equally bright
c. Bulb A will be dimmer, B brighter, C will be brightest

Your explanation

____

____

Your observation

Build the circuit IV and do observations to test your prediction.

Observations

____

____

Do you want to change your prediction and explanation (yes/no), if yes write below

____

____

Lesson 7: Simple Electric Circuit (Week 2, Day 3) Educator: Manabile MP Year: 2011 July School: A and C

Subject: Physical Sciences			**Grade**: 10				**Duration**: 1 Hour	
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc			LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO:1 & 2 Languages LO: 1& 2 Mechanical Tech LO: 3				CO: 1- 6 DO: 1- 5	
Link with previous knowledge: Electrostatics			**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.					
Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy**			**Evidence of achievements**	**Time frame**
				Forms	**Methods**	**Tools**		
Determination of the proportion of a voltage across each circuit component	**Activity 7.1** The teacher Gives learners a circuit diagram with 3 resistors of different resistances, connected in series to construct a real circuit. The teacher gives learners an opportunity to	**Activity 7.1** Learners in groups of five members construct the circuit as shown on the circuit diagram. Learners will make prediction, there after measure the voltage through each resistor. Finally they discuss	Circuit boards, cells, resistors, switch, voltmeters	Practical task	Group assessment	Rubric	Learners are able to determine the proportion of a voltage across each circuit component	25 min

	predict the resistance which will have more voltage if voltmeter is connected across it. **Activity 7.2**	their findings. **Activity 7.2**						
Calculations based on resistance – voltage proportionality.	The teacher give learners excise based on the fact that voltage is proportional to the resistance to calculate the voltage across one component. That is, V(across r_1) = $(r_{1} \div R_{t}) \times V_{t}$	Learners write class activity to calculate the voltage through the circuit component using the fact that resistance and voltage through a circuit element are proportional.	Calculators Dairy books	Class work	Peer assessment	Marking memorandum	Learners are able to calculate the voltage through the circuit component using the fact that resistance and voltage through a circuit element are proportional.	35 min

Expanded Opportunities: Learners are taken to the car and observe how a cigarette lighter get hot and asked to draw its circuit diagram.
Reflection: It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.
Special Needs: All learners were actively engaged in the class room activities. No sign of special attention.
Enrichment/Applications: Homework/Activities Page 140 learners' book, question 8

Lesson 8: Simple Electric circuit (Week 2, Day 3) **Educator: Manabile MP** **Year: 2011 July** **School: A and C**

<table>
<tr><td colspan="3">Subject: Physical Sciences</td><td colspan="4">Grade: 10</td><td colspan="2">Duration: 1 hour</td></tr>
<tr><td colspan="3">Core Knowledge Area: Electricity & magnetism
Theme: Electric circuits
Context: Electric circuits in the house, radio, car, power generation, etc</td><td colspan="4">LO 1 LO 2 LO 3
AS 1-4 AS: 1-3 AS: 1& 2
Integration : Mathematics LO: 1
Information Tech LO: 4
Electrical Tech LO: 2</td><td colspan="2">CO: 1- 6

DO: 1- 5</td></tr>
<tr><td colspan="3">Link with previous knowledge: Electrostatics</td><td colspan="6">Link with the next knowledge: Matter and materials- electrical conductors, insulators and semiconductors.</td></tr>
<tr><td rowspan="2">Concepts</td><td rowspan="2">Educator Activity</td><td rowspan="2">Learner Activity</td><td rowspan="2">Resources</td><td colspan="3">Assessment Strategy</td><td rowspan="2">Evidence of achievements</td><td rowspan="2">Time frame</td></tr>
<tr><td>Forms</td><td>Methods</td><td>Tools</td></tr>
<tr><td>

Solve problems in which the voltages across elements in a circuit add up to emf.</td><td>Activity 8.1

Through question and answer method, the teacher leads learners to solve problems in which voltages across the circuit components add up to the emf.</td><td>Activity 8.1

Learners solve problems in which voltages across the circuit components add up to the emf.</td><td>

Calculators. Dairy books</td><td>

Class test</td><td>

Educator assessment</td><td>

Memoran dum</td><td>

Learners are able to solve problems in which the voltages across elements in a circuit add up to emf.</td><td>

60 min</td></tr>
</table>

Expanded Opportunities:

Learners are taken to the car and observe how a cigarette lighter get hot and asked to draw its circuit diagram.

Reflection:

It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.

Special Needs:

All learners were actively engaged in the class room activities. No sign of special attention.

Enrichment/Applications: Homework/Activities

Page 140 learners' book, question 8

Lesson 9: Simple Electric Circuit (Week 2, Day 4) Educator: Manabile MP Year: 2011 July School: A and C

Subject: Physical Sciences	**Grade**: 10	**Duration**: 1 Hour
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO: 1 English LO: 1 Information Tech LO: 4	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy**			**Evidence of achievements**	**Time frame**
				Forms	**Methods**	**Tools**		
	Activity 9.1	**Activity 9.1**						
Current,	The teacher switches on the torch and asks learners to define "current".	Learners define current	Calculators. Circuit board, cell, resistor, switch. ammeter	Practical task and debate	Peer assessment	Checklist	Learners are able to define current	25 min
	The teacher defines and explains the conventional current using	Learners write important facts and definition in their dairy books	Dairy books	Class work	Self assessment	Memoran dum	Learners are able to define conventional current	10 min

	electrostatics then electric circuit.							
$I = Q \times \Delta t$	The teacher explains the equation $I = Q \times \Delta t$ and assists learners to calculate current using this equation.	Learners write the description of each symbol and calculate current using the equation $I = Q \times \Delta t$	Calculators	Class work	Educator assessment	Memoran dum	Learners are able to use the said equation to calculate current	25 min

Expanded Opportunities:

Question 12, page 143: from learners' book

Reflection:

It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.

Special Needs:

All learners were actively engaged in the class room activities. No sign of special attention.

Enrichment/Applications: After school (extra lesson) activities

Question 16 and 18 page 146 to 147, learners' book

Lesson 10: Simple Electric Circuit (Week 2, Day 5) Educator: Manabile MP Year: 2011 July School: B and C

Subject: Physical Sciences	**Grade**: 10	**Duration**: 1 Hour
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO: 1 & 2 languages LO: 3 Tourism Studies LO: 4	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy**			**Evidence of achievements**	**Time frame**
				Forms	**Methods**	**Tools**		
	Activity 10.1	**Activity 10.1**						
Determine the current through the battery in a circuit with several resistors in series relative to a circuit	The teacher forms seven research teams. Each team is given a prediction sheet. A group has to predict by filling >, < or =, then construct a circuit guiding by a given circuit diagram.	Learners in research teams use a prediction sheet to fill >, < or =. The teams construct a circuit and measure current at the identified points. They debate their findings. Each	Prediction sheet, A1 chart with circuit diagram, circuit boards, battery, resistors of equal	Presenta tion	Peer assessment	Checklist	Learners are able to determine the current through the battery in a circuit with several resistors in series relative to a circuit with a single	15 min

with a single resistor.	They use ammeter to measure current at the identified points. Discuss the discrepancies. **Activity 10. 2** The teacher guides learners to summarize the research work from the groups **Activity 10.3** The teacher hands out the exercise to learners and assists them to calculate the current passing through the resistors in series.	team report to the class for general discussion. **Activity 10.2** Learners write the summary in their dairy books **Activity 10.3** Learners in groups calculate the current passing through the circuit if resistors are connected in series. The equation $R_t = r_1 + r_2 + \ldots$ is used together with $V = IR$	resistances, ammeters. Dairy books Problems based on circuit with series resistors and their pre-worked out solutions	Class work Class Work	Educator assessment Self assessment	Rubric Memoran dum	resistor. Learners are able to summarize the activity in their own words Learners are able to solve problems based on resistors in series	5 min 10 min

Determine the current through the battery in a circuit with several resistors connected in parallel in series relative to a circuit with a single resistor.	**Activity 10.4** The teacher displays A1 chart size with the circuit diagram having two resistors connected in parallel. As in activity 10.1, learners predict by filling >, < or = then connect the voltmeter across identified points to measure the voltage of circuit elements in parallel. Each group is given the prediction sheet. Groups report and their findings are compared through discussion. The teacher guides learners to summarize their observation.	**Activity 10.4** Learners in groups construct the circuit which is similar to the circuit diagram on the chart. Each group fill in the prediction sheet there after measure the current through the identified points, then fill the table using the information obtained from the measurements. Learners summarize their discussion based on their observation	Prediction sheet, A1 chart with circuit diagram, circuit boards, battery, resistors of equal resistances, ammeters.	Presenta tion	Educator assessment	Rubric	Learners are able to determine the current through the battery in a circuit with several resistors connected in parallel in series relative to a circuit with a single resistor.	10 min

		versus their hypotheses.						
	Activity 10.5 The teacher hands out the exercise to learners and assists them to calculate the current passing through the resistors in parallel	**Activity 10.5** Learners in groups calculate the current passing through the circuit if resistors are connected in parallel. The equation $R_t = 1/r_1 + 1/r_2 + \ldots$ is used together with V = IR	Problems based on circuit with series and parallel resistors together with their pre-worked out solutions	Home work	Educator assessment	Memoran dum	Learners are able to solve problems based on resistors in parallel	10 min
Determine the current	**Activity 10.6** The teacher assists learners to extend and accommodate the series and parallel concepts by guiding them to solve problems based on combined series and parallel	**Activity 10.6** Learners through teacher mediation, solve problems based on circuit diagrams with series and parallel connection of resistors.	Materials from the environment	Project	Educator assessment	Scoring rubric	Learners are able to determine the current through the battery in a circuit with combine series and parallel	

through the battery in a circuit with combine series and parallel resistors	connections. The teacher divide the class into two teams and assign each team a project which will make them to go beyond (expand their study opportunities on electric circuit).	Learners in two teams are given a project to make. One team is requested to make a Christmas tree having lights with different brightness such that when one light burns others stay on while the other team build a house with two rooms using hard board and wire it.					resistors	

Expanded Opportunities:

Activity 10 .6 above was given as a project

Special Needs:

Even slow learning learners showed significant improvement in using the formula and getting the correct solutions

Enrichment/Applications:

An old radio was brought to the class were learners could learn about combined series and parallel connection of resistors

Homework/Activities from LSM:

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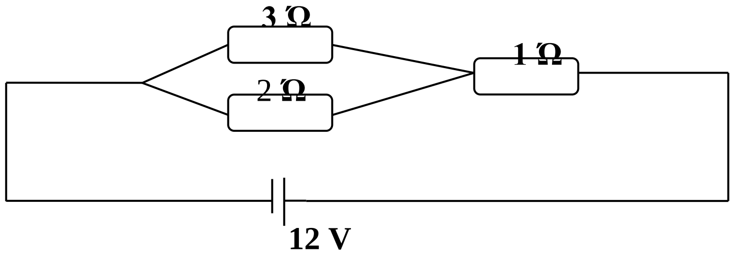

Calculate

1. The effective resistance of the circuit
2. The total current flowing in the circuit
3. The potential difference across the parallel combination
4. The current through 2 Ω resistor

Lesson 11: **Simple Electric Circuit (Week 3, Day 1)** **Educator: Manabile MP** **Year: 2011 July** **School: B and C**

Subject: Physical Sciences	**Grade**: 10	**Duration**: 1 Hour
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1&2 **Integration :** Mechanical Tech LO: 1 Electrical Tech LO: 2 Information Tech LO: 2 AS:3	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy**			**Evidence of achievements**	**Time Frame**
				Forms	**Methods**	**Tools**		
Microscopic description of resistance in terms of electrons moving through a conductor and	**Activity 11.1** The teacher instructs learners to play the maize grain game. The teacher details the microscopic description of resistance in terms of electrons moving through a conductor	**Activity 11.1** Learners voluntarily play the maize grain game. Learners are instigated to relate the game with the microscopic description of resistance in terms of electrons moving	Learners, coloured wool string, maize grains, A4 charts with symbols of battery, charge, bulb, ammeter and game rules.	Role-play	Self assessment	Rubric	Learners are able to describe resistance (microscopically) in terms of electrons moving through a conductor and transferring its kinetic energy.	30 min

transferring its kinetic energy.	and transferring its kinetic energy in relation to the game, while the game is on. **Activity 11. 2** The teacher provides learners with a description of electric circuit and instructs them to construct it. The teacher allow learners to predict what resistance of nichrome wires with different thickness lengths, in terms of one will be less or more or equal to the other. Measure their resistance and discuss their findings	through a conductor and transferring its kinetic energy. **Activity 11.2** Learners predict the resistance of a resistor, according to its colour codes and then measure it using ammeter and voltmeter. Learners predict the resistance of one nichrome wire in relation to one another. Measure their resistances and discuss their findings. They also touch the wires during the experimental stage to feel if really electrons transfer	Circuit boards, battery, ammeter and stop watch. Electric wire, heater, resistor, nichrome wires with different thickness and lengths.	Practical task	Group assessment	Checklist	Learners are able to explain energy transformation into heat or light	30 min

		its kinetic energy.						

Expanded Opportunities:

The wire heater is plug on the wall. Learners could easily learn the concept of a moving charge, transferring energy (heat energy).

Reflection:

It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.

Special Needs:

All learners were actively engaged in the class room activities. No sign of special attention.

Enrichment/Applications: Homework/Activities

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1. Learners should write an essay on how the geyser, electric kettle and electric iron work.
2. Question 17, page 146

Lesson 12: Simple Electric Circuit (Week 3, Day 2) Educator: Manabile MP Year: 2011 July School: B and C

Subject: Physical Sciences	**Grade**: 10	**Duration**: 1 Hour
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1& 2 **Integration :** Agricultural Sciences LO: 4 Languages LO: 1 Electrical Tech LO: 1	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	Educator Activity	Learner Activity	Resources	Assessment Strategy			Evidence of achievements	Time frame
				Forms	Methods	Tools		
Definition of resistance	**Activity 12.1** The teacher displays A1 chart with George Ohms' photograph. The teacher asks one learner to read George Ohm's historical background in relation to the resistance. The	**Activity 12.1** A learner reads aloud the historical background of George Ohms. Learners in groups define resistance in terms of voltage and amperes. Learners learn the colour coding and the writing of	Photograph of George Ohms. Flat battery and the one which is not flat. Different resistors, Chart with colour coding and resistance of	Debate	Peer assessment	checklist	Learners are able to define resistance	30 min

	teacher guides learners to define resistance in their own words. The teacher displays A1 chart with pictures of resistors and their colour coding corresponding to their resistances.	resistance of a resistor.	resistors.						
Energy transformation	**Activity 12.2** The teacher provides learners with flat batteries and instructs them to construct a circuit. They are later given new batteries. The teacher interrogates learners to provide a scientific reasoning why batteries go flat The teacher	**Activity 12.2** Learners in groups make a circuit with a flat battery unaware, and then replace it with new battery. Discuss the behaviour of two circuits in terms of energy transformations that takes place in the battery and through the resistors in a circuit.	Circuit boards, flat batteries, new batteries and light bulbs	Class work	Educator assessment	memorandum	Learners are able to explain energy transformation taking place in a battery and through the resistors in a circuit.	30 min	

	demonstrate what happens when the battery goes flat by using Zn-Cu electrochemical cell							

Expanded Opportunities: Lemon fruits are connected to form a battery.
Reflection: Learners were actively involved during Zn-Cu cell construction. This cell explained well what I meant by flat battery.
Special Needs: All learners were actively engaged in the class room activities. No sign of special attention.
Enrichment/Applications: Homework/Activities They were requested to bring along different resistors with different colour codes to the class.

Lesson 13: **Simple Electric Circuit (Week 3, Day 3) Educator: Manabile MP Year: 2011 July School: B and C**

Subject: Physical Sciences	**Grade**: 10	**Duration**: 3 weeks (**15 hrs**)
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO: 1 Languages LO: 1 Eng Graphics LO: 1 & 2	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy**			**Evidence of achievements**	**Time frame**
				Forms	**Methods**	**Tools**		
Adding resistors in series in a circuit increases the resistance of the circuit.	**Activity 12.1** The teacher Instructs learners to construct two circuits, one with one bulb and the other with two bulbs in series. The circuit must have equal batteries connected in series. Asks learners to	**Activity 12.1** Learners construct two circuits, one with one bulb and the other with two bulbs in series. They predict the brightness of bulbs in two the circuit and then switches on and observe, and make final	Circuit boards, resistors (bulbs) and batteries.	Group work	Self	Checklist	Learners should be able to draw conclusion that increasing resistors in series, increases the resistance of the circuit	60 min

	predict the brightness of bulbs in two the circuit and then switches on and observe then make final comparison of the two circuits.	comparison of the two circuits (the brightness of the bulbs).						

Expanded Opportunities:

Learners were taken to the car, the car was started while the lights were on, learners could observe the change in brightness of the bulbs.

Reflection:

It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.

Special Needs: All learners were actively engaged in the class room activities. No sign of special attention.

Lesson 14: Simple electric Circuit (Week 3, Day 4) Educator: Manabile MP Year: 2011 July School: B and C

Subject: Physical Sciences	**Grade**: 10	**Duration**: 1 Hour
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS: 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO: 2 Languages LO: 1 Information Tech LO: 2	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	Educator Activity	Learner Activity	Resources	Assessment Strategy			Evidence of achievements	Time frame
				Forms	Methods	Tools		
Adding resistors in parallel in a circuit, decreases the total resistance of the circuit.	**Activity 14.1** The teacher Instructs learners to construct two circuits, one with one bulb and the other with two bulbs in parallel. The circuit must have equal batteries connected in series.	**Activity 14.1** Learners construct two circuits, one with one bulb and the other with two bulbs in parallel. They predict the brightness of bulbs in two the circuit and then switches on and observe, and	Circuit boards, resistors (bulbs) and batteries.	Practical task	Peer assessment	Rubric	Learners are able to state that adding resistors in parallel in a circuit, decreases the total resistance of the circuit.	60 min

	The teacher asks learners to predict the brightness of bulbs in two the circuit and then switches on and observe, then make final comparison of the two circuits.	make final comparison of the two circuits (the brightness of the bulbs).						

Expanded Opportunities:
Learners are given door bell electrical circuit diagram, DC door bell, batteries, wire and switch. The teacher requests learners to construct a real circuit for the DC door bell.

Reflection:
It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.

Special Needs: All learners were actively engaged in the class room activities. No sign of special attention.
Enrichment/Applications: Homework/Activities Question 26, page151.

Lesson 15: Simple Electric Circuit (Week 3, Day 5) **Educator**: Manabile MP **Year**: 2011 July **School**: B and C

Subject: Physical Sciences	**Grade**: 10	**Duration**: 1 Hour
Core Knowledge Area: Electricity & magnetism **Theme**: Electric circuits **Context**: Electric circuits in the house, radio, car, power generation, etc	LO 1 LO 2 LO 3 AS: 1-4 AS: 1-3 AS: 1& 2 **Integration :** Mathematics LO: 1 & 4 Languages LO: 2 Eng Graphics LO: 1	CO: 1- 6 DO: 1- 5
Link with previous knowledge: Electrostatics	**Link with the next knowledge**: Matter and materials- electrical conductors, insulators and semiconductors.	

Concepts	**Educator Activity**	**Learner Activity**	**Resources**	**Assessment Strategy**			**Evidence of achievements**	**Time frame**
				Forms	**Methods**	**Tools**		
Construct and short cut a circuit	**Activity 15.1** The teacher instructs learners to construct circuit with battery, one bulb and the switch. The teacher asks learners to predict they what would happen if another is connected across the bulb. After they	**Activity 15.1** Learners construct circuits with battery, one bulb and the switch. They predict what would happen if another is connected across the bulb. After they have debated their predicted, they	Circuit boards, resistors (bulbs) and batteries.	Investig ation	Group assessmen t	Rubric	Learners must be able to construct a circuit and short circuit	35 min

Draw a diagrams to show a short circuit	have debated their predicted, they connect the wire, switch on and observe, then make final discussion. The teacher guides learners to conceptualize the short circuit. **Activity 15.2** The educator asks learners to draw the circuit diagram for the short circuit they have constructed.	connect the wire, switch on and observe, then make final discussion. Each group presents its work. **Activity 15.2** Learners draw the circuit diagram for the short circuit they have constructed.	Dairy books Pencils Rulers and rubbers.	Class work	Educator assesses	Checklist	Learners must be able to draw a short circuit	25 min

Expanded Opportunities: Learners are given door bell electrical circuit diagram, DC door bell, batteries, wire and switch. The teacher requests learners to construct a real circuit for the DC door bell.
Reflection: It was done by both educator and learners at the end of the lesson. Important contributions that will improve the same presentation were noted and written down.
Special Needs: All learners were actively engaged in the class room activities. No sign of special attention.
Enrichment/Applications: Homework/Activities Question 26, page151.