Teaching Electrostatics in Grade 11 Physical Sciences using a Conceptual Change Approach

Zingiswa Ndeleni

3082736

Submitted in fulfilment of the requirements for the degree of

Masters in Science Education

in the Science Learning Centre for Africa

in the Faculty of Education,

University of the Western Cape

SUPERVISOR: PROFESSOR M.S. HARTLEY

DECLARATION

I declare that "**Teaching Electrostatics in Grade 11 Physical Science using a Conceptual Change Approach"** is my work, that it has not been submitted for any degree or at any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

……………………………………….. …15/11/2017……………………..

Zingiswa Ndeleni Date

Acknowledgements

Any adventure or endeavour cannot be accomplished or attained without moral and spiritual support from the others. By so saying I want to thank the following individuals for their support from the bottom of my heart:

Prof. Shaheed Hartley, my study supervisor, who was always available, regardless of his hectic and congested schedule, and gave expert advice. You provided superb academic guidance when the going was getting tough. You contributed much of your time to this study. Thank you very much for your words of encouragement, inspiration and motivation.

To my family, I would like to thank you for the tolerance and understanding you exercised during the time of my study because, as you know, I was often away from home.

To my fellow study group members who put in a lot of effort and hard work. I remember that we were always putting more effort into the work and thus at the end we became friends. You will always be remembered.

To my grade 11 learners affectionately referred to as "the target population". Don't be afraid because you were targeted for a good cause. Through your desire for knowledge, interests, probing questions and keen participation this study became a success.

Above all, great reverence is given and directed to the Almighty God the Beginning and the End.

Abstract

The study was conducted at a senior secondary school situated in a deep rural area of the district of Cofimvaba in the Eastern Cape Province. It was motivated by academically struggling grade 12 learners in my school who were experiencing problems in mastering the electrostatics concept which is introduced in grade 10. The aim was to come up with alternative teaching strategies that can assist learners in grasping the concept. This study employed the conceptual change framework as a teaching strategy to improve learners' understanding of electrostatics. Theories that underpin this study are constructivism and conceptual change. The sample for this study was a Grade11 physical science class with a total sample size of forty-five learners. It was a case study as the researcher focused on a single class in a school. This study employed a mixed approach as both qualitative and quantitative instruments were used in the data collection process. Learners wrote the pre-test that served as a baseline evaluation. An intervention in the form of a lesson presentation followed, addressing the four stages of conceptual change. A post-test followed immediately after the presentation to assess the results of the conceptual change approach. Five learners were randomly selected from the total population for interviewing. The study found that learners understanding of electrostatics improved after the conceptual change lesson and learners indicated that they found the lessons much more interesting. The study provided insight into the use of the conceptual change framework as a teaching strategy and contributed to the limited baseline data available on the teaching of electrostatics in rural schools in South Africa.

Key words: science education, conceptual change theory, electrostatics, rural schools, Eastern Cape, physical sciences instruments.

TABLE OF CONTENTS

List of Figures

List of tables

LIST OF ABBREVIATIONS

NSC	-National Senior Certificate
MST	-Mathematics Science and Technology
GET	-General Education and Training
FET	-Further Education and Training
TVET	-Technical and Vocational Education and Training
NMMU	-Nelson Mandela Metropolitan University
MATHSUP	-Mathematics Skills Upgrade Programme
SSUP	-Science Skills Upgrade Programme
ETDP	-Education, Training and Development Practices
DBE	-Department of Basic Education
ACE	-Advanced Certificate in Education
ICT	-Information Communications and Technologies

CHAPTER ONE
RATIONALE OF THE STUDY

1.1 Introduction

The aim of this study is to investigate the use of the conceptual change approach to enhance the teaching of electrostatics in Grade 11 physical sciences. This chapter introduces the research problem and the research question by providing the background to the study, the context in which the study is conducted and also the significance and limitations of the study.

1.2 Background to the study

South Africa is facing a big challenge as far as mathematics and physical sciences is concerned. As far as educational achievements, the annually-reported statistics from the National Senior Certificate (NSC) exam in Grade 12 are particularly misleading since they do not take into account those pupils who never make it to Grade 12. For every 100 pupils that start school, only 50 will make it to Grade 12. A total of 40 of the 50 learners will pass, and only 12 will qualify for university. Those 18-24 year olds who do not acquire some form of post-secondary education are at a distinct economic disadvantage. They not only struggle to find full-time employment, but also have one of the highest probabilities of being unemployed for sustained periods of time, if not permanently (Berger, 2013).

Furthermore, Berger (2013) also highlighted that many critics have pointed out that the National Senior Certificate (NSC) pass requirements are sub-standard and encourage mediocrity. Arguably the more serious problem is widespread drop-out before Grade 12, and that over time more pupils seem to be choosing less demanding exam subjects. Regarding the latter, it is revealing to note that over the four-year period between 2008 and 2011, the proportion of pupils taking mathematics (as opposed to mathematical literacy) has fallen from 56 per cent to 45 per cent, as more pupils opt for the easier mathematical literacy.

The Eastern Cape Province is a large province with many rural districts. The province has historically been seriously impacted by discriminatory education delivery in the pre-democratic system in South Africa. In the current democratic system, the province continues to struggle to overcome the serious under performance in the vast majority of the schools. The province was ranked last out of the nine provinces in both mathematics and physical sciences performance in the 2012 NSC examination. Key findings indicated by the Department of Education (DOE) (2014) as reasons for the poor performance were:

- Many vacant posts existed throughout the system – at school, district and provincial level.
- Most of the rural schools were faced with multi-grade teaching.
- Whilst a mathematics, science and technology (MST) sub-directorate was in place, it operated as a unique entity with limited engagement with the curriculum directorate and limited engagement with district subject advisors. However, there was one MST official per district who was responsible for implementation of MST activities in each district.
- The general education and training (GET) and further education and training (FET) directorates had provincial subject planners and subject advisors in districts that were responsible for curriculum implementation in schools. They trained and supported teachers.
- Schools had a serious shortage of qualified and competent educators - the resultant impact on the teaching of mathematics and science was sufficiently serious to foreground the need for a systematic programme to upgrade educators' competence both in content and pedagogy to enable them to teach the curriculum efficiently. The province reported poor teacher development, both in-service and pre-service.
- Teachers also raised concerns about the competency of some curriculum advisors and the inadequate ratio of curriculum advisors to teachers. This often resulted in teacher workshops being below standard. They also suggested that workshops be complemented by follow-up classroom support by curriculum advisors.
- An absence of effective monitoring and evaluation was evident in the schools that were selected by the province for the investigation.
- Some training was done during contact teaching time which impacted on teaching and learning. The distance that teachers had to travel was a contributory obstacle in resolving this problem.

- Budgetary constraints led to a serious shortage of physical resources such as laboratories and equipment and impacted on the execution of practical work in physical sciences required by the curriculum.
- ICT in teaching and learning was non-existent in the vast majority of schools that were selected by the province for the investigation.
- Communication was a general problem throughout the system. For example, even curriculum advisors did not have access to e-mail at work. Most schools were provided with a laptop and 3G facility but claimed that they did not know how to use the technology.

Table 1: Learner results in physical sciences in NSC examinations: 2011-2014

Year	No. Wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2011	180 585	96 441	53.4	61 109	33.8
2012	179 194	109 918	61.3	70 076	39.1
2013	184 383	124 206	67.4	78 677	42.7
2014	167 997	103 348	61.5	62 032	36.9

In comparison to 2013, it was also noted in Table 1 above that the number of candidates writing the subject decreased by 16 386. This was very disconcerting as the numbers writing examinations in 2011 and 2012 remained steady and then increased in 2013. Figure 1 below illustrates percentage achievements from 2011-2014. The percentage of candidates performing below the 30% category increased from 2011 to 2013. This signified a drop in the overall performance. There was also a decrease in the percentage of candidates achieving at all levels from 30 to 80% which meant fewer candidates passing.

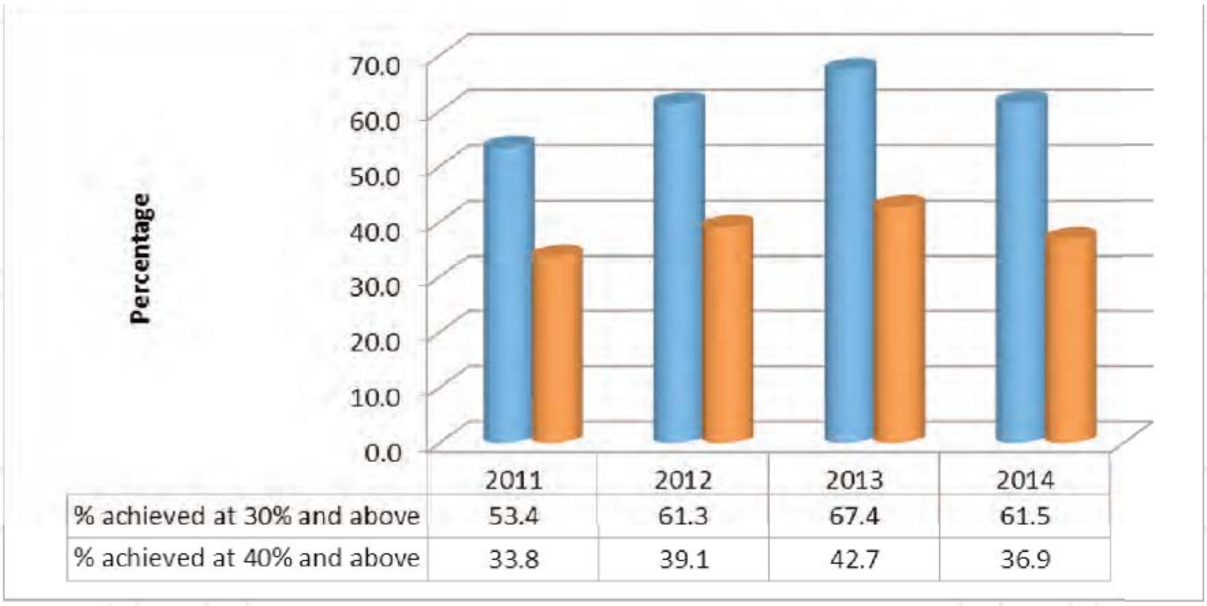


Figure 1: Graphic representation of learner achievement in NSC physical sciences

The general performance of candidates in physical sciences in the NSC examinations reflected a decline from the previous two years as presented in Table 1 below (NSC Diagnostic Report, 2014). The number of candidates who passed at the 30% level declined by 5.9 percentage points and those who passed at the 40% level also declined by 5.8 percentage points. Candidates achieving distinctions over 80% increased marginally from 3.1% to 3.3% of total candidates.

The percentage of candidates performing in the 80-100% categories marginally increased showing an increase in the number of distinctions compared to 2013 (NSC Diagnostic Report, 2014).

1.3 State of science education in South Africa (SA) and the Eastern Cape Province

1.3.1 Implementation Plan for Mathematics, Science and Technology

Although the Implementation Plan for Mathematics, Science and Technology, which was published in 2012, may not fully describe the national MST strategy, it provided a more recent perspective on government's strategy. In particular, it identified failures and achievements since the initial publication of the national MST strategy. The first thrust, regarding the participation and performance by historically disadvantaged learners, received most of the attention, with shortcomings in the dedicated school's strategy being a principal concern. It was also acknowledged that technology education was not promoted effectively.

The document also introduced new terminology: ‘Pillars’ replaced ‘thrusts’ in defining the following implementation strategies:

A. Improving of participation and performance of girl learners.

B. Support for teaching and learning.

C. Teacher development.

D. Provision of resources.

These pillars related to previous statements of intent with three much generalized pillars (B, C and D) and one more specific pillar (A). However, overall the document was confusing and poorly prepared and, unlike the 2001 strategy document, did not inspire confidence and was unhelpful to provinces.

1.3.2 Provincial implementation strategies

There was considerable variation in the provincial MST strategy documents. The variation had less to do with the recognition of the national MST strategy of 2001 as a base document of the implementation plan of 2012, as with the extent to which provincial plans interpreted the operational implications and actions to achieve the main goals.

Gauteng and Limpopo produced the most comprehensive strategic documents that were strong on content and logic. Four other provinces (Eastern Cape, KwaZulu Natal, Northern Cape, and Western Cape) produced somewhat smaller strategy documents, which were also well presented, logical and clear. In a number of these cases the analyses and proposals were supported by references or bibliographies which demonstrate that the strategies were based on informed research.

The key pillars and thrusts of the national documents found expression in slightly different ways in each of the provincial strategies. In many instances, national terminology was amended to a provincial terminology, so that we found objectives, key thrusts, strategic pillars, focus areas and domains, as well as simply pillars and thrusts. Most provincial strategies had either 4 or 5 such key pillars and most included some distinctive variations.

The following programmes were introduced in the Eastern Cape in an attempt to improve the NSC results of the province:

- Mathematics and science education in East London, King William's Town, Port Elizabeth, Uitenhage, Grahamstown and Dutywa classrooms received a high-tech boost in 2014, through a leading-edge professional skills upgrade programme attended by 210 maths and 50 science teachers.
- Fifty Technical and Vocational Education and Training (TVET) college mathematics lecturers, from five colleges throughout the province, were also put through their paces in the same part-time, year-long programme, developed and run by Nelson Mandela Metropolitan University's Govan Mbeki Mathematics Development Unit (GMMDU).
- The Grade 11 and 12 teachers and TVET lecturers completed two short learning programmes through the NMMU-accredited Mathematics Skills Upgrade Programme (MATHSUP) and Science Skills Upgrade Programme (SSUP), with funding provided by the Education, Training and Development Practices (ETDP) Seta and the provincial Department of Basic Education (DBE).
- The investment in skills upgrade programmes for in-service teachers formed part of a provincial strategy by the DBE to improve the state of mathematics and science education in secondary schools in the province. A similar cohort of teachers was identified to register for the MATHSUP and SSUP skills upgrade programmes in 2015.
- A programme was conducted by the University of the Western Cape called Advanced Certificate in Education (ACE in FET) Physical Sciences where fifty sciences teachers received training.
- Forty-five teachers from those who were the recipients of the ACE course continued into the BEd Honours course registered with the University of the Western Cape. Twenty-six teachers were enrolled with the University of the Western Cape studying Masters in Science Education.

1.4 Context of the study

The Eastern Cape Province is one of the provinces where learners have performed consistently poorly in physical sciences. The challenge to schools where learners are not performing well in the subject has been to come up with strategies to address underachievement in the subject. One of the factors that influenced the poor results was the various conceptions that learners bring to classes about science concepts in the curriculum. One of the topics that the researcher identified as a contributing factor to serious misconceptions is the concept of electrostatics.

The researcher is a physical sciences teacher at a Senior Secondary School in the Eastern Cape Province. The researcher has been teaching physical sciences for twelve years. The school where the study was conducted is situated in a deep rural area in an education district of the Eastern Cape. Learners came from illiterate families where education was not considered important. physical sciences was one of the learning areas where learners were not performing up to the desired standard but it is one of the subjects regarded as critical because of its demand for the critical thinking and the constructionist approach. The researcher did an analysis of the Grade 11 final examinations results of 2013 and discovered that one of the main topics that learners failed was electrostatics.

Electrostatics is one of the topics in the Grade 12 syllabus which is an exit point to the Further Education and Training [FET] band. The FET band runs from Grade 10 to Grade 12. The examiner's reports which presented analysis of learners' responses showed that learners had misconceptions about the concept of electrostatics.

Table 2: Content areas in physics examination of physical sciences

Question	Area of question
1	Multiple choice questions
2	Newton's laws
3	Vertical projectile motion
4	Momentum
5	Work, energy and power
6	Doppler effect
7	Electrostatics
8	Electric circuits
9	Motors, generators and AC
10	Photo electric effect

Table 2 presents the list of content areas in the physics examination paper of the National Senior Certificate. The concept of electrostatics is introduced firstly in lower grades but learners experience problems to grasp the core content and context in which it is found. In the lower grades, it is introduced as static electricity, i.e. electricity that is due to the gain of charge when an object is at rest. Learners in Grade 11 demonstrate misconceptions when expected to define and differentiate between electric field and magnetic field. Learners also struggle to draw electric field lines around a charged sphere. The statement of Coulomb's law becomes an easy task to be stated, but calculations based on its application pose problems to learners. The problem was further witnessed in the diagnostic report of 2014 where a question by question analysis pointed out that electrostatics was the content area that learners failed the second worst in the whole paper.

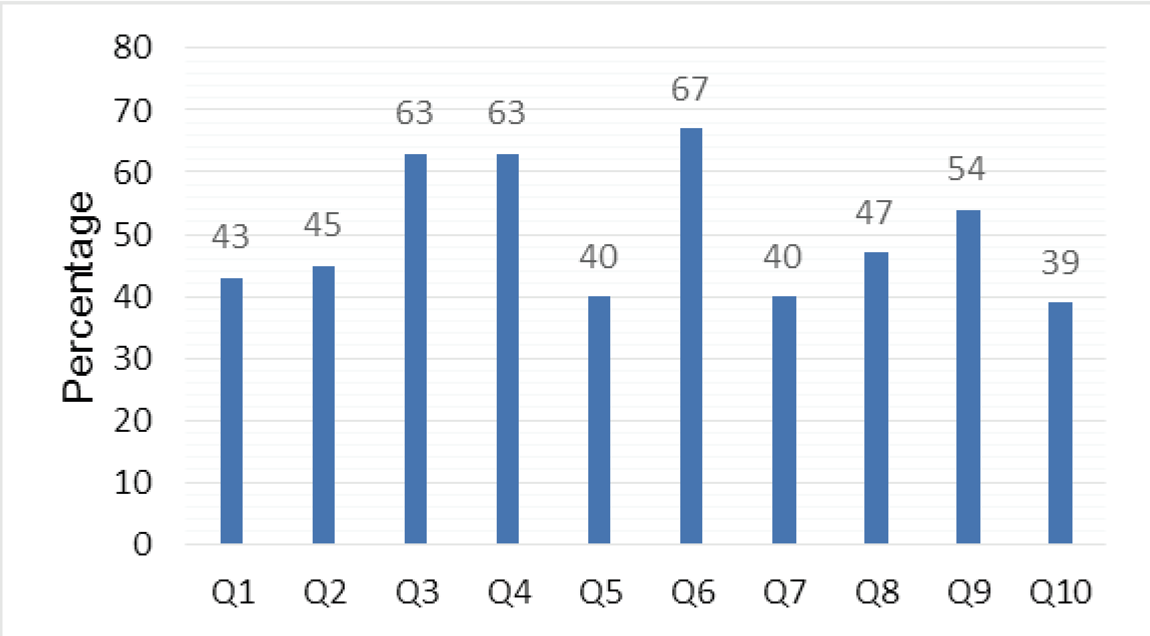


Figure 2: Average mark per question expressed as a percentage

From Figure 2 given above, electrostatics was asked in question seven. The percentage mark for question 7 was 40% which highlights the problem. Various reasons were identified and put forward in the diagnostic report of 2014 including the following:

- Learners drew the electric field pattern for original charges as single positive charges. Some learners could not calculate the net electrostatic force.
- Learners could not define 'electric field' and omitted per unit positive charge.
- Learners used the original charges instead of the charges after contact.

1.5 Problem statement

The level at which learners were responding to questions on electrostatics indicated that they had challenges in understanding the concept. The concept of electrostatics was introduced in Grade 7. In the lower grades it is introduced as static electricity, i.e., electricity that is due to the gain of charge when an object is at rest. Learners in high school showed misconceptions of defining and differentiating between an electric field and a magnetic field. The content area of electrostatics continues until the learners reach the exit point, i.e., Grade 12. Poor achievement of learners in questions regarding electrostatics contributed to the negative results of the school.

1.6. Research question

In order to address the research problem identified above, this study was directed at answering the following research question:

> ***How can a conceptual change approach be used to teach electrostatics in Grade 11 Physical Sciences?***

The following research sub-questions were addressed in this research:

I. What was learners' initial understanding of the concept of electrostatics?
II. How can the conceptual change lessons implemented to teach the concept of electrostatics?
III. What was the learners' understanding of electrostatics after the conceptual change lessons?
IV. What were the learners' perceptions of the conceptual change approach?

1.7 Significance of the study

This study is significant for a number of reasons. Firstly, it could contribute towards a change in Physical Sciences learners' understanding of the concept of electrostatics. Secondly, the study also highlighted the relevance of using a conceptual change approach to teach electrostatics as a challenging concept. Thirdly, the study will add value to limited research conducted on the application of conceptual change strategies in rural school contexts. Fourthly, the study could contribute towards improvement of learners' results in the section of electrostatics in the NSC examination. Fifthly, the study will serve as base line data with regard to the use of conceptual change theory in rural schools in the Eastern Cape.

1.8. Limitations of the study

This case study was conducted at one school and the results can therefore not be generalised to other schools in the district or the province. The sample used in this study is relatively small consisting only of one class of Grade 11 Physical Sciences learners. The study also considers the application of the conceptual change approach to one concept, namely electrostatics. The researcher is a teacher at the sample school and the outcomes of the study should take cognisance of this.

1.9 Structure of the thesis

The thesis has the following structure:

Chapter 1: Rationale of the study

The chapter highlights the background of the study, the rationale and the problem statement. It also provides research questions that are answered by the research.

Chapter 2: Literature review

This chapter provides the theoretical framework that underpins this study. It also highlights international, national and local studies that impact on this research.

Chapter 3: Methodology

The methods employed in this study are discussed in this chapter. It includes sampling, the research instruments used in this study as well as the data collection.

Chapter 4: Results and discussions

The data collected is analysed and findings are highlighted in this section.
Discussions based on the findings are detailed in this chapter.

Chapter 5: Conclusion and recommendations

Conclusion and recommendations of the study are discussed in this chapter.

References

All sources that are used in this study are listed. An alphabetical reference list which is in APA 6th edition style is found in this section.

1.10. Conclusion

This chapter introduced the research problem and highlighted the background and context in which the study was conducted. It also provided the significance and limitations to the study. The following chapter will provide the theoretical base of the study and will review the literature that is associated with the research area.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

This chapter highlights the theories that underpin this study and reviews existing literature on the topic of investigation. It will highlight previous studies, indicate how these are linked to this investigation and identify possible gaps in the field. The main research question for this study is:

How can a conceptual change approach be used to teach electrostatics in Grade 11 Physical Sciences?

2.2 Theoretical framework

This study is underpinned by the theories of constructivism and conceptual change.

2.2.1 Constructivism

According to constructivist principles, individual learners build their knowledge by making connections to existing knowledge. As a teaching and learning theory, constructivism can be implemented using strategies such as problem-solving and inquiry strategies (Gunter et al., 1991). Robottom (2004) defines knowledge as concepts that are constructed in the mind of the learner. Conceptual change is a learning process in which learners change conceptions through capturing new ideas and knowledge and replacing the old with the new. Robottom (2004) defines knowledge as concepts that are constructed in the mind of the learner. Each learner has to construct his/her own knowledge. The view is therefore a more individual construction, thus highlighting the theory of constructivism (Trowbridge & Wandersee, 1994). Constructivism, according to Asan (2007), has an important influence in the science classroom. Robottom (2004) states that learners use their own beliefs, interpretations and ideas to interpret information conveyed by teachers. Suping (2003) and Novak (1990) further state that Piaget's assimilation is directly linked to constructivism, because learners are reluctant to obtain new concepts and replace older concepts.

Research on the role of students' pre-instructional ("alternative") conceptions in learning science developed in the 1970s drawing primarily on two theoretical perspectives (Driver & Easley, 1978). The first was Ausubel's (1968) dictum that the most important single factor influencing learning is what the learner already knows and hence to teach the learner accordingly. The second theoretical perspective was Piaget's idea of the interplay of assimilation and accommodation. His clinical interview method deeply influenced research on investigating students' conceptions (White & Gunstone, 1992). By the end of the 1970s and the beginning of the 1980s preliminary conceptual change ideas addressing students' conceptions were revealed in the various studies that developed. Conceptual change viewed as epistemology, namely when the research looks at students' learning of concepts, initially involved only an understanding of how students' conceptions evolved. Later, constructivist ideas developed by merging various cognitive approaches with a focus on viewing knowledge as being constructed. These approaches were influenced by the already mentioned Piagetian interplay of assimilation and accommodation, Kuhnian ideas of theory change in the history of science and radical constructivism (Duit & Treagust, 1998).

Other researchers were concerned that conceptual change had initially taken on an over rational approach (Pintrich, Marx, & Boyle, 1993). Certain limitations of the constructivist ideas of the 1980s and early 1990s led to their merger with social constructivist and social cultural orientations that more recently resulted in recommendations to employ multi-perspective epistemological frameworks in order to adequately address the complex process of learning (Duit & Treagust, 2003; Tyson et al., 1997; Zambia, 2005).

2.2.1.1 The constructivist model of knowledge

The most important points of departure of constructivism can be summarised (Jordaan, 1992) as follows:

The knowledge pool that a learner possesses at any given moment is the result of his direct experience with his life-world (the empirical, physical world) as well as his interaction with his parents, teachers, other adults, the mass media, brothers/sisters, friends, etc. during formal, informal and non-formal situations. The learner's mind is therefore not an empty vessel that can be filled with knowledge. He already has a prior knowledge pool that plays a vital role in the acquisition of new knowledge. When new knowledge is presented to the learner, he uses his existing knowledge to interpret and give meaning to it; that is, he constructs knowledge out of that which is presented and existing knowledge. The new information is therefore not accepted and integrated in an unchanged form into the learner's cognitive structure. It can happen that parts of the new information that are not in keeping with the learner's conception be summarily rejected, whilst others are accepted in a changed form. It is also true that parts of the existing structure can be changed in the process. The knowledge constructed in this manner, represents the named persons'/institutions' interpretation of reality and is as such previously interpreted knowledge. Depending on the "correctness" with which these persons' institutions interpreted the reality and the manner in which the learner integrates this into his own cognitive structure, will determine whether the new knowledge links with scientifically accepted ideas. Because the prior knowledge with which various individuals enter the teaching-learning situation differ, it is comprehensible that they would also interpret and construct the new information in different ways, i.e. differ in the assimilation of information into their conceptual structures. The process through which new information (ideas) is made part of the learner's cognitive structure, is referred to as 'conceptual change' (discussed in 2.3 above).

Von Glaserfeld (1984, 1995) described the construction of knowledge as a search for a fit rather than a match with reality. In the constructivist model, knowledge is assumed to fit reality the way a key fits a lock. It is the difference between the concepts "fit" and "match" that shows how constructivism differs from the traditional view of knowledge. According to the traditional view, knowledge corresponds or matches reality, and therefore two or more individuals with the same knowledge must have similar copies or replicas of reality in their minds. Once we allow knowledge to "fit" reality the way a key fits a lock, we find ourselves in a very different position because many keys, with different shapes, can open a given lock. Each of us builds our own view of reality by trying to find order in the chaos of signals that impinge on our senses. The only thing that matters is whether the knowledge we construct from this information functions satisfactorily in the context in which it arises.

Carr, et al . (1994) indicates that the context in which we learn something affects the way individuals construct knowledge. Learning about a scientific concept may be much easier through contexts with rich links to students' interests, such as teen culture and the human body. A further complication when considering learning in science is the developing realisation that individual students hold many, often conflicting, concepts about their world, some of which they use in the classroom, others in the world outside. Happs (1980) reported that within a chemistry classroom students reported that the world is made up of atoms and molecules, but they talk of materials in their "real world" in quite different terms, denying that blood, flesh and paper are molecular, or even chemicals.

Watts (1994) notes that the heart of constructivism is the view that cognition is the result of proactive mental construction. Conceptualisation arises through the interaction between previously accumulated knowledge and current data and, as Simpson (1990) points out, it is constantly at work testing and ascribing meaning to new information in terms of the individual's prior conceptions of phenomena in the world. Constructive processes include construction, deconstruction and reconstruction. These imply that cognition has structure and organisation. As we construct and qualify meanings, we do so against a backdrop of comparing or contrasting with other meanings.

Constructivism views knowledge as transitory and provisional. Knowledge of the world is constructed on the basis of the constraining influences of the nature of the phenomena, personal context, language, predisposition, etc., and judged by such criteria as utility, plausibility and fruitfulness (Strike and Posner, 1985). Constructivism implies a metacognitive position which tends to take two forms: for teachers it is termed "reflection" (Buchanan, 1990) and for students it is "learning about learning" (White, 1988). There is a clear strand through constructivism that the person at the centre of the enquiry is not just an `active meaning maker', but knows it too.

Teaching and learning are not the same process: we can teach and teach well, without having the pupils learn (Adams, 1990). The constructivist model of knowledge attempts to answer a basic question of epistemology, namely: "How do we come to know what we know?" The constructivist answer would be: Knowledge is constructed in the mind of the learner. This view of learning attaches importance to meaning as constructed by individuals in their attempt to make sense of the world. Osborne and Whittrock (1983) also emphasise that constructivism highlights the importance of what learners bring to science lessons and the construction of meaning through their own experiences.

A constructivist approach to teaching and learning acknowledges and recognizes the existence of learners' pre-knowledge prior to formal teaching and learning experiences. This pre-knowledge is actively applied by learners in responding to and making sense of new situations (Watt, 1983; Fraser & Tobin, 2003). In this study, learners come with informal prior knowledge that they have.

This contrast between assimilation and accommodation presents another face of the paradox described above. That is, learners with relatively little prior conception of content to be learned have few barriers to learning new content. However, the literature is replete with studies showing the beneficial effect of prior knowledge on new learning. This body of literature also demonstrates that content learned in a disconnected fashion - that is, unintegrated with prior knowledge - is less meaningful and useful (Anderson, 1990). Thus it is clear that prior knowledge can be useful in learning new content. However, prior knowledge can be organized in such a way that the concepts connecting this knowledge compete with concepts understood by a discourse community (e.g., a scientific field). Given that the scientific discourse community can influence the school curriculum (e.g., in terms of what is taught, how it is organized, what is in the textbook and curriculum materials, etc.) in such a situation, students' prior conceptions can serve to resist the development of the more veridical conceptions that are represented in the curriculum.

Clearly, the process of accommodation is critical for the continuing educational development of learners. Without the process of accommodation working on prior conceptions of content, little conceptual growth would occur. Not surprisingly, then, most work on conceptual change has focused on what processes encourage or drive accommodation. To explain how current conceptions influence how an individual will view new information, Posner et al. (1982) use the metaphor of a conceptual ecology. Several assertions are implied by this metaphor. One is the systemic assumption that concepts exist in interrelated networks and that a change in one concept will affect how other concepts are viewed. Conceptual change in one area often leads to anomalies in the individual's conceptual ecology. This system view of learning suggests that considerable forces can be present that can have important consequences for whether conceptual change occurs or not. A second assertion is that individuals hold certain commitments and beliefs about the nature of knowledge. These epistemological beliefs are used by an individual as bases for determining what can or cannot be true or what is or is not a valid explanation of a problem raised in the effort to incorporate new experiences and information into that individual's conceptual ecology.

Finally, there is the possibility of ideas competing for the same conceptual niche; this is particularly important for accommodation. In such cases, the idea that wins out will most likely be the one that successfully resolves anomalies and conforms to the individual's beliefs about the nature of knowledge and truth - a survival-of-the-fittest ideas and concepts. The metaphor begins to exhaust itself at this point. Ecosystems are not purposeful, but individual learners and communities of scholars can and do have goals, purposes, and intentions, thereby suggesting a role for an individual's motivational beliefs. It is not clear how competing ideas in a purposeful ecosystem of the mind might behave differently from organisms and populations in a biological ecosystem.

Constructivism is a relatively new (past few decades) approach to knowledge. The two classical theories of rationalism and association have dominated psychology and education for a number of centuries. Rationalism (Richardson, 1988) has as its premise that knowledge is an innate quality of the human. We are born with the knowledge we have. Learning is the process by which we reveal to ourselves the knowledge we already possess by systematic logical deductions or rational discourse. Teaching can be considered as the awakening of the dormant seeds. Blossoming of knowledge occurs when teachers create a season for it in class by structuring lessons in which students bring forth the knowledge they possess. One of the main protagonists of rationalism was Plato who rejected the notion that knowledge can be experienced through the senses.

Association, in contrast, proposes that knowledge is gained from one's activities. Knowledge is acquired through the experiences of the senses. Knowledge is organised and condensed in abstract forms. Aristotle, who supported this view, proposed an empirical method of realising knowledge by creating opportunities to stimulate the senses. The data obtained in this way are used to create knowledge (Richardson, 1988).

2.2.1.2 Piaget and constructivism

Constructivism views the learner as playing an active role in building understanding and making sense of the given information (Ormrod, 2011; Woolfolk, 2010). Redish (2002:30) defined constructivism as follows: *"Individuals build their knowledge by making connections to existing knowledge; they use this knowledge by productively creating a response to the information they receive".*

The constructivist principle has a wide range of intellectual roots: Piaget, Vygotsky, Gestalt, Bartlett and John Dewey, to mention but a few (Colman, 2009:166). There is not a single view of knowledge construction by the scientists; however, they agree on two central ideas (De Muynck & Van der Walt, 2006; Woolfolk, 2010):

1. The learners are actively constructing their own knowledge (individual constructivism).
2. Social interaction plays a central role during knowledge construction (social constructivism).

There are, according to Woolfolk (2010:313), three groups of thought that play a role regarding the construction of knowledge. Firstly, the information-processing theories claim that knowledge construction is a representation of the outside world. Learning is affected by direct teaching, feedback and explanation. Knowledge accurately reflects the outside world. Secondly, the Piaget chain of thought views the construction of knowledge as transforming, organising and reorganising prior knowledge. Piaget claimed that experience is the key, as it influences thinking and thinking influences knowledge. Therefore, teaching should consist of exploration, discovery and investigations. Thirdly, Vygotsky claimed that knowledge is constructed by social interactions and experiences. The outside world will be reflected by the knowledge through a filter of culture, beliefs, language, interactions with others and direct teaching. The afore-mentioned ideas should form part of the teaching-learning strategy in the classroom.

Bodner (1986) points out that much of the reaction to Piaget's work (both pro and con) has been the result of a natural tendency to assimilate his writings into existing conceptual structures based on the traditional view of knowledge. This is unfortunate because Piaget's writings (see Figure 3) show that he too was an avid constructivist. An example is the following:

> No behaviour, even if it is new to the individual, constitutes an absolute beginning. It is always grafted onto previous schemes and therefore amounts to assimilating new elements to already constructed structures (innate, as refexes are, or previously acquired) (Piaget, 1976:17).

Von Glaserfeld (1995) maintains that Piaget's definition of assimilation as described by the above extract must be understood as treating new materials as an instance of something known. Cognition comes about when a cognising organism fits an experience into a conceptual structure it already has. Piaget believed that knowledge is acquired as the result of a life-long constructive process in which we try to organise, structure, and restructure our experiences in light of existing schemes of thought, and thereby gradually modify and expand these schemes. Indeed, his definition of knowledge as "invariance under transformation" has no meaning outside the constructivist perspective (Bodner, 1986).

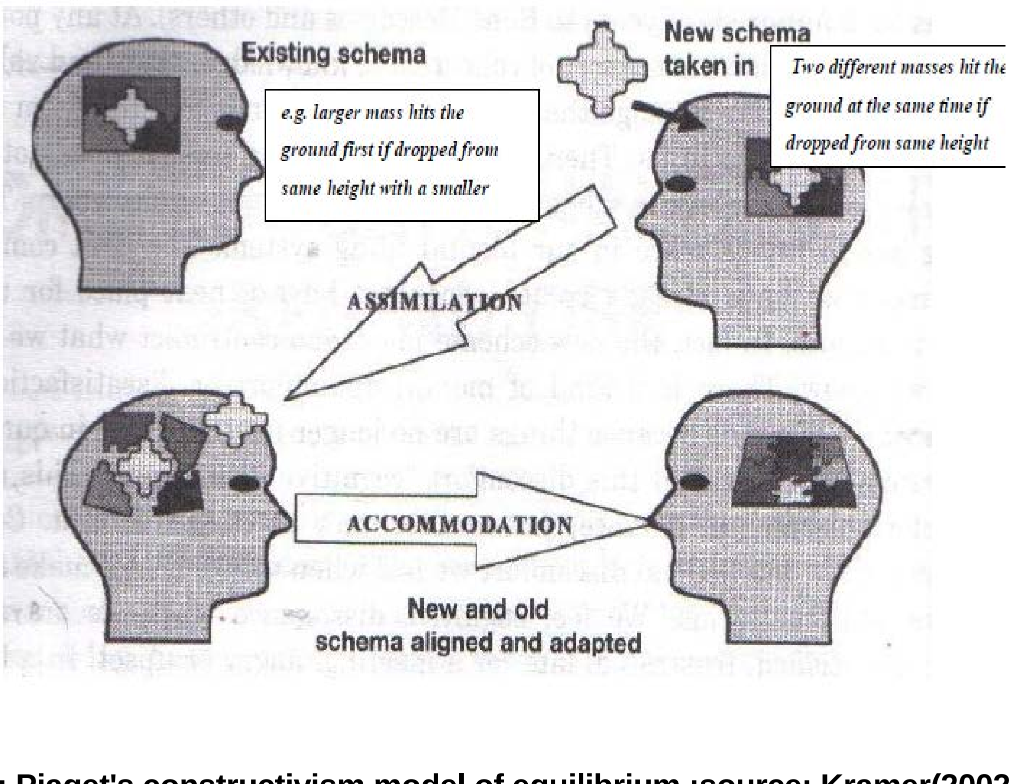


Figure 3: Piaget's constructivism model of equilibrium :source: Kramer(2002:8)

From the constructivist's perspective, the data we perceive from our senses and the cognitive structures or schemes we use to explain these data both exist within the mind. Von Glaserfeld (1995) has argued that assimilation occurs when what we perceive (percepts) is adjusted to fit the conceptual structures (concepts) we have already assembled. When that does not work, when our experiences do not fit our ideas, equilibration occurs by adjusting our schemes (concepts) to fit the sensory data we perceive (percepts), and this process is known as accommodation. Assimilation does not find recurring patterns of sensory data but imposes patterns by ignoring differences between what is perceived and what is expected.

2.2.1.3 Social constructivism

Constructivism also implies a social context where ideas and conceptions are communicated, shared, tested, negotiated and reported. It involves caring for ideas, personal theories, self-image, human development, professional esteem, people - it is not a take-or-leave-it epistemology (Watts, 1994).

Piaget (1976) describes learning as following chronological development. He implies that over a given age group a child would be capable of accomplishing tasks that are in keeping with a set level of development. He proposes his renowned stages of development linked to age. The abilities of children are coupled to these stages. Vygotsky (1978) holds the view that a clear distinction should be made between the mental capabilities and actual capabilities (in a social context) of individuals. The difference between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers is what he calls the ‘zone of proximal development’. Vygotsky therefore holds the view that social interaction can increase the level of development of individuals.

According to Reagan and Osborn (2002:60), “Radical constructivism is premised on the belief that an individuals’ knowledge can never be a true representation of reality (in an observer-independent sense) but rather a construction of what he or she experiences”. They continue to state that, with regard to social constructivism, the alternative to radical constructivism, “the process of knowledge construction inevitably takes place in a socio-cultural context, and that therefore knowledge is in fact socially constructed”. According to Fraser and Tobin (1997:8) with regard to social constructivism, “Learning is not viewed as transfer of knowledge but the learner actively constructing, or even creating, his or her knowledge on the basis of the knowledge already held”. The active teaching and learning methods are based on social constructivism as appose to behaviorism which is a more teacher-centred approach, where student performance is directly dependent on teacher performance. According to Jones & Brader-Araje (2002:1) behaviourism “placed the responsibility for learning directly on the shoulders of teachers”. According to De Graaf, Saunders-Smits and Nieweg (2005:38), “students bring to their learning understandings (and mis-understandings), skills and propensities to behave in certain ways, and that they build upon them or modify them in learning situations; construct new understandings, skills and behaviours”.

Adams, Kaczmarczyk, Picton and Demian (2007:2) indicate with regards to Bloom’s taxonomy, “The higher level cognitive skills of *analysis*, *synthesis* and *evaluation* are relevant to our ability to effectively solve problems. The effective development of these skills, however, requires mediation”. According to Ada (2009:164), with active learning, “High levels of social interaction and collaboration contributed to the establishment of a community of learning, nurturing a space for fostering higher order thinking through co-creation of knowledge processes”.

Dialectical constructivism or social constructivism (Brown, Collins, & Duguid, 1989; Rogoff, 1990) views the origin of knowledge construction as being the social intersection of people, interactions that involve sharing, comparing and debating among learners and mentors. Through a highly interactive process, the social milieu of learning is accorded centre stage and learners both refine their own meanings and help others find meaning. In this way knowledge is mutually built. This view is a direct reflection of Vygotsky’s (1978) sociocultural theory of learning, which accentuates the supportive guidance of mentors as they enable the apprentice learner to achieve successively more complex skills, understanding, and ultimately independent competence. The fundamental nature of social constructivism is collaborative social interaction in contrast to the individual investigation of cognitive constructivism. Through the cognitive give and take of social interactions, one constructs personal knowledge. In addition, the context in which learning occurs is inseparable from emergent thought. This latter view - known as ‘contextualism’ in psychology - becomes a central tenet of constructivism when expressed as situated cognition. Social constructivism captures the most general extant perspective on constructivism with its emphasis on the importance of social exchanges for cognitive growth and the impact of culture and historical context on learning.

While there are several interpretations of what [constructivist] theory means, most agree that it involves a dramatic change in the focus of teaching, putting the students' own efforts to understand at the centre of the educational enterprise (Prawat, 1992). Thus despite the differences sketched above, there is important congruence among most constructivists with regard to four central characteristics believed to influence all learning:

1) Learners construct their own learning;
2) The dependence of new learning on students' existing understanding;
3) The critical role of social interaction; and
4) The necessity of authentic learning tasks for meaningful learning (Bruning, Royce & Dennison, 1995; Pressley, Harris, & Marks, 1992).

For the learner to construct meaning, he must actively strive to make sense of new experiences and in so doing must relate it to what is already known or believed about a topic. Students develop knowledge through an active construction process, not through the passive reception of information (Brophy, 1992). In other words, learners must build their own understanding. How information is presented and how learners are supported in the process of constructing knowledge are of major significance. The pre-existing knowledge that learners bring to each learning task is emphasized too. Students' current understandings provide the immediate context for interpreting any new learning. Regardless of the nature or sophistication of a learner's existing schema, each person's existing knowledge structure will have a powerful influence on what is learned and whether and how conceptual change occurs.

2.2.1.4 Constructivism and its implications for teaching

If students come to lessons with ideas about their world which already make sense to them, then teaching needs to interact with these ideas, first by encouraging their declaration, and then by promoting consideration of whether other ideas make better sense.

As stated earlier, knowledge is being constructed in the minds of learners based on their pre-existing cognitive structures and such knowledge provides a theoretical basis for distinguishing between meaningful and rote-learning. The teacher's role as manager of the learning situation becomes crucial for the successful construction of new knowledge. Given the limited time and resources that teachers have available to ensure that students obtain a scientific view of concepts, it becomes important that teachers use the experiences of students as the foundation to facilitate the (re)construction process.

The constructivist model therefore requires a subtle shift in perspective for the individual who stands in front of the classroom. A shift from someone who "teaches" to someone who tries to facilitate learning; a shift from teaching by imposition to teaching by negotiation. As Lochhead (1989) affirms, we essentially teach students what to think instead of how to think. Only if our teaching is directed at how an answer is derived, instead of what the answer is, would we be able to make a significant impact. The constructivist approach emphasises the knowledge that the learner has; it is this knowledge that determines his perception of existence and how new knowledge is constructed. The learning process may be enhanced in this way.

2.2.2 Conceptual change theory

The term 'conceptual change' refers to meaningful learning occurring when a learner accepts new conceptions on the grounds that they are intelligible, plausible and fruitful. Conceptual change learning is achieved by the acquisition of new information and reorganising the existing knowledge. Posner et al. (1982) do make the statement that they are using Piaget's terms but not borrowing the concepts in total. Piaget's work describes how learners learn through the assimilation and accommodation of knowledge. Posner et al. (1982) suggested that the conditions for accommodation of new concepts are similar to Kuhn's conditions for the acceptance of a new scientific paradigm. Posner et al. (1982) hypothesize that there are four conditions for conceptual change. These steps are summarised below:

- Dissatisfaction: The learners must first realize that there are some inconsistencies and that their way of thinking does not solve the problem at hand.
- Intelligibility: For learners to accommodate a new conception, they must find it intelligible. The concept should not only make sense, but the learners should also

be able to regurgitate the argument and ideally be able to explain that concept to other classmates.

- Plausibility: The new conception must be plausible for it to be accommodated. The new concept must make more sense than the old concept. It must have (or at least appear to have) the capacity to solve the problem.
- Fruitfulness: For the new conception to be accommodated, the learners need to find it fruitful in the sense that this concept should have the potential to be extended to other incidences, and open up new areas of inquiry.

Posner et al.'s conditions with some minor revisions have received wide acceptance by the scientific community. Dykstra (1992) organized a three level taxonomy of conceptual change to exist:

- Differentiation, wherein new concepts emerge from existing, more general concepts, for example velocity and acceleration in kinematics.
- Class extension, wherein existing conceptions considered different are found to be cases of subsuming concepts, for example being at rest and constant velocity from the Newtonian point of view.
- Reconceptualization, wherein a significant change in the nature of a relationship between concepts occur, for example, in the change from "force implies motion" to "force implies acceleration".

The instructional strategy in which teachers are expected to lead their students through the following stages is proposed by Nussbaum & Novick (1982):

- An exposing event which requires a student's interpretation based upon his or her existing conceptions;
- A discrepant event which creates a conflict between exposed preconceptions and newly observed phenomena which cannot be explained; and
- A learning support system which helps students' search for a solution and encourages emerging accommodation.

An exposing event was created by the simulations they watched and then they analysed the observations. During those discussions learners became dissatisfied with what they already know compared with what they discovered from the activity.

Similarly, four possible teaching strategies for conceptual change learning were suggested by Hewson and Hewson (1983):

- Integration
- Differentiation
- Exchange
- Conceptual bridging

The first strategy, integration, is the most commonly used method. The aim is to integrate new conceptions with existing conceptions and is based on the assumption that the students' existing conceptions are those which the teachers have taught.

The second strategy is to differentiate the student's existing conceptions about a given scientific phenomenon into more clearly defined, separate conceptions. The objective is to encourage the student to examine different aspects of the phenomenon. In doing so the student will realize that what was plausible in one situation is no longer plausible in a different, more complex situation.

The third strategy is exchange. The aim is to exchange an existing conception for a new one because they contradict one another. Since a student is not going to exchange a plausible conception for one which is seen to be implausible, it becomes necessary to create dissatisfaction with the existing conception as well as showing that the new conception has more explanatory and predictive power than the old one.

The fourth strategy is conceptual bridging where abstract concepts are linked with meaningful common experiences of the learner. In a study done by Hewson and Hewson (1983) where these teaching strategies were applied to the experimental group, they concluded that explicitly dealing with students' alternative conceptions caused a better acquisition of scientific concepts. They also agreed that taking into account students' alternative conceptions is worthwhile since they adversely influence meaningful understanding of the learners if ignored.

According to Hewson & Hewson (1983) there are different stages in conceptual change teaching. These include:

- Diagnosis or elicitation: Does the teacher use any diagnostic techniques to elicit the student's existing conceptions and reason why they are held?
- Status change: Does the teacher use strategies designed to help students lower the status of existing, problematic knowledge, and raise the status of other, competing ideas? Are there other application sites where the new conception can be used?
- Evidence of outcome: Is there evidence that students' learning outcomes are based, in part, on an explicit consideration of their prior knowledge?

On the other hand, there are particular features that are present during different stages of conceptual change teaching. These include:

- Metacognition: Are students encouraged or able to "step back" from one or more ideas held by themselves or others in order to think about them and express an opinion about them?
- Classroom climate: Is there an attitude of respect by both teacher and students for the ideas of others, even when they are contradictory?
- Role of Teacher: Is the teacher able to provide opportunities for students to express themselves without fear of ridicule, and to ensure that he or she is not the sole arbiter of what counts as an acceptable idea in the classroom?
- Role of Learner: Are students willing to take responsibility for their own learning, to acknowledge others' ideas, and to change their views when another seems more viable to them? Can students monitor their own learning?

Students do not change their minds easily, so they resist change. As a result, it takes a long time to learn the right scientific terms. This is a tiring and a very difficult process. Actually, a misconception is not a wrong answer caused by faulty or missing information. It is information that is completely different from the scientific definition of a concept. If students try to justify their wrong answers with some reasons, and they are positive about that, then we should speak of misconceptions, in other words, all misconceptions are faulty information.

The process of learning in a conceptual change model depends on the extent of the integration of the individual's conceptions with new information. If he or she knows little about the topic under study, new information is likely to be combined easily with his or her existing ideas; the process that accounts for this event is what Posner et al. (1982) refer to as assimilation. On the other hand, the individual may have well-developed concepts about the topic under study. Often, these concepts may conflict and be contrary to what is understood as true by experts in that domain; such individual ideas are often referred to as alternative frameworks, and studies have shown these to be highly resistant to change (Champagne, Gunstone, & Klopfer, 1985; Nussbaum & Novick, 1982; Osborne & Freyberg, 1985). Overcoming these frameworks requires a more radical transformation of individual conceptions. This process is what Posner et al. (1982) refer to as accommodation. The processes of assimilation and accommodation are guided by the principle of equilibration whereby individuals seek a relatively stable homeostasis between internal conceptions and new information in the environment (Chapman, 1988; Piaget, 1985).

Stepans (1994)) provides the opportunity for students to equivocate between new and old conceptions as well as to apply new conceptions to similar and different contexts in which learning occurs. Stepans(1994)six stages include the following:

Stage 1

Commit to a position or outcome phase.The teacher asks the student questions or presents a problem or challenge. Students become aware of their own preconceptions about a concept by responding to the questions, or by attempting to solve the problem or challenge before any activity begins. As students formulate their answers or solutions, they become familiar with their views, and may become interested in knowing the answer to the question or the solution to the problem or challenge. During this phase the teacher does not comment on students' responses.

Stage 2

Expose beliefs phase.

Students in small groups share and discuss their ideas, predictions and reasoning with their classmates before they begin to test their ideas with activities. Students in small groups share and discuss their ideas, predictions and reasoning with their classmates and a group member presents them to the whole class. The teacher classifies students' responses into categories and a whole-class discussion follows. This discussion gives students the opportunity to change their initial beliefs and explain the reasons that led them to this decision if they wish to. During this phase the teacher also does not comment on students' responses, but may help students clarify their views using a variety of ways.

Stage 3

Confront beliefs phase.

Students confront their existing ideas through collaborative experiences that challenge their preconceptions by working with materials, collecting data and consulting resources. Students in small groups were actively engaged in learning activities, the outcomes of which they were required to record and interpret after discussion among group members. In this phase the teacher provides technical assistance to students and answers clarification questions if requested. Students in most cases become dissatisfied with their existing ideas during this phase by experiencing the difference between the result they were expecting and what they actually see, thus giving the opportunity to the teacher to introduce and develop the scientific model.

Stage 4

Accommodate the concept phase.

Students accommodate a new view, concept or skill by summarizing, discussing, debating and incorporating new information. Students whose ideas are close to scientifically acceptable ones explain their views to their classmates with the aid of the teacher. After a procedure that includes summarizing, discussing and debating, and incorporating new information, most of the students accommodate the new concept and leave their previous concepts behind. The teacher helps them draw conclusions and formulate principles relating to the newly acquired information.

Stage 5

Extend the concept phase.

Students apply and make connections between the new concept or skill and other situations and ideas. Students apply their newly acquired knowledge and skills in different situations. These situations may be presented by the teacher, or their fellow classmates, or by themselves.

Stage 6

Go beyond phase.

Students pose and pursue new questions, ideas and problems of their own. Students seek additional situations where acquired concepts or skills may be put into practice. Students can accomplish this by delving into personal experiences, questioning friends, relatives and professionals, or conducting research to discover situations which can be dealt with in the same way.

Conceptual change text is one of the successful conceptual change strategies to facilitate conceptual understanding (Al Khawaldeh & Al Olaimat, 2010; Kenan & Ozmen, 2012). The new curriculum of physics courses at secondary schools have been redesigned with a constructivist approach. The most significant requirements of the constructivist approach are that the teacher should guide rather than teach. During the practical activity, the researcher was guiding the learners when they conducted an experiment. The researcher guided the learners while they performed practical activities and completing the worksheets. The teacher brings out students' old knowledge, corrects the misconceptions if there are any, makes up for missing information, and finally enables them to participate in class actively. In addition, he gives examples to students from daily life so that they can associate their old knowledge with the new one. He encourages his students to adopt scientific methods, illustrating that one of the most critical issues in teaching science is misconceptions.

Overcoming those misconceptions and other deficiencies plays a major role in making learning effective and permanent (Osborne and Freyberg, 1996). In the studies that aim to convert students' misconceptions into scientific understanding so as to develop personal conceptual image schemas, researchers generally use conceptual change texts, concept mapping, analogies, and extra materials (Stavy, 1991). What underlies constructivism is students' structuring the information on their own, and learning becomes meaningful throughout the process of the conceptual change approach. This approach, which aims to correct students' misconceptions regarding concepts, principles and phenomena in physics, consists of many strategies. Many teaching studies in recent years have attempted to take into account research on students' conceptions of natural phenomena. A number of different features have begun to emerge from these studies as characteristic components of what can be called conceptual change teaching (Hewson, 1991).

Under the conceptual change model, there are four conditions which must be met in order for conceptual change to occur. These conditions are outlined in 4 (Posner et al., 1982):

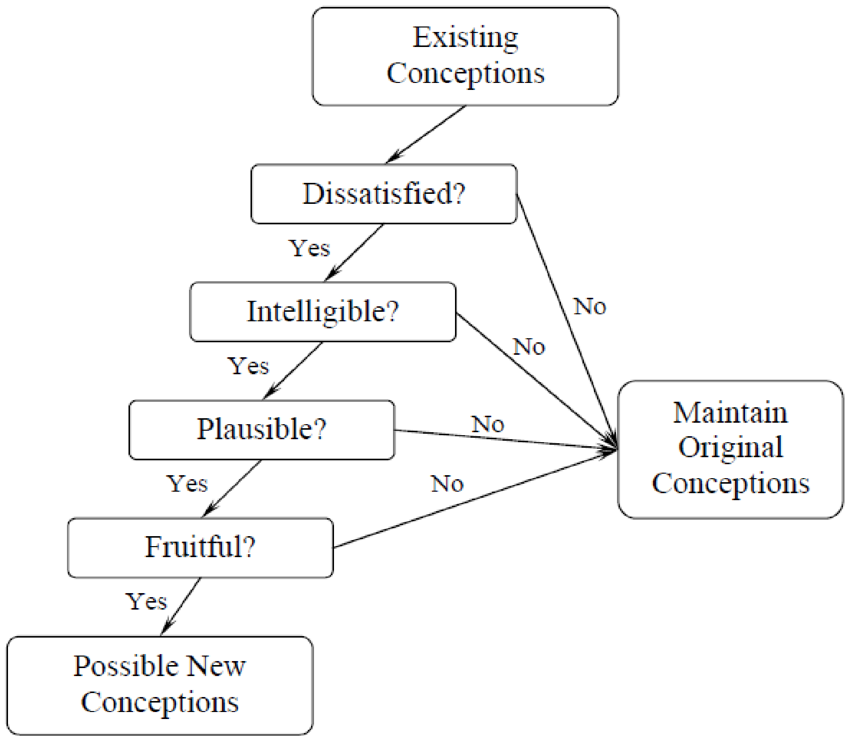


Figure 4: Posner et al.'s (1982) conceptual change model

2.2.2.1 Additional suggestions that provoke conceptual change

Zirbel (2005) suggests that to form new concepts or change old inadequate ones, the learners have to be led through several processes. First, s/he has to consciously notice and understand what the problem is; second, s/he has to assimilate more information and try to fit it into already existing neural networks; third, s/he has to critically think through all the argumentation in his/ her own words and reorganise his/her thoughts - s/he has to accommodate the knowledge and evaluate it against his or her prior beliefs, and finally s/he has to work towards obtaining fluency in the newly acquired and understood concept so that this concept itself has then become a mere building block for future, more advanced concepts. The claim here is that during the process of conceptual change what happens in the student's mind is a reorganisation of his or her thoughts, the creation of new neural networks, and the re-wiring of old ones. The next section explains how the instructor may help facilitate this process.

Step 1: Hooking students (acknowledging information)

The educator has to assure that the particular idea does get noticed efficiently. In other words, the new idea has to be addressed up enough so that it gets noticed and preferably also so that the student is initially intrigued by it enough to want to know more.

Step 2: Suggesting bridges (assimilating information)

The natural needs to be presented in such a simplified fashion that the student can follow every part of the argument clearly. The student should at least have the feeling that something makes sense. Meaningful associations are particularly useful, because they might help the student make meaningful connections. Suggesting to the student how to chunk the information might be another way a good instructor might be able to help.

Step 3: Querying and confronting the student (accommodating information)

A good instructor will confront the student with why his/her prior beliefs no longer work. What is important here is that the student thinks aloud and articulates the problem in his or her own words. The instructor can guide the student by challenging the student with the right questions.

Step 4: Practicing and constructing (familiarising information)

A good instructor can now provide meaningful examples that go beyond regurgitating the problems, examples that involve applying the new knowledge and testing it. Also, suggesting how to transfer the newly acquired concepts to other areas might help too. Clearly, the very last step of making original discoveries is in the hands of the student himself. All a good instructor can do is to challenge the student to go beyond his or her limits.

The researcher employed the four stages for conceptual change. Those stages are: dissatisfaction, intelligibility, plausibility and fruitfulness.

2.2.2.2 A knowledge process of conceptual change

The "classical" conceptual change approach as introduced by Posner, Strike, Hewson, and Gertzog (1982) involved the teacher making students' alternative frameworks explicit prior to designing a teaching approach consisting of ideas that do not fit students' existing conceptions and thereby stimulating dissatisfaction. A new framework is then introduced based on formal science that may explain the anomaly. However, it became obvious that students' conceptual progress towards understanding and learning science concepts and principles after instruction frequently turned out to be still limited. There appears to be no study which found that a particular student's conception could be completely doused and then replaced by the scientific view (Duit & Treagust, 1998). Indeed, most studies show that the old ideas stay alive in particular contexts. Usually the best that can be attained is a 'peripheral conceptual change' (Chinn & Brewer, 1993) in that parts of the initial idea merge with parts of the new idea to form some sort of hybrid concept (Jung, 1993) or synthetic model (Vosniadou & Brewer, 1992).

In the classical conceptual change model that emphasised students' epistemologies (Posner et al., 1982), student dissatisfaction with a prior conception was believed to initiate dramatic or revolutionary conceptual change and was embedded in radical constructivist epistemological views with an emphasis on the individual's conceptions and his/her conceptual development. If the learner was dissatisfied with his/her prior conception *and* an available replacement conception was intelligible, plausible and/or fruitful, accommodation of the new conception may follow. An intelligible conception is sensible if it is non-contradictory and its meaning is understood by the student; plausible means that in addition to the student knowing what the conception means, he/she finds the conception believable; and the conception is fruitful if it helps the learner solve other problems or suggests new research directions. Posner et al (1982). insist that a plausible conception must first be intelligible and a fruitful conception must be intelligible and plausible. Resultant conceptual changes may be permanent, temporary or too tenuous to detect.

2.2.2.3 Learners' conceptual status

Conceptual status classifies a concept's status as intelligible, plausible or fruitful (Hewson, 1982; Hewson & Lemberger, 2000; Hewson & Thorley, 1989) and is particularly useful for assessing changes in students' conceptions during learning.

When a competing conception does not generate dissatisfaction, the new conception may be assimilated alongside the old. When dissatisfaction between competing conceptions reveals their illogicality, two conceptual events may happen. If the new conception achieves higher status than the prior conception, accommodation, which Hewson (1982) calls "conceptual exchange", may occur. If the old conception retains higher status, conceptual exchange will not proceed for the time being. It should be remembered that a replaced conception is not forgotten and the learner may wholly or partly reinstate it at a later date. Both Posner et al. (1982) and Hewson (1982) stress that it is the student, not the teacher, who makes the decisions about conceptual status and conceptual changes. This position is in harmony with constructivist learning theory and the highly personal nature of mental models (Norman, 1983).

2.3 Studies related to electrostatics

There are very important terms that serve as a stepping stone for the learners to the concept of electrostatics. These include: a charge, force, and electric field strength. Without the prior knowledge or without the aid of teachers' scaffolding approach, learners will experience a challenge in responding to the questions that are targeting the information that they might have on this concept. With the lack of knowledge of the law of charges and Coulomb's law of electrostatics, learners also experience problems of indicating the direction of electric field strength as it is a vector quantity. Teachers' use of everyday knowledge might assist the learners to apply the concept and master the questions that they may raise as a test of their skills.

A second set led to a technological use of the mechanism of operation underlying the phenomena of electrostatics. Among the best known devices on which this is based are the mechanism of photocopiers or ink-jet printers, but there is also a wide use of electrostatics based in the environmental field: as both for controlling dust emission (smoke precipitators) and for selection of waste. There are also systems for removal of house dust, which increase their operating efficiency by exploiting the properties of electrostatically active materials. With regard to educational aspects, electrostatics is historically the first approach to electromagnetism, therefore, it is a basic subject of each curriculum aiming to teach electromagnetism issues.

Learning is depicted as a process of conceptual change giving explicit recognition to the educational research that has clearly shown that students come to class with a set of well-established science-related conceptions. These conceptions are usually often deviant to those being taught and as such are typically labelled alternative conceptions, naive conceptions, preconceptions, misconceptions and so on (Linder, 1993). Learners tend to hold erroneous notions about the science concepts and when they are confronted with empirical evidence that contradicts their beliefs, some learn the more scientifically accepted view, but given the time they regress to their non-scientific ideas. This is as a result of committing the new knowledge in their short-term memory and, in the process, the learner hardly accepts the new concept. In this regard, Heller and Finley (1992) assert that researchers agree that the first step in designing instruction that promotes such conceptual changes is to assess students' prior knowledge. Since electricity is a complex field with tightly structured knowledge architecture, performance on this type of task is highly dependent upon the level of mastery (Rozencwajg, 1992).

Conceptual difficulties are accompanied by incorrect ways of reasoning with a reductionism that leads to causal and common sense reasoning. Two main problems were identified in the comprehension of the superposition principle: a difficulty in accepting the existence of an electric field in a medium where charges are motionless, and an interpretation of formulae as if the quantities at the right of the equal sign were the cause of the quantities to the left. A more general survey of learners' conceptual knowledge of electromagnetism points out that they do not seem to be able to deduce the direction of the electric field from a change in potential. They seem to confuse whether an increase or a decrease in potential determines direction (Hammer, 2000).

It is critical to explore students' ideas at the outset of instruction, during instruction and after it has been completed. This allows us to assess the incoming knowledge of students to try to tailor instruction to build on, redirect, or challenge their initial ideas. By following the evolution of knowledge, we can understand better why instructional interventions do or do not work, and gauge how initial knowledge is impacted by formal instruction. Experience suggests that many conceptual difficulties arise in the course of instruction as students try to make sense of what they are being taught in the context of what they already know. Finally, assessing student's abilities to apply what they have been taught allows us to identify especially persistent conceptual difficulties.

Concepts of electricity are more abstract than other topics such as mechanics, and the required mathematics is very sophisticated (Chabay & Sherwood, 2006). Second, students are unable to grasp the meanings of the representation tools of field lines and equipotential lines. Electric field lines are found to be confused with the line of trajectory, and most students are found to fail to reflect the density of field lines to the magnitude of electric force (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001). Learners often have trouble understanding how the electric field would propel a test charge through the field if it were free to move. This is because they cannot visualise the distribution of force translates into the concept of super imposed forces at a distance.

When dealing with problems of electrostatics, students tend to adopt the Coulombian model and ignore Faraday's idea of the field model, which may be due to the epistemological similarity between the Coulombian and Newtonian models (Galili, 1995). Vinemont & Rainson (1992) found that university students tend to inappropriately adopt the superposition law of Gauss' Law and Coulomb's Law, disregarding the fact that the given charge density of the conductor surface has been influenced by an outside charge. In sum, the literature has highlighted the difficulties of grasping the key ideas of electric fields, force, potential and energy.

The existing barriers in comprehending electrostatics seem not only due to the abstraction and complexity of the related terminology/concepts, but also to the lack of recognition of the functions/values of the tools. In order to facilitate students' learning in electrostatics, several studies have reported on their strategies, including (1) adopting oriented-research to enhance the idea of the electric field (Furio, Guisasola, Almudi & Cicero, 2003). By means of problem-based learning, students are guided to bridge the gap between theories, to appreciate the needs for shifting from Coulumb's towards electric field models, and to construct a comprehensive knowledge framework; (2) teaching content incorporated with the science history of the development of electromagnetism (Pocivi, 2007). Both projects incorporated the "invention" of the electric field, which aimed to reinforce the students' recognition and appreciation of the critical tool of the electric field. In addition, the strategy of using theme demonstrations to integrate the related knowledge of a broad topic has been recognized in the literature (Buncick, Betts & Horgan, 2001). The purposes of using theme demonstrations to integrate related knowledge include (1) illustrating the meanings of terminology/principles via real-life examples, (2) providing multiple times for practicing is required, especially for becoming acquainted with complex principles, and (3) allowing comparison of related principles with their meanings, functions and limitations (Aron, 1994; Buncick et al., 2001).

2.4 Students' misconceptions on the concept of electrostatics

Knight (2000) highlighted some of the learners' misconceptions on the concept of electrostatics:

- Students don't distinguish clearly between the electric attractions from the magnetic ones and, some of them, neither from the gravitatory ones. Some students say that the north magnetic pole repulses the positive electric charges. That means they may have a big confusion between attractions and repulsions that have to them a very different nature.
- Many students think that the isolated materials cannot be charged. Part of this difficulty is that students do not differentiate between charge and motion of charge (current).
- Because the current will not flow through an insulator (no *motion* of charge), students erroneously conclude that the insulator cannot be charged and they don't distinguish between an object (insulator/conductor) and its state of charge (charged or neutral).
- Some students think about the charge as an object more than a property of the matter. Or some may think a charge is a substance that can be painted on matter.
- Relating everyday phenomena some students think that a lightning rod is useful to collect the lightning and, because of this, it doesn't arrive at the house.
- Some students think that "neutral" is a third type of charge.
- Students, in general, don't recognize charge conservation.
- They think there is a fundamental reason why electrons have to be negative.

- Some students think that an object positively charged has received an excess of protons and that the protons can move as the electrons do into many materials.
- Students don’t have a good comprehension of the structure and of the atomical properties of solid materials. They don’t know what neutral, not neutral or charged means at an atomic level.

2.5 Conclusion

The chapter provided the literature that had bearing on this study. The following chapter will give a detailed report on the method that was implemented in this study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

The chapter introduces the research design and research instruments. It also provides justification for the selection of the samples and research instruments, and also indicates how issues of validity and reliability will be addressed. This chapter provides an outline of the research methodology that was used to collect the data to answer the research question below:

How can a conceptual change approach be used to teach electrostatics in Grade 11 Physical Sciences?

The following research sub-questions were addressed in this research:

I. What was learners' initial understanding of the concept of electrostatics?

II. How were the conceptual change lessons implemented to teach the concept of electrostatics?

III. What was the learners' understanding of electrostatics after the conceptual change lessons?

IV. What were the learners' perceptions of the conceptual change approach?

3.2 Research design

A research design refers to the strategy to combine the different components of the research in a consistent and logical way (Babbie & Mouton, 2001). The design of this study was a case study with one class in a single school used as the sample for data collection. This study followed a mixed method approach, including both qualitative and quantitative research methods. The use of mixed method research serves as a source of triangulation where the data is gathered using different methods to see the convergence of results. Quantitative methods focus on testing explanations, capturing of standardized data and statistical analysis (Johnson and Onwuegbuzie, 2004). The strength of quantitative research lies in its reliability (repeatability) – the same measurements should yield the same results time after time (Babbie and Mouton, 2001). Qualitative research is defined by Creswell

(1998:15) as “an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem.

3.2.1 Case study

This study adopted a single case-study design. A case study is defined as “an exploration of a bounded system or a case over time through detailed and in-depth data collection involving multiple sources of information rich in context” (Creswell, 1998:272). The researcher builds complex, holistic pictures, analyses words, reports detailed views of informants, and conducts the study in a natural setting. It allows the researcher to “appreciate the uniqueness and complexity of the case, its embeddedness and interaction with its contexts” (Stake, 1995). Similarly, Yin (1989:23) defines a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used. A case study does not rely on any particular method of data collection, therefore, any method of data collection can be employed (Merriam, 1988; Yin, 2007).

This study was done using one single Grade 11 class of learners doing physical sciences in a school in the Eastern Cape.

Advantages and disadvantages of using a case study

Advantages of using a case study

- It allows for investigation, and retains holistic and meaningful characteristics of real life events.
- It is an organisational and managerial process concerning itself with neighbourhood change.

Disadvantages of using a case study

- Case studies have been viewed as a less desirable form of inquiry and the greatest concern is the lack of rigour.
- Bias and equivocal evidence presents itself and influences the direction of the findings and its conclusions.
- It provides a little basis for scientific generalisation (Yin, 1989).

3.3 Sample

The research site was a secondary school in a rural district in the Eastern Cape. The sample consisted of one Grade 11 physical sciences class with a total of 45 learners. The researcher had access to the institution as she was also a teacher in that school. The whole population of the class participated in the pre-test. The same sample took part in the intervention which was in the form of lesson presentation and practical work. After the intervention, a post-test was administered which measured whether conceptual change was a success. Five learners were selected randomly out of the total population to be respondents in the interviews. Table 3 below summarises the steps followed when selecting the sample for the study.

Table 3: Table of sampling technique

Participants	**Sample size**	**Technique**
physical sciences learners	1 of 5 physical sciences classes	Purposely selected (class that researcher is teaching)
Learners for the lesson	45 (total learners in selected class)	Total population of one class
Learners for focus group interviews	5 groups of 9 per group	Random selection

3.4 Pilot study

A pilot study was included in the research design prior to data collection to determine the feasibility of the test in terms of the relevance of the questions and applicability of the content. This utilisation of pilot studies is in line with Huysamen (cited in Strydom, 2000), who posits that the aim of piloting a study is to investigate the suitability and feasibility of the research instruments. The test was piloted on a small group of Grade 11 learners from a neighbouring school.

3.5 Data collection plan

Data collection is the act of gathering necessary information that is related to a particular study through various methods and sources. The data was collected according to the following research sub-questions (see Table 4) that represented a summary of the data collection plan.

What was learners' initial understanding of the concept of electrostatics?

Step 1: Pre-test:

A question paper in the form of multiple-choice questions (see Appendix D) was prepared and used as a base-line evaluation and to diagnose the learners' misconceptions. A pre-test is a preliminary test administered to determine a student's baseline knowledge or preparedness for an educational experience. It addresses a constructivist approach which states that learners come to school with prior knowledge.

How can the conceptual change lessons implemented to teach the concept of electrostatics?

Step 2: Activity 1: Dissatisfaction

The lesson was introduced using videos involving electrostatics and these were watched by the learners under the guidance of the researcher. Learners were requested to predict the outcomes of videos presented. Learners were given an opportunity to write down their predictions individually, after which they formed groups and wrote predictions as groups. The researcher served as facilitator in the class. Learners were provided an opportunity to discuss the predictions and compare them to their original understanding as individuals and also as expressed in the pre-test. In this way the step of leading learners to be dissatisfied with their original thoughts was engineered.

Activity 2: Intelligibility

During this step the learners performed practical activities on electrostatics in groups. The teacher acted as a facilitator, guiding the learners. Learners actively participated in the discussions, sharing ideas with group members. The teacher encouraged the learners to participate in the activities as groups and to answer questions on the worksheets (Appendix D) individually. During this step the learners had to think about the equipment and apparatus provided to them and how to structure the practical activities in a logical and meaningful way. In this way the process of intelligibility was introduced.

Activity 3: Plausibility

Learners were given an opportunity to do an exercise based on findings of the experiment (see Appendix E). During this period, learners shared their different ideas and discussed them. Learners were expected to collectively come up with the best solution. After discussions, the teacher explained the concept scientifically and answered the questions. The worksheet (Appendix D) allowed learners to consider the solutions as plausible given their experience in the previous steps.

Activity 4: Fruitfulness

The teacher asked the learners to apply the concept in different situations including activities in the form of calculations (see Appendix D and Appendix E) conducted to reinforce the concept. At this stage learners were asked about examples relating the concept to real life where their knowledge of electrostatics applied. This step served to address the fruitfulness of the concept.

What was the learners' understanding of electrostatics after the conceptual change lessons?

Step 3: Post-test

A worksheet similar to the pre-test was used as the post-test (refer to Appendix G). A post-test is a test given after a lesson or a period of instruction to determine what the learners have learned. The average normalised gain is calculated to indicate the effectiveness of the intervention. The purpose of giving them the same test was to find what was the change brought by the intervention towards the understanding of the concept.

(i) What were the learners' perceptions of the conceptual change approach?

Step 4: Interviews

Learners were interviewed (Appendix H) to obtain their perceptions of the teaching process that was followed and whether they found that conceptual change approach added value to their learning.

Figure 5 below demonstrates the steps followed in the study:

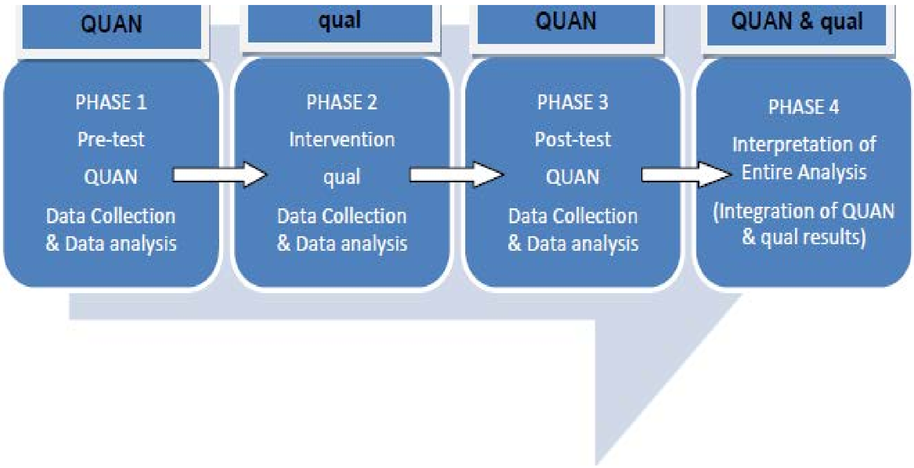


Figure 5: Steps followed during the collection of data

Table 4 below summarises the steps that were taken when data was collected:

Table 4: Data collection plan

Research Question	Steps	Method	Instrument	Respondents	Analysis
How can a conceptual change approach be used to teach electrostatics in Grade 11 Physical Sciences?					
(i) What was learners' initial understanding of the concept of electrostatics?	1	Pre- test	Mark sheet	Learners	Memorandum
(ii) How were the conceptual change lessons implemented to teach the concept of electrostatics?	2	Intervention lesson- addressing the four stages of conceptual change Lessons will be video-taped	Lesson plan Observation schedule	Learners	Inquiry method Thick description
(iii) What were the learners' understanding of electrostatics after the conceptual change lessons?	3	Post-test	Mark sheet	Learners	Memorandum
What were the learners' perceptions of the conceptual change approach?	4	Interviews	Interview schedule	Learners	Coding for themes

3.6 Data collection instruments

According to Cohen, Manion and Morrison (2008) there is no single prescription for which data collection instruments are to be used, rather the choice should be "fitness for purpose". In order to collect data for this study, the following instruments were used:

3.6.1 Pre-test

The pre-test appearing as Appendix 1 was set. Tests served as a means by which the presence, quality, or genuineness of anything is determined. A pre-test is administered to determine a student's baseline knowledge or preparedness for an educational experience or course of study. A pre-test is also used as a guide in the preparation of intervention lessons. In this study the conceptual content of the test was based on the following concepts: definition stating of Coulomb's law of electrostatics, relationship between the quantities: electrostatic force, the distance between the two spheres, charging by rubbing and calculations based on the law and definition of the electric field.

3.6.2 Post-test

A post-test similar to the pre-test was administered following the intervention that was done after the misconceptions were identified in the pre-test. The scores were recorded and analysed with the aim of finding whether teaching the concept of electrostatics using the conceptual change approach was a success. The results of the post-test were analysed according to the key items that each question was testing.

3.6.3 Interview schedule

The third instrument used in the study was the interview schedule. Scott and Usher (2011) see interviews as essential tools in educational research with pre-conceptions, perceptions and beliefs of social actors in an education setting forming an important part of the backdrop of social interaction. Frey and Oishi (1995) define interviews as a purposive conversation in which one person asks prepared questions (interviewer) and another answers them (interviewee). According to Morse (1998) interviews can use the language that is best known to the respondent so that they can understand what is being asked.

Semi-structured interviews were conducted on five focus groups of nine learners each in order to get the deeper understanding of responses learners gave in the pre- and post-tests. Since interviews are conducted for a specific purpose, and are not an ordinary daily exercise (Dyer, 1995), the researcher arranged a convenient day and time with the participants well informed in advance, making sure there would be enough time for in-depth answers. The interview questions were planned but flexible in order to allow the responses to form the basis of another question. The interviews were recorded. Beforehand, the researcher made sure the participants understood the nature and purpose of the study. The researcher obtained the participants' permission to record the interviews and assured them of their confidentiality. All the participants gave their consent before the interview commenced.

Patton (1990) viewed an unstructured interview as more like an informal conversation while Smith (1975:189) refers to unstructured interviews as "depth interviewing". Schuman and Presser (1981) describe a structured interview as consisting of pre-specified questions and the response of the respondent is greatly restricted. They further describe an unstructured interview as allowing the respondent to freely express his/her view on a certain issue.

Advantages and disadvantages of interviews

Advantages of interviews

- Interviews help the researcher to have control over the topic as well as the format of the interview.
- Prompting may be included regarding questions and if an inappropriate question is asked.
- Assists the researcher to record the data on why no responses were made (David and Sutton, 2004).

Disadvantages of interviews

- Interviews may adhere too closely to the interview guide and this may be the cause of not probing for relevant information.
- Respondents may hear and interpret questions in a different manner since there is a set interview guide (David and Sutton, 2004).

3.7 Data analysis

Learners' scores were analysed using the quantitative data analysis approach. The marks from the pre-test and post-test scores were analysed and compared through the use of statistical analysis. The scores of the learners were then compared and analysed using the measures of central tendency, namely: the mean, median and mode. Learners' responses from the interviews were analysed manually and coded for themes. Responses that were given by learners were audio-taped and transcribed verbatim. Transcription helped the researcher become more familiar with the data. After interview transcription, the data was assigned categories in the form of tags. The data was translated in cases where learners responded using their mother-tongue which is isiXhosa in this school. Responses were then categorised into key themes. Themes were coded with different colours. The video-taped lesson was analysed using an observation schedule. The researcher coded the groups who participated in the interviews as :

Focus group interview 1 FG1
Focus group interview 2 FG2
Focus group interview 3 FG3
Focus group interview 4 FG4
Focus group interview 5 FG5

3.8 Validity

Validity refers to how a test measures what it is supposed to measure. The concept of validity is described by a wide range of terms in qualitative studies. This concept is not a single, fixed or universal concept, but rather a contingent construct, inescapably grounded in the process and intentions of particular research methodologies and projects (Winter, 2000). The different instruments were used to collect data and this enabled the researcher to view the evidence from different angles and aimed to corroborate the findings of the study (Yin, 2009:116). The researcher used more than one instrument to triangulate the results. The memorandum as an instrument for the tests and the interview schedule as an instrument used in the interviews were triangulated to address the validity in this study. The researcher gave the test to a colleague to validate the instruments. Triangulation is defined to be a validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study (Creswell & Miller, 2000:126).

3.9 Reliability

Reliability is the degree to which an instrument produces stable and consistent results. The researcher piloted the instrument; respondents who were not part of the sample were requested to write the tests. Language issues were taken into considerations to avoid unambiguity and bias of the instrument.

3.10 Ethical considerations

During data collection every effort was made to comply with the required research ethics. The researcher therefore guarded against causing any harm to the participants and did not reveal confidential information that would embarrass them or endanger their daily lives. It was made clear to the research subjects that their participation was voluntary, and that they could withdraw at any time without having to give reasons. In other words, the participation in this study was based on informed consent. Also, at no time was any data fabricated or falsified, as this would have constituted a most serious transgression of the scientific code of ethics. The participants were informed that the findings of this investigation would be shared with them at platforms like community development meetings - some participants in the formal school setting gave their email addresses for them to be emailed a copy of this study. The researcher assured the participants of the use of pseudonyms to protect their identity and that of the school.

The following steps were taken to ensure that the study conformed to the ethical standards laid down by the Senate Research Committee of the University of the Western Cape:

- Permission for the study was obtained from the Eastern Cape Department of Education.
- Permission was obtained from the school principal to do the study.
- Signed consent forms were obtained from parents of the participants.
- Participant consent forms were completed.
- The name of the school involved was kept anonymous.
- All interviewees were anonymous in respect to the subject's name.

3.11 Conclusion

This chapter examined the research methodology and techniques used in the study. In the next chapter, the data collected will be presented and discussed.

CHAPTER FOUR

DISCUSSION AND ANALYSIS

4.1 Introduction

The previous chapter outlined the methodology employed to collect the data. This chapter will provide the findings to answer the research question. In this chapter, findings obtained after the analysis of the data are provided. Firstly, the quantitative results obtained through the pre- and post-tests are presented to establish the learning impact of the intervention. Thereafter the qualitative data that was collected during the intervention by means of audio-recordings are presented to enlighten the quantitative data in order to determine understanding in terms of the effectiveness of the teaching strategies and to answer the research questions

How can a conceptual change approach be used to teach electrostatics in Grade 11 Physical Sciences?

The following research sub-questions were addressed in this research:

I. What was learners' initial understanding of the concept of electrostatics?

II. How were the conceptual change lessons implemented to teach the concept of electrostatics?

III. What was the learners' understanding of electrostatics after the conceptual change lessons?

IV. What were the learners' perceptions of the conceptual change approach?

4.2 Learners' initial understanding of the concept of electrostatics

Learners were given a pre-test consisting of a number of questions addressing the concept. Table 5 shows how learners performed in the pre-test. A total of 17% (8 learners) achieved a mark of 2 out of 20. The majority of the learners (22 learners or 48% of the total learners) achieved 4 out of 20.

Table 5: Analysis of learners' pre-test scores

Scores	No. of learners
2	8
4	22
6	8
8	3
10	2
12	2

As can also be seen in Figure 6 most learners struggled to achieve good marks in the test which was based on concepts taught in the previous grades. Very few of the learners managed to obtain a maximum of 50%. The majority of the learners obtained around 20%.

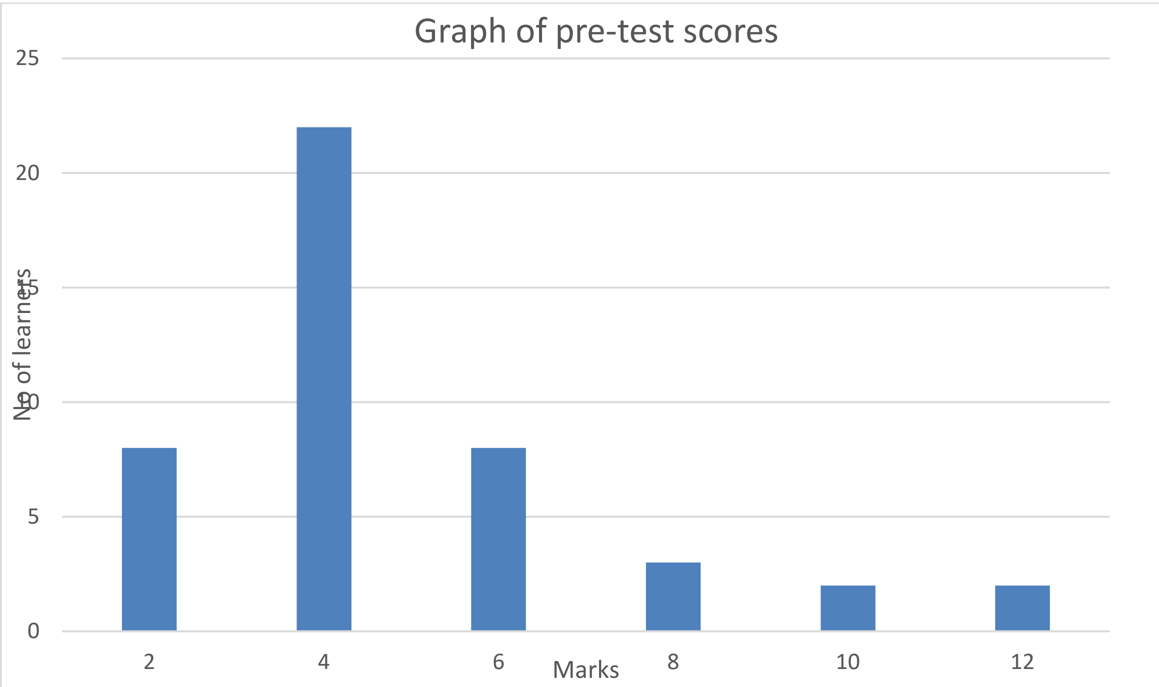


Figure 6: Graph of learners' pre-test scores

Table 6 and Figure 7 demonstrated the pass rates of learners in the pre-test per question. Many learners struggled with questions 1, 3, 7, and 9 respectively. Question 1 tested learners' prior knowledge about inverse relationships and most learners showed that they lacked the proper understanding. Only 16% of the total population managed to answer question 3 correctly. The question needed them to apply their prior knowledge of charging an object by rubbing and to determine which charges it would possess.

Table 6: Percentage pass per question

Question	Percentage
1	9
2	55
3	16
4	42
5	80
6	22
7	2
8	20
9	9
10	11

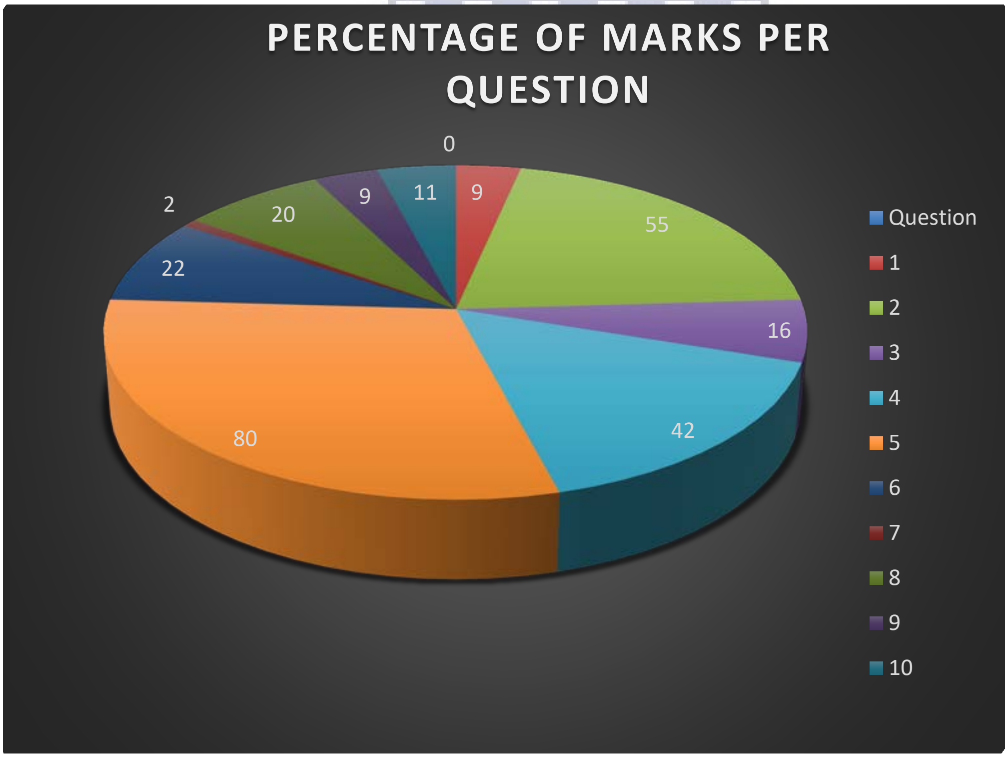


Figure 7: Graph of learners' pass rate as percentage per question

Question 7 tested the learners' prior knowledge on conductors and insulators. They struggled as 98% could not get the correct answer. Question 9 also tested their knowledge about charging by rubbing an object - a concept that was introduced in the lower grade. The responses they gave showed that they had different conceptions about the concept. The law of charges was the only concept where 80% of the learners got it right. Figure 7 shows graphically the performance of the learners per question as a percentage. As can be seen almost all the learners had a challenge with question 7 and from the test scripts many learners did not even attempt the question.

4.3 The conceptual change approach

The conceptual change lessons were developed to address the four stages of the conceptual framework proposed by Posner et al (1982).

4.3.1 Dissatisfaction

According to Posner et al. (1982), the learners must first realize that there are some inconsistencies and that their way of thinking does not solve the problem at hand. This process is called dissatisfaction. In addressing dissatisfaction in this study the teacher used simulations that involved charges and electric fields. The second simulation involved balloons and static electricity where learners had to watch thereafter answer the questions based on what they had seen. Figure 8 showed electric field lines around the oppositely charged spheres. Learners had to give the properties of field lines by watching the simulation.

The lesson to achieve dissatisfaction consisted of three parts. In the first part the following activity was done:

The teacher brought a paper, a cloth and a ruler. One learner was chosen from the class to come forward and was given an instruction to tear the paper into small pieces. While the learner tore the paper, the second learner was asked to come forward and was given a ruler and a cloth. The whole class watched attentively to see what would happen. The pieces of paper were sprinkled on the table, and the learner with a ruler was instructed to rub it with a cloth. After rubbing the ruler, a second command was to bring the ruler closer to the pieces of paper. The whole class together with the teacher observed what happened to the pieces of paper. All the pieces of paper were attracted by the ruler. The teacher then wrote a question on the board asking: “What caused the pieces of paper to be attracted by the ruler?”

One of the learners stood up and answered the question by saying:

> The reason why the pieces of paper were attracted by the ruler is that they are made from different materials of different quality [Learner 1].

Another learner put up a hand and responded to the question:

> It is because the ruler is having different charges to those of the paper [Learner 2].

Learners were given a chance to interact and consult their textbooks or any other relevant sources they may have had and look for the correct reason. While they were busy arguing about the two responses, the teacher was writing the follow up questions based on what was performed in the demonstration on the chalkboard. Some of the questions asked and responses given by the learners include the following:

Teacher: What is static electricity?

Learner 2: It is the electricity used to light in our homes.

Learner 5: Electricity at rest.

Teacher: Name the types of charges that you know.

Learner 1: Positive charge and negative charge.

Learner 8: Positive, negative and neutral charges.

The second part of the lesson involved the following simulation involving charges:

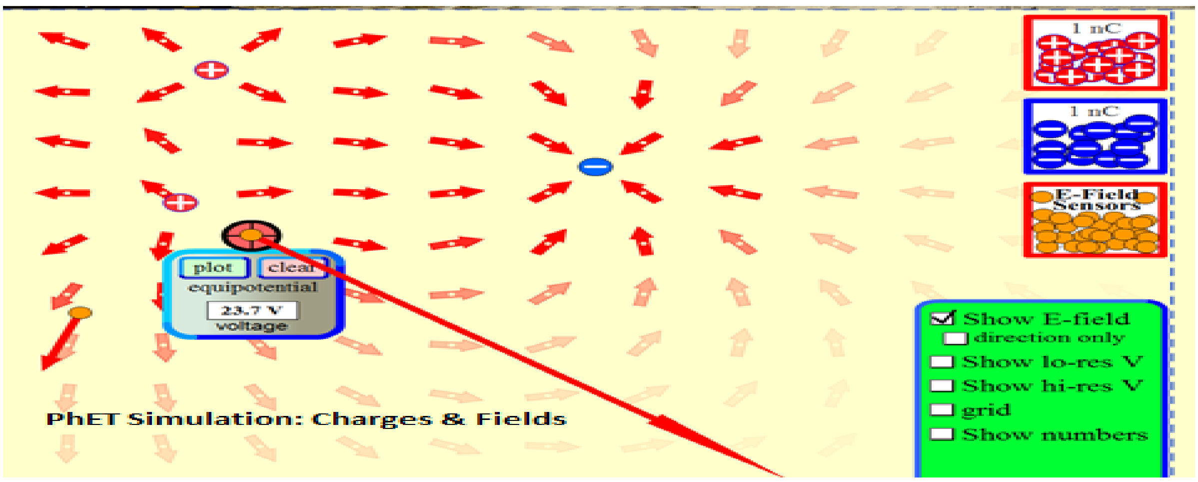


Figure 8: PheT simulation: charges and fields

The learners had to watch and answer the questions based on what they saw. The simulation addressed field lines and their properties. The teacher asked questions to check if learners had alternative conceptions on the concept of electrostatics. Some of the questions asked together with responses given by the learners were:

Teacher: What is the direction of field lines around a positive test charge?
Learner 12: Field lines are moving away from the positive test charge.
Learner 9: No, they are closer to the positive test charge.

Teacher: If the sphere is negatively charged, what will be the direction of the field lines?
Learner 7: Field lines are towards the negative test charge.

Teacher: Looking at the simulation what conclusion can be drawn with regards to the properties of field lines?
Learner 16: Field lines do not cross each other.
Learner 5: The lines start from the negative test charge and end in the positive test charge.

In the last part of the lesson, learners were informed about probable misconceptions related to the phenomena asked in the questions and they were encouraged to discuss these questions. During discussions, learners were asked to reflect on their initial answers especially those given in the pre-test. The discussion with the teacher and the encouragement was to remind learners what they answered and to relate their new knowledge with what they thought previously. This reflection was directed at making students dissatisfied with their previous conception, and in so doing supported the first condition of Posner et al.'s (1982) model, namely dissatisfaction.

4.3.2 Intelligibility

Posner et al. (1982) argued that for learners to accommodate a new conception, they must find it intelligible. The concept should not only make sense, but the learners should also be able to regurgitate the argument and ideally be able to explain that concept to other classmates. The teacher designed a practical investigation where learners would be hands on. The teacher allowed them a chance to write their findings in various groups and discuss them. The experiment was to investigate electric forces between charged particles using ordinary apparatus like aluminium cans, paper cups and fishing lines (see Figure 9).

Practical activity

Figure 9: Charges transferred from one electroscope to another electroscope

In order to explore electrostatic phenomena, the researcher prepared a device as seen in the picture above. It allowed the learners to visualize the effects of the small forces which learners were to explore. Learners worked in small groups of nine where they had to assemble the device and follow the procedure given to them (see appendix D). Learners were to connect electroscopes with a fishing line using alligator clips. After connecting the two electroscopes they had to charge the first electroscope so that the aluminium strip is well diverted. They were given an opportunity to observe what would happen.

While using the apparatus, learners showed interest in the activity as that was also witnessed by their involvement in the experiment. Some of the learners in some of the groups asked for the second session of the experiment as they claimed that there were learners who were ‘owning’ the handling of apparatus and connecting the electroscopes. Learners were even playing with the apparatus during the write up and completion of the worksheet. After the completion of the experiment by various groups, learners were to complete the worksheet having guiding questions. While they completed the worksheet, the teacher checked the answers and marked while moving around the groups. Learners had to draw conclusions by writing down the mathematical expression of the law. Most of the learners were able to manipulate the formula by changing the subject of the formula.

The teacher summarised the lesson by writing the relationship between the quantities as an equation on the board:

$F\alpha Q_1Q_2$ and $F\alpha 1/r^2$

Mathematically:

Introducing k= Coulomb's Constant, $F=KQ_1Q_2/.r^2$ is known as Coulomb's equation. Learners used the formula to state the law. By doing so, they were making sense of the law and drew conclusions using the equation.

4.3.3 Plausibility

The new conception must be plausible for it to be accommodated. The new concept must make more sense than the old concept. It must have (or at least appear to have) the capacity to solve the problem. The teacher addressed plausibility in the study by giving the learners questions based on the practical activity that they performed. Questions included completion of the table using readings taken from the practical activity that they performed, and structured questions that were in the form of calculations (see Appendix G). Learners were provided with worksheets that they were to complete in groups through discussions. They were informed that the duration of the exercise would be 45 minutes. One of the questions asked them to determine the electrostatic force between the two charges placed a certain distance apart. In the questions, the teacher also included word problems that involve the relationship between the force and the distance between the charges.

Learners were expected to write the relationship in words. By doing so the teacher was trying to emphasise the relationship between the quantities. Most of the learners were able to use the formula and substituted the quantities given. This was also shown from the above question which asked the type of force that existed between the two given spheres. Most of the learners (90%) showed an understanding of Coulomb's law of electrostatics as they were able to get the correct responses.

Question 2 required the learners to calculate the electric force given two spheres with the charges they possess. One sphere had a charge of 3µC while the other one carried a charge of 4µC. The distance was given in millimetres. Learners converted the distance with ease. The following are some of the answers from the structured questions:

Option 1

2.1 r =300mm

Q_1 =3x10^{-6}, Q_2 =4x10^{-6}, k=9,0x10^{9}

$F=kq_1q_2/r^2$

$=9{,}0x10^9x3x10^{-6}x4x10^{-6}/ (300)^2$

$=1{,}2x10^{-6}$ N.

Option 2

2.1 Q_1=3X10^{-6} ,Q_2=4X10^{-6} ,r=0,3 k=9,0x10^{9}

$F=kQ_1.Q_2/r^2$

$=9{,}0X10^9X3X10^{-6}X4X10^{-6}/(0{,}3)^2$

F=1,2 N.

2.2 Option1 Attraction

Option 2 Repulsion

Only 15% of the learners used option 1 when calculating the electric force. That was an incorrect option as they used the distance which was in millimetres. That indicated that plausibility was a success as 85% of the learners managed to convert the distance to metres. All the learners managed to substitute quantities correctly. Question 2.2 was a follow-up question for option 1.

Learners were given two spheres carrying the same charge. They had to recall the law of charges. Very few learners got it wrong. Eighty-five percent (85%) of the class got the right answer stating that it is a force of repulsion as the force exists between spheres carrying the same charge (see Appendix D).

4.3.4 Fruitfulness

For the new conception to be accommodated, the learners need to find it fruitful in the sense that this concept should have the potential to be extended to other incidences. Questions were in the form of a class exercise, structured in a way that the everyday knowledge that they had was combined with the scientific way of thinking. The following questions were asked in order to check if learners found the activities performed in the first three stages for conceptual change could lead to the solution of real life situation problems. Some of the questions included the following:

1) Explain what causes the lightning?
2) How does earth benefit from lightning?
3) List the most dangerous places to be during a thunderstorm.
4) Should you take a shower during a thunderstorm? Give a reason for your answer.
5) Name the safest places to be during a thunderstorm.
6) Describe the first aid measures you should take if someone is struck by lightning.

Learners responded with confidence in the questions above. That gave the researcher a clear indication that they grasped the concept. A summary of learners' responses:

> Lightning involves the interaction of charges, namely negative and positive charges. [L11]

It was clear that learners were giving an explanation that negatively charged particles sink to the bottom of the cloud.

> When the negative and positive charges grow large enough, a giant spark lightning occurs between two charges within the cloud. [L8]

They highlighted that

> Lightning helps the earth to maintain electrical balance because the earth carries charges. The earth is recharged by thunderstorms. [L12]

Learners listed the dangerous places to be during thunderstorm as being in water, under a tree, talking on a land-line phone. They also stated that one must avoid being in an open space like in the veld, and herding cattle during a thunderstorm is also dangerous. These responses indicated that some learners had undergone a change from their initial conception of electrostatics and electric charges. They did not hesitate to give the safest place to be during a thunderstorm as being indoors because of the electrical wiring in our homes and the cables of telephones are sealed. Being in a vehicle was another safe place identified by the learners.

However, as pointed about by Hewson & Hewson (1983), many learners still kept some of their initial understanding. To this end, some learners held onto their cultural beliefs. The following were answers that indicated that learners still persisted with their own interpretations of questions:

- If a person is hit by a lightning, he is bewitched or it is because of wrong doings [L4].
- If one is struck by lightning there is something that has to be done to connect him with his ancestors [L2].
- When someone is hit by a lightning he/she is wearing shiny materials like a watch or ear-rings [L3].
- If a person is hit by a lightning, there is an interaction of charges that are at rest [L5].
- Do not stand under the tree when there is lightning [L1].
- Avoid wearing shiny objects during thunderstorms [L10].

4.4 Learners' understanding after the intervention

The post-test was in the form of multiple-choice questions. A similar test was administered but more of the questions were testing their calculation skills. The results were analysed quantitatively using tables and graphs (see Table 7).

Table 7: Analysis of the post-test

Marks (%) and levels (L)	Frequency
10-29 (L1)	3
30-39 (L2)	15
40-49(L3)	7
50-59(L4)	5
60-69(L5)	5
70-79(L6)	6
80-100(L7)	4

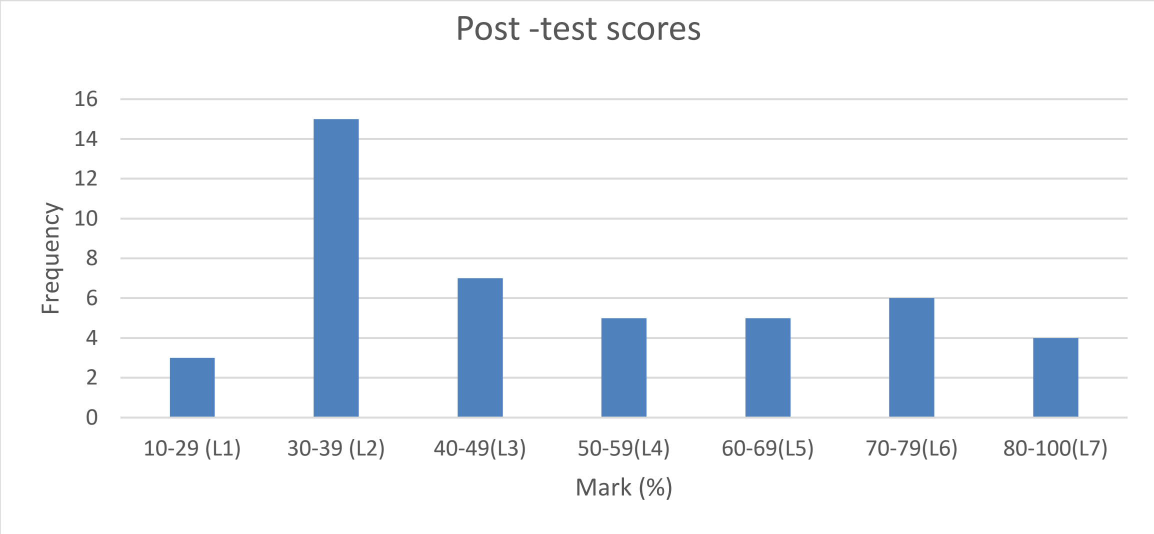


Figure 10: Graph of post-test scores

Figure 10 shows the results of the test which was administered after the intervention. Forty-four percent of the learners achieved at above fifty percent. There was an improvement in the achievement of learners as 20 out of 45 learners scored at 50% and above. Only three learners out of the total population achieved at a percentage below 30%. From the analysis of questions, it was clearly highlighted by the performance of the learners that they still had a challenge of grasping the concept of electric field as most answered that question incorrectly.

4.5 Comparing the results of pre-test and post-test

The performance of the learners from pre-test to post-test was used as a measure whether the conceptual change approach was a success in teaching of physical sciences as a subject. There was a huge difference in the marks that learners achieved before and after the approach was implemented. Learners' performance in the pre-test was at an average of 33%. It appeared that the understanding of learners with regard to the concept of electrostatics improved as there were only three learners who achieved level 1. The results of the post-test improved by an average of 60% because the average percentage of the post-test was 93,33%. Table 8 demonstrates the impact of teaching using a conceptual change approach.

Table 7: Learners' pre-test vs. post-test scores

	Pre-test	Post-test
Marks(Levels)	Frequency	Frequency
1 (0-29)	30	3
2 (30-39)	8	15
3 (40-49)	3	7
4 (50-59)	2	5
5 (60-69)	2	5
6 (70-79)	0	6
7 (80-100)	0	4

Only 15 learners passed in the pre-test. It is shown from the table that after the intervention learners improved in their results as only 7% of the whole population scored below 30%. The results in the post-test indicated that there was an improvement from what learners knew when they administered the pre-test.

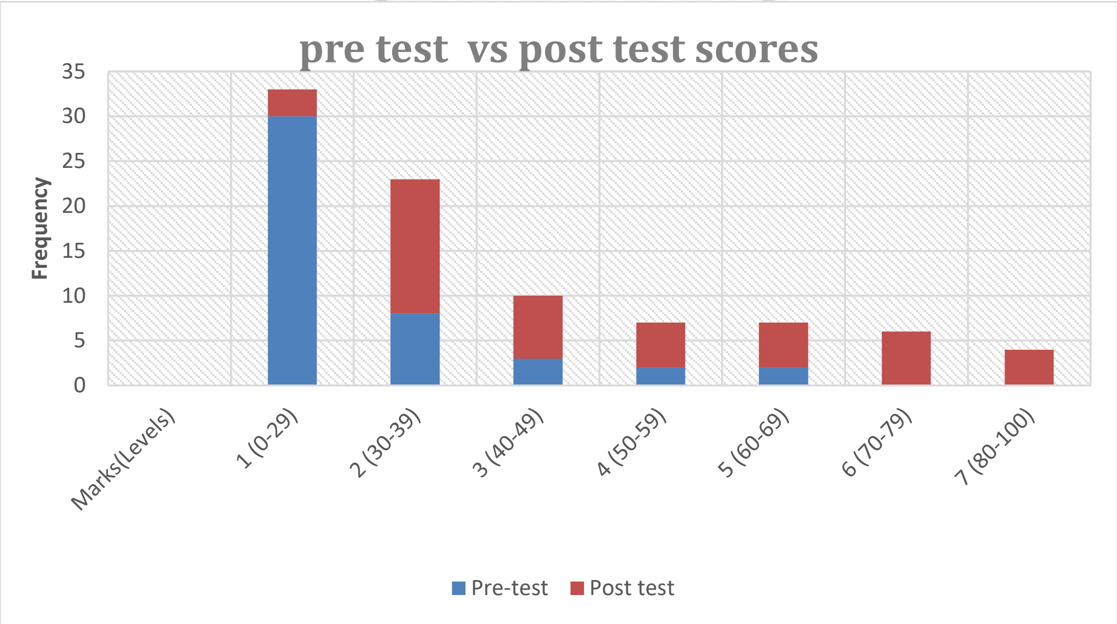


Figure 11: Graph of pre-test vs. post-test scores

Figure 11 indicated that learners performed better when the conceptual change approach was implemented; more learners during the pre-test were at level 1 (0-29%). About 67% of the learners achieved at level 1 in the pre-test. That changed to 13,3% in the post-test. The level of their performance in the post-test improved as there were 27 learners who managed to pass the test from level 3 to level 7.

4.5 Learners' perceptions in interviews

Responses given by learners were grouped into categories with the aim of creating themes. The themes that came out of the focus group interviews include:

1. Definition of the concepts
2. Understanding of the concept
3. Application of the concept in real life
4. Learners' attitude towards the subject
5. Examples given by learners

Table 9 provides a summary of learners' responses in the focus group interviews. The categories used to analyse the responses from the focus group interviews were: no answer (NA), misconception (M), partially correct (PC) and correct (C).

Table 8: Themes from the focus-group interviews

Themes	NA	M	PC	C
1.Definition of concept				
Electrostatics			√	
Electric field		√		
Electric field strength			√	
2. Understanding of the concept				
Stating Coulomb's law				√
3. Applying the concept in everyday life		√		
Cause of lightning		√		
Myths around being struck by lightning		√		
4. Examples given by learners				
Electrostatic force		√		
Force of attraction				√
Repulsion				√
Electric field lines			√	
5. Attitude of learners towards the subject				√
Science is an interesting subject				√

Integration with everyday life activities		√		

4.5.1 Definition of the concept

Learners were asked to define or explain the following concepts:

A. Electrostatics

> Electrostatics is the interaction of charges that are mainly at rest [LB_2].
>
> Electrostatics is the study that involves the charges that are mainly at rest [LB_4].

B. Electric field strength

> Electric field strength is region in space in which a charge would experience a force [LB_2].
>
> No ma'am, she is defining electric field not electric field strength, it is the force experienced per unit positive test charge [LB_4].

From their responses it was evident that misconceptions occurred as they were confusing electric field with field strength.

4.5.2 Understanding of the concept

At first learners were just stating Coulomb's law correctly as they struggled to understand the mathematical expression of the law. Most of the learners were unable to write the proportionality relationship. The majority of the learners managed to write the mathematical expression of the law.

4.5.3 Applying the law in everyday life

In applying the law, the researcher asked the learners the causes of lightning. They came up with different misconceptions as far as the concept is concerned. Some stated that if someone is struck by lightning there is witchcraft connected with the wrong doings that the person performed. Fifty percent of the population came up with the answers that were partially correct; they stated that if someone is hit by lightning there is an interaction between the charges that one possesses and those of lightning.

4.5.4 Examples of terms given by learners

Learners gave examples which include the following:

Electrostatic force

Force of attraction

Repulsion

Electric field lines

They also gave definitions of those examples:

> Electrostatic force is the force that exists between the two charges that are placed a certain distance apart [LA_3].
>
> Force of attraction is the type of force that exists between the oppositely charged objects [LB_8].
>
> Repulsion is the electrostatic force that exists between the two oppositely charged objects or spheres [L A_1].
>
> Electric field lines are lines drawn to visualise the electric field around a charged object [LB_{10}].

It was clear that learners' understanding of the concepts have been improved as most of them were able to give definitions of terms. A small number of learners still demonstrated misconceptions of the concepts.

4.5.5 Attitude of learners towards Physical Sciences as a subject

Learners indicated that before the presentation of the lesson and performing of the practical activity, they had a negative attitude towards the subject as they regard it as a subject for bright learners. The animations that they watched also changed their way of perceiving physical sciences as a difficult subject. Learners highlighted from the interviews that physical sciences is an interesting subject because practical work arouses curiosity to learn more. The abstract nature of physical sciences is made clear through practical work. Some of the comments that they gave include the following:

> My attitude has now changed, initially I perceived the subject physical sciences as the one to be done only by bright learners. Activities that we performed created interest in most of us to do more [FG_3L_2].

> What he said is true ma'am, our performance is going to improve now that we see the importance of hands-on activities on the understanding of the subject [FG_1 L_5].

4.6 Conclusion

This chapter gives an analysis of the results of the pre-test, intervention, post-test and interviews following the four conditions for the conceptual change approach. Responses from the interviews were analysed in this chapter. The following chapter will synthesise the major findings and the implication of the study.

CHAPTER 5

Summary and Conclusion

5.1 Introduction

In the previous chapter results have been analysed. In this chapter the major findings, implications of the study and issues arising out of the study will be discussed in detail.

5.2 Overview of the scope of the thesis

5.2.1 Rationale of the study

Chapter 1 provided the background and introduced the research problem leading to the research questions. The study was carried out in a school situated in a deep rural area in the Eastern Cape Province. The researcher was a Physical Sciences teacher at the research school. Learners at the school came from disadvantaged families where education was not considered to be the primary aim of changing the lives of the young citizens. Physical sciences was one of the subjects that were known as critical subjects because of the poor performance of learners in the National Senior Certificate examination. The chapter described the state of science education in the province, nationally and internationally and highlighted intervention strategies employed by the Education Department in the district, province and nationally. The chapter provided the significance and limitations of the study.

5.2.2 Literature review of the study

Chapter 2 presented the theories that underpin the study which are constructivism and the conceptual change approach. According to constructivist theory, individual learners build their knowledge by making connections to existing knowledge. As a teaching and learning theory, constructivism can be implemented using strategies such as problem-solving and inquiry strategies (Gunter et al., 1991). Robottom (2004) defines knowledge as concepts that are constructed in the mind of the learner.

The term ‘conceptual change’ refers to meaningful learning occurring when a learner accepts new conceptions on the grounds that they are intelligible, plausible and fruitful. Conceptual change learning is achieved by the acquisition of new information and reorganising the existing knowledge. Posner et al. (1982) do make the statement that they are using Piaget's terms but not borrowing the concepts in total. Piaget's work describes how learners learn through the assimilation and accommodation of knowledge. Posner et al. (1982) suggested that the conditions for accommodation of new concepts are similar to Kuhn's conditions for the acceptance of a new scientific paradigm. Posner et al. (1982) hypothesize that there are four conditions for conceptual change. These steps are summarised as: dissatisfaction, intelligibility, plausibility and fruitfulness (see sections 2.2.2 & 2.2.3).

5.2.3 Research methodology

Chapter 3 outlined the design of the study employing a mixed method (qualitative and quantitative) approach. The pre-test and post-test were analysed using quantitative analysis. Responses from the interviews were analysed using the qualitative approach. This is a case study as it involves one school. Mixed methods were used with the aim of triangulation. Sampling involved 45 grade 11 learners. The sampling technique used in this study was discussed (Figure 3 in section 3.3). Instruments for the study were piloted at a neighbouring school with the purpose of investigating the suitability and feasibility of the research instruments. Instruments used in the study were discussed in detail in chapter 3.

5.2.4 Results of the study

The pre-test and post-test results were presented and analysed. Similarly, the interviews were analysed qualitatively. The results were discussed and interpreted by using tables and figures.

5.3 Major findings of the study

The following research question was used to identify the misconceptions and learners' understanding of the concept of electrostatics:

How can conceptual change as a teaching strategy be used to improve learners' understanding of electrostatics in physical sciences?

The data was collected according to the following research sub-questions:

What was learners' initial understanding of the concept of electrostatics?

A change in the ideas that learners bring to the sciences class indicates that teaching physical sciences using the conceptual change approach could lead to improvement in learners' results The difference in learners' scores in both the pre-test and the post-test also confirmed that changing the teaching strategy to the conceptual change approach improves the learners' understanding of the scientific conceptions. The pre-test highlighted learners limited understanding of static electricity even after four years of learning about it in their earlier grades.

How can the conceptual change approach be used to teach the concept of electrostatics?

Preparation of different activities with the aim of addressing the four stages for conceptual change aroused the interest among the learners and changed their attitude towards the subject as a whole. Learning by doing created curiosity to know more amongst the learners. Simulations watched by the learners made the lesson appear easier and understandable to learners. What they saw changed the abstract nature of science to be more concrete in nature, which aroused interest amongst the learners. Dividing the learners into small and manageable groups created a sense of ownership and responsibility as each group was aiming for appreciation. The activity aroused the interest of the learners and this is witnessed by the responses that they gave when completing the worksheet. The ability to combine the everyday knowledge with scientific knowledge was a sign that the conceptual change approach was a success. The four stages of the conceptual change approach presented an interesting framework for the teacher to follow as it guided the teacher's pedagogy when teaching the curriculum content on electrostatics. Each stage had the teacher come up with creative and interesting formats to ensure that the specific stage was addressed. In all the stages of dissatisfaction, intelligence, plausibility and fruitfulness focussed the teachers approach to teaching the content.

What was learners' understanding of electrostatics after the conceptual change approach?

There was a drastic improvement even in the levels in which learners performed. There were learners who managed to achieve a percentage of 80% and above. This achievement is an important step for learners in this school. It might not seem a huge change but the upward movement from pre to post-test represents a big shift in the understanding of the learners at this school.

What was the learners' perception of the conceptual change approach?

The learners expressed their satisfaction with the approach as many experienced an improvement in their understanding of the content. They enjoyed the teaching approach where they were exposed to hands-on activities that required them to figure out the solutions (intelligibility) amongst themselves. Many of them indicated that they experienced a better understanding (dissatisfaction) of static electricity and found that they could use their new found knowledge to answer new questions that the teacher posed (plausibility). They could also relate static electricity to what they know and experience in their daily lives (fruitfulness) especially around issues of lightning. However, some students still stubbornly clung to their understanding of lightning as perceived in their culture.

5.4 Implications of the study

Learners' prior knowledge plays a key role in further teaching and learning in that misconceptions are inconsistent with scientific views. Therefore, learners cannot form suitable and correct relations between concepts and as such meaningful learning cannot occur. Therefore, teachers should be aware of learners' misconceptions and their harm to learning while developing their instruction materials and planning. Teachers also might have the same misconceptions learners have. Therefore, they should obtain courses that can help them ascertain and remediate their misconceptions.

This study has shown the complexities of various groups of learners' ideas including misconceptions and some alternate misconceptions held within the science curriculum at the pre-test stage. After the intervention lessons were taught, which included an exposure to classroom activities to address the difficulties encountered by learners before, there was an improvement in the results and a change in the learners' ideas. As a practice-based constructivist epistemology the construction of concepts by learners could help them interrogate their prior knowledge and seek for ways to make necessary adjustments in their own understanding of a given phenomenon. However, it is worth further considering the potential of this instructional tool in a different context for enhancing the learners' understanding of the concept of electrostatics and some other science concepts. This has marked the achievement of a meaningful learning process and therefore the evidence attached to these findings can be attributed to addressing the incorrect notions about topics on electricity and magnetism as a whole in an explicit way. Furthermore, the importance of the curriculum rests upon the following provision and commitments by all parties in the teaching and learning fraternity:

- Extensive teacher training with regard to the concept of electricity to achieve the aims of the physical science curriculum.
- Teachers as the agents that are directly hands-on are aware of the challenging areas in terms of understanding that needs to be acquired by learners on each topic they have experience of teaching. Therefore, it is imperative for them to be invited by the science curriculum panel of the Department of Education to participate in the curriculum development sessions.
- The authors of the science textbooks must work collaboratively with the science panel of the Education Department when developing the science curriculum and also ensure an acknowledgement of the teachers' voice.

The language in which the science textbooks are written should also be accessible to the majority of learners using it to alleviate further linguistic challenges often experienced by the second language learners to understand the content.

The learners' thinking skills are vital and must be promoted both in the classroom and in textbooks to enhance the presentation of science that takes cognizance of the socio-cultural environment of the learners.

The knowledge included in the curriculum should be relevant, appropriate and recognizable by learners. It should also make the space available to accommodate and integrate the learners' ideas to be meaningful in order to shape their scientific knowledge. Lastly, it should be amendable to a pedagogy that makes school science attractive, exciting and a rewarding experience.

There is not much written about the implementation of the conceptual change approach in physics education in South Africa. The findings from this study can serve as a guide to teachers, textbook writers and curriculum developers in South Africa regarding instruction in the teaching of electrostatics and other physics areas. Science textbooks, as a main source of knowledge in schools, might be revised and planned by considering the active participation of the learners and following the conceptual change approach. The teaching of physics should give learners the opportunity to construct the electrostatics concept. Learners should understand whether there is maintenance or change of substances' individuality during matter transformation.

This study is directed to learners, teachers of physical sciences and curriculum advisors. In teachers, the importance of using different approaches when teaching the subject is that it arouses the interest among learners to learn the subject. Changing the old approach of the chalk and talk method when teaching and using the conceptual change approach instead could improve learners' understanding. The study answered the research question because learners' understanding of the subject improved when the conceptual change approach was used. This is witnessed by the responses given by the learners during the interviews. Some of the groups highlighted that initially they considered physical sciences as a subject that has to be done only by brilliant learners, but after those intervention stages that perception has changed.

5.5 Limitations of the study

This case study was conducted at one school and the results can therefore not be generalised to other schools in the district or the province. The results of this study cannot be used by a large number of schools as it focused on a particular class at a particular school. The sample size of this study is a Grade 11 class of 45 learners. Findings of this study cannot be used for the whole school as a focus was on a single class out of four classes of physical sciences. Instruments used in the study were piloted to a very small number of schools in the circuit. Therefore, the study cannot give a true reflection of the challenges experienced by other institutions.

5.6 Recommendations for future research

The following are recommendations for future study

- A larger study of the application of conceptual change approach to teaching involving all the schools in a particular district.

- A comparative study of this approach in various Eastern Cape education districts and even between provinces
- Studies that involve various physical science concepts
- Studies that utilise the conceptual change approach in other science subjects like, life sciences, natural sciences, geography, etc.

5.8 Conclusion

This chapter gave an overview and summary of the study. The study represents one case study where conceptual change approach is used as a teaching strategy to teach static electricity in physical science. The results indicate that there is room for this approach; something much needed to improve learners' outcomes in physical sciences in the National Senior Certificate.

References

Adams, S. (1990). An analysis of border crossing between learners' life-world and school science. *Journal of the South African Association of* Research *in Mathematics and Science Education, 3*(1), 14-21.

Al Khawaldeh, S.A., & Olimant, A.M. (2010). The contribution of conceptual change texts accompanied by concept mapping to eleventh grade students: Understanding of cellular respiration concepts. *Journal of Science Education and Technology, 19*, 115-125.

Andersson, B. (1990). Pupils' conceptions of matter and its transformations (age 12-16). *Studies in Science Education, 18*, 53-85.

Aron, A. (1994). *A guide to introductory physics teaching.* New York: John Wiley & Sons.

Asan, A. (2007). Concept mapping in science class: A case study of the fifth grade students. *Educational Technology & Society, 10*(1), 186-195.

Babbie, E., & Mouton, J. (2001). *The practice of social research.* Cape Town: Oxford University Press.

Bell, B., Osbourne, R., & Tasker, R. (1985). Finding out what children think. *Learning in Science : The Implications of Childrens' Science*, 5-27.

Bell, B. ,Osbourne, R., & Tasker, R. (1985). *Finding out what children think: Learning in science: The implications of childrens' science.* London: Heinemann.

Bell, B., Osbourne, R., & Tasker, R. (1993). Finding out what children think: Learning in science: The implications for science Instructions. *Review of Educational Reseasrch, 63*, 1-49.

Bodner, G. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*, 873-878.

Brown, J.S., Collins,A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Education Researcher, 18*(1), 32-42.

Buncick, M.C., Betts, P.G., & Horgan, D.D. (2001). Using demonstrations as a contextual road map: enhancing course continuity and promoting active engagement in introductory college of physics. *International Journal of Science Education,23 (12),*1237-1255.

Calik, M., Kolomuc, A., & Karagolge, Z. (2010). The effects of conceptual change pedagogy on students' conceptions of rate of reaction. *Journal of Science Education and Technology, 19*(5), 422-433.

Carr,M.,Baker,M.,Bell,B.,Biddulph,F.,Jones,A.,Kirkwood,V.,Pearson,J.,&Symington,D.(1994).The constructivist paradigm and some implications for science content and pedagogy.In Freshman, P. ,Gunstone R. & White,R. (Eds). The content of science. Constructivist approach to its teaching and learning(p.147-160).London: The Falmer Press.

Chabay, R., & Sherwood, B. (2006). Restructuring the introductory electricity and magnetism. 74(4), 329-336.

Champagne, A.B., Gunstone, R.F., & Klopfer, L.E. (1985). Instructional consequences of students' knowledge about phenomena. In West, L.H.T. and Pines, L. (Eds). *Cognitive structure and conceptual change.* Orlando Fl.: Academy Press.

Champagne, A.B., Klopfer, L.E. & Gunstone, R.F. (1982). Cognitive research and the design of science instruction. *Educational Psychologist,* (17), 31-53.

Chin, C.A., & Brewer, W.F. (1993). The role of anomalous data in knowlwdge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research, 63*, 1-49.

Corbetta, P. (2003). *Social research, theory, methods and techniques.* London: Sage Publications.

Cresswell, J. (1998). *Qualitative inquiry and research design: Choosing among five approaches.* Thousand Oaks,CA: Sage Publications.

De Muynck, B., & Van der Walt, H. (2006). *The call to know the world. A view on constructivism and education.* Amsterdam: Buijten & Schipperheijn Motief.

Dede, C., Salzman, M., Loftin, R.B., & Sprague, D. (1999). Multisensory immersion as a modelling environment for learning complex scientific concepts*. In Feurziey, W. & Roberts, N. (Eds.). Modelling and simulation in science and mathematics education.* New York: Springer Verlag.

Dewey,I., Dykstra, J.R., Boyle, C.F., & Monarch, I.A. (1992). Studying conceptual change in learning physics. *Science Education,* 76(6), 615-652.

di Sessa, A. (1993). Towards an epistemology of physics. *Cognition and Instruction,* 10(2&3), 105-225.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education,*(5), 61-84.

Duit, R,. &. (1995). *Students' conceptions and constructivist teaching approaches. In Fraser, B.J. & Wallberg, J.W. (Eds.).Improving science education.* The University of Chicago Press.

Duit, R.,&Treagust, D.F.(2003).Conceptual change :a powerful framework for improving teaching and learning. *International Journal of Science Education,25(6),* 671-688

Fraser, J.B., & Tobin, G.K. (2003). *International handbook of science education.* Kluwer Academic Publishers. Dordrecht.

Furio, C .,& Guisasola, J. (1998).Difficulties in learning the concept of electric field. *Science Education,82(4),*511-526.

Guba, E.G., & Lincoln, Y.S. (1981). *Effective evaluation.* San Francisco: Jossey Bass.

Gunstone, R.F., & Northfield, J. (1992). Coneptual change in teacher education: The centrality of metacognition. Paper presented at Annual Meeting of the American Education Research Association. San Francisco, CA.

Gunter, A.M., Estes, J.H., & Schaub, J. (1991). *Instruction: A model approach.* Allyn and Bacon. City?

Hammer, D. (2000). Student resources for learning introductory physics. *American Journal of Physics Education,Research Supplement, 68(SI)*, 552-559.

Hancock, B. (1998). *Trent focus for research and development in primary health care : An introduction to qualitative research.* Trent Focus.

Harrison, A.G., & Treagust, D.F. (2000). Learning about atoms, molecules and chemical bonds: A case study of multiple model use in grade 11 chemistry. *Science Education, 84*, 352-381.

Hazelton, R.L.C., Stetzer, M.R., Heron, P.R.L. , & Shaffer, P.S. (2013). Investigating student ability to apply basic electrostatics concepts to conductors. *AIP Conf. Proseedings*, *1513*, 166-169.

Hewson, P. (1981). A conceptual change approach to learning science. *European Journal of Science Education, 3*(4), 383-396.

Hewson, P. (1982). A case study of conceptual change in special relativity. The influence of prior knowledge in learning. *European Journal of Science Education, 4*(1), 61-78.

Hewson, P.W. , & Thorley, N.R. (1989). Conditions for conceptual change in the classroom. *International Journal of Science Education, 11*, 541-553.

Hewson, P.W., Lemberger, J. (2000). Status: The hallmark of conceptual learning: An example from learning genetics. In Millar, R., Leach,J., & Osborne, J. (Eds. *Improving science education: The contribution of research (In honour of Rosalind Drivers' work in science education).* London: Open University Press. 110-125.

Huysamen, G. (2000). The differential validity - matriculation and univesrity performance as predictors of post-first-year performance. *South African Journal of Higher Education, 15*(2), 146-151.

Igwebuike, T. (2012). Effects of conceptual change pedagogy on achievement by high ability intergrated science students on energy concepts. *Journal of Research Studies in Educational Technology, 1*(2), 3-14.

Kaboro, P. (2014). Effects of teaching using a dance analogy on physics students's motivation, self- concept and conceptualisation of heat concepts in secondary schools in Nyandarua Country. Kenya: Unpublished thesis, Laikipia.

Kaboro, P.G., Nguta, C.M., & Okere, M.O. (2015). Effects of teaching using a dance analogy on secondary schools physics students' conceptualisation of heat concepts. *International Journal of Information Research Review, 2*(10), 1274-1284.

Kapartzianis, A., & Kriek, J. (2014). Conceptual change activities alleviating misconceptios about electric circuits. *Journal of Baltic Science Education, 13*(3), 292-315.

Kramer, D. (2002). *OBE teaching toolbox:OBE strategies, tools and techniques for implementing Curriculum 2005.* (2nd edition). Cape Town: Vivlia.

Kryjevskaia, M., Stetzer, M.R., & Heron, P.R.L. (2013). Student difficulties measuring distance in terms of wavelength. Lack of basic skills or failure to transfer. *Physics Rev. ST. Physics Education Research* (9). Retrieved 01 01, 06

Kvale, S. (1996). *Interviews: An introduction to qualitative research Interviewing.* London: Sage Publication.

Maloney, D., O'Kuma, T., Hieggelke, C., & Van Heuvelen, A. (2001). Surveying students' conceptual knowledge of electricity and magnetism: Physics education research. *American Journal of Physics Supplement, 69*(7), 512-523.

Novak, J. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching, 27*(10), 937-949.

Nussbaum, J., & Novick, S. (1982). Alternative frameworks, conceptual conflict and accommodation: Towards a principled teaching strategy. *Instructional Science*,*11(3)* ,183-200.

Omrod, J. (2011). *Educational psychology: Developing learners.* (7th edition). Boston: Pearson International.

Osborne, R.,& Wittrock, M. (1985). The generative learning model and its implications for science education. *Studies in Science Education, 12*, 59-87.

Osborne, R.J., & Crossgrove, M.M. (1983). Childrens' conceptions of the changes in the state of water. *Journal of Research in Science Teaching, 20*(9), 825-838.

Osbourne,R.J., & Freyberk.,P. (1996). Learning in science: The implication of children's physics education research. *American Journal of Physics Supplement.*

Osbourne, R. (1983). Modifying childrens' ideas about electric current. *Research in Science and Technological Education,* (1), 73-82.

Patton, M. (1990). *Qualitative evaluation and research methods.* (2nd edition). Newbury Park, CA: Sage Publications.

Pintrich, P.R., Marx, R.W., & Boyle, R.A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W.A. (1982). Accomodation of a scientific conception: Towards a theory of conceptual change. *Science Education, 66*(2), 211-227.

Radziszewska, B., & Rogoff,B. (1991). Childrens' guided participation in planning errands with skilled adult & peer partners. *Developmental Psychology, 24*, 840-848 Ramorogo, G. (1998). *The Effect of an Exemplary Teaching and Learning Materials on Students' Performance in Biology. Unpublished thesis.* UWC, Cape Town.

Rankhumise, M. (2014). Using a bicycle analogy to alleviate students' alternative conceptions and conceptual difficulties in electric circuits. *Mediterranean Journal of Social Sciences, 5*(15), 2039-2117.

Redish, E. (2002). *Teaching Physics with the Physics suite.* University of Maryland. Maryland: http//www2.physics.umd.edu/nredishBook. Retrieved August 8, 2012

Robottom, I. (2004). Constructivism in environmental education: Beyond conceptual change theory. *Australian Journal of Environmental Education, 20*(2), 93-101.

Smith, H. (1975). *Strategies of social research.* New Jersey: England Cliffs: Prentice-Hall.

Stake, R. (1995). *The art of case study research.* Thousand Oaks, CA: Sage Publications.

Stavy, R. (1991). Using analogy to overcome about conservation of matter. *Journal of Research in Science Teaching, 28*(4), 305-313. Something missing in this title?

Stepans, J. (1994). Targeting students' science misconceptions: Physical science activities using the conceptual change model. Riverview, Fl.: Idea Factory .

Strike, K., Posner, G.J. (1985). A conceptual change view of learning and understanding. In West, L.H. & Pines, L. (Eds.). *Cognitive structure and conceptual change* (pp. 211-231). New York: Academic Press.

Strydom, P. (2000). *Discourse and knowledge: The making of enlightenment sociology.* Liverpool: Liverpool University Press.

Suping, S. (2003). Conceptual change among students in science. In ERIC, *Clearing for Science, Mathematics and Environmental Education (ED 482723).*

Towbridge, J.E., & Wandersee, J.H. (1994). Using analogy to overcome about conservation of matter. *Journal of Research in Science Teaching, 31*, 459-475.

Trumper, R. (1990). Being constructive: An alternative apporach to the teaching of the energy concept - Part 1. *International Journal of Science Education, 12*, 343-354.

Tyson, L., Vanville, M., Grandy, J., Harrison, A.H., & Treagust, D.F. (1997). A multidimentional framework for interpreting conceptual change events in the classroom. *Science Education, 81*, 387-404.

von Glaserfeld, E. (1990). An exposition on constructivism: Why some like it radical. In Davis, R.B., Maher, C.S & Noddings, N. (Eds.). Constructivist views on teaching and learning of mathematics. *The National Council of Teachers of Mathematics.*Reston,Virginia,Inc.19-29.

Vosniadou, S., & Brewer, W.F. (1994). *" Mental models of the day/night cycle" Cognitive Science,* (18),123-183.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological precesses.* Cambridge, M.A.: Havard University.

Wandersee, J.H., Mintzes, J.J., & Novak, J.D. (1994). *Research on alternative conceptions in science. Handbook of research on science teaching and learning: A project of the National Science Teachers' Association.* New York: MacMillan.

Watt, M. (1983). Some alternative views of energy. *Physics Education, 18*, 213-216.

Watts, D. (1983). Students' conceptions of light - a case study. *Physics Education, 20*, 183-187.

White, R., & Gunstone, R. (1989). Meta-learning and conceptual change. *International Journal of Science Education, 11*, 577-586.

Winter, G. (2000). A comparative discussion of the notion of validity in qualitative and quantitative research, *4*(3&4). Retrieved February 25, 1998, from http://www.nova.edu/ssss/QR/QR4-3-winter.html

Woolfolk, A. (2010). *Educational psychology.* (11th edition). London: Pearson Educational International.

Yin, R. (1989). *Case study research: Design and methods. Applied Social Research Methods Series* (Vol. 5). London: Sage.

Yin, R. (2009). *Case study research: Design and methods.* Los Angeles: Sage.

Zembylas, M. (2005). Three perspectives of linking the cognitive and emotional in science learning: Conceptual change, socio-constructivism and post-structuralism. *Studies in Science Education, 41*, 91-116.

Zidler, D. (1997). The central role of fallacious thinking in science education. *Science Education, 81*, 483-496.

Zirbel, E. (2005). *Paper III Teaching for Conceptual Change,submitted at AER.*

APPENDICES

Appendix A

Pre-Test

Name of learner: ------------------   Date -------------

Answer the following questions by choosing the correct options. Do not write the statement but write the number which is the correct answer next to the question number.

1. When the distance between two charges is halved, the electrical force between them...

A) quadruples. B) doubles. C) halves. D) reduces to one fourth.

2. If you comb your hair and the comb becomes negatively charged, ...

A) electrons were transferred from the comb onto your hair.

B) electrons were transferred from your hair onto the comb.

C) protons were transferred from the comb onto your hair.

D) protons were transferred from your hair onto the comb.

3. Which statement correctly describes how to charge something negatively by conduction?

A) Touch it with a positively charged object.

B) Touch it with a negatively charged object.

C) Momentarily ground it with a positively charged object nearby.

D) Momentarily ground it with a negatively charged object nearby.

4. If a neutral conductor is touched by a rubber rod with a negative charge on it, what will happen?

A) Electrons will flow from the conductor onto the rubber rod.

B) Electrons will flow from the rubber rod onto the conductor.

C) Protons will flow from the conductor onto the rubber rod.

D) Protons will flow from the rubber rod onto the conductor.

5. Protons and electrons...

A) repel each other. B) attract each other. C) have no effect on each other.

6. Coulomb's law says that the force between any two charges depends...

A) inversely on the product of the charges.

B) directly on the square of the distance between the charges.

C) directly on the product of the charges.

D) inversely on the square root of the distance between the charges.

7. In a good insulator, electrons are usually...

A) free to move around.

B) free to move around after an impurity has been added.

C) semi-free to move around.

D) tightly bound in place.

8. A leaf electroscope is neutral. As a negative charge is brought close to the electroscope, the leaves spread apart because the approaching negative charge...

A) attracts and pulls electrons away from them.

B) attracts and pulls protons away from them.

C) pushes electrons down onto them.

D) pushes protons down onto them.

9. The reason a pith ball will be attracted to a charged rubber rod is that...

A) the rod is positive and attracts electrons in the pith ball.

B) the rod is negative and repels electrons in the pith ball, attracting the nearer protons.

C) the rod is positive and repels electrons in the pith ball, attracting the nearer protons.

D) the rod is negative and attracts electrons in the pith ball.

10. Amy uses a piece of silk to rub a comb. The comb then becomes positively charged. This net positive charge accumulates because the comb:

A. gains electrons.

B. gains protons.

C. loses electrons.

D. loses protons.

[20]

APPENDIX B

Dissatisfaction: PhET simulations

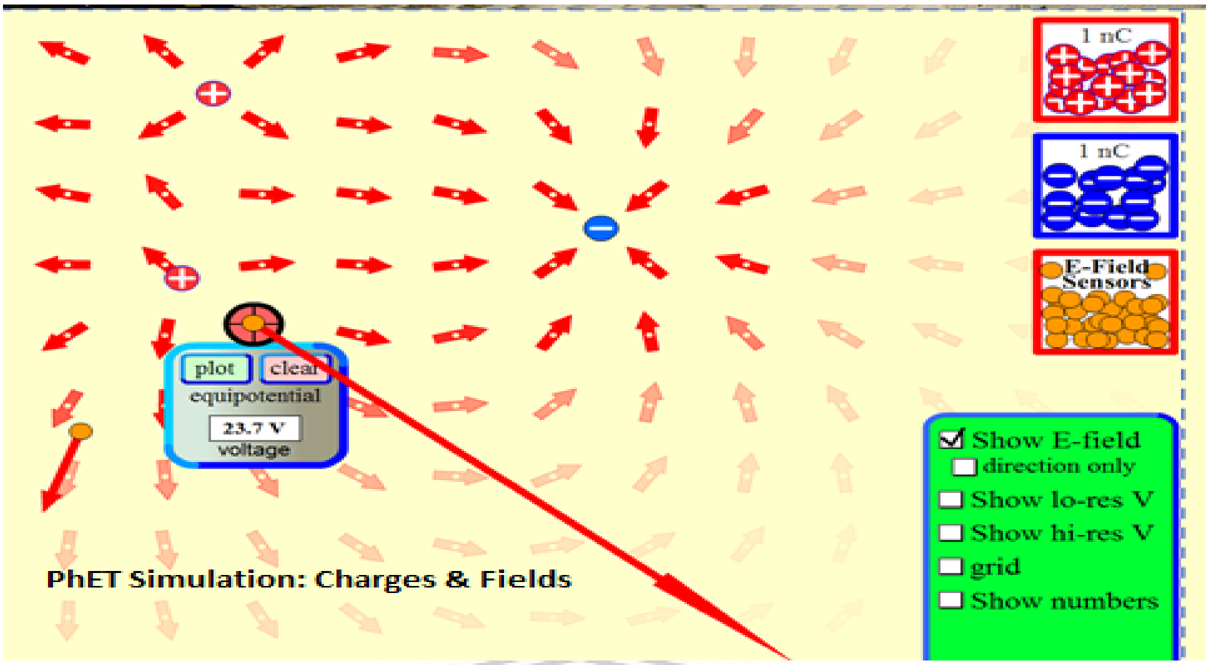


Figure 8: PhET Simulation: Charges and Fields

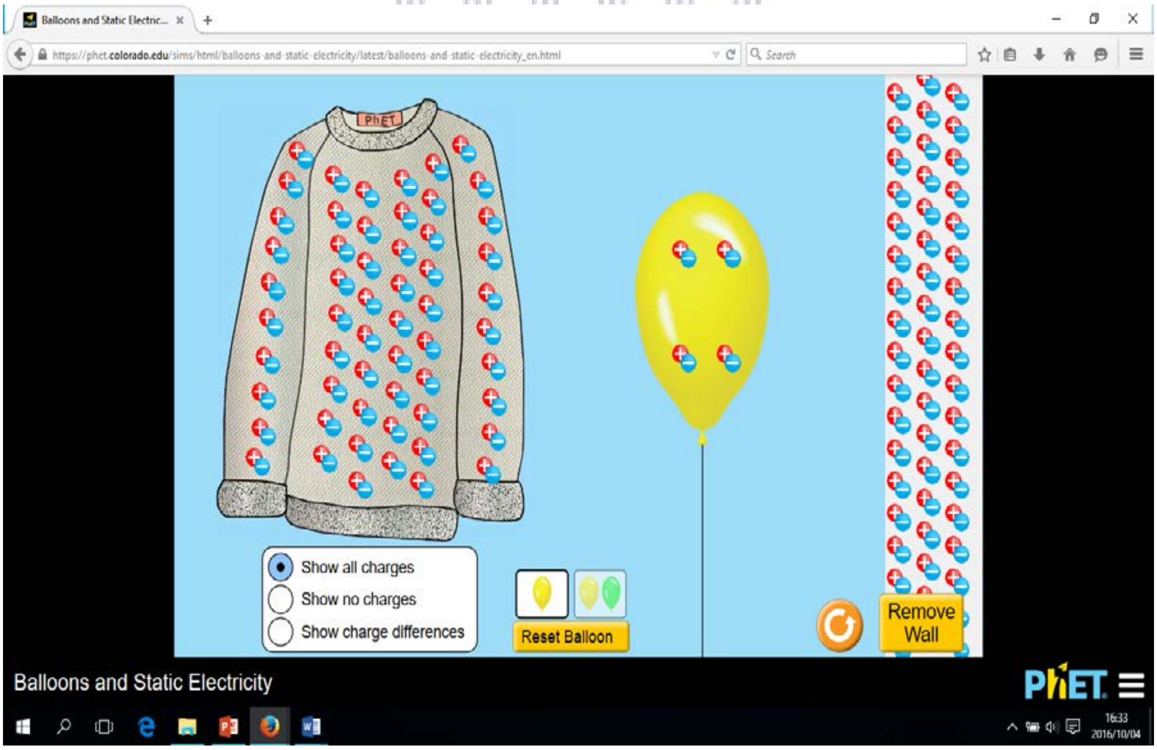


Figure 9: Balloons and static electricity

APPENDIX C

<u>Lesson plan</u>

Topic: Electrostatics__________________ <u>Grade:11</u>

Core knowledge area :<u>_Electricity and Magnetism</u>

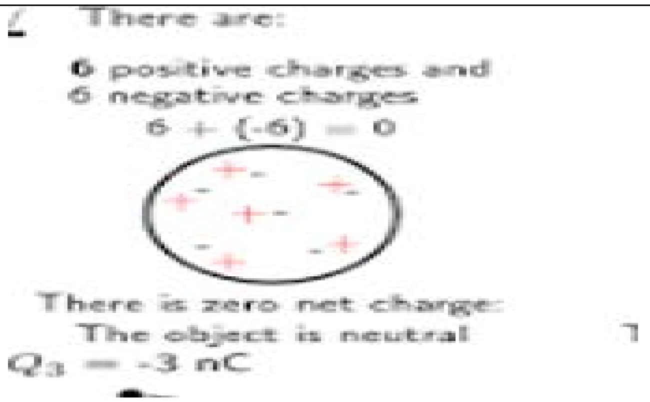
Lesson objectives

At the end of the lesson learners will be able to:

- state Coulomb's law of electrostatic;
- calculate electrostatic force exerted by charged objects; and
- define an electric field and draw electric field lines around the charged spheres.

LESSON STRUCTURE

Time	Teacher's activities	Learners' activities	Teaching approaches
5 min.	The teacher poses questions on prior knowledge. What is static electricity? List the two types of charges that you know. Introducing the concept of electrostatics. The teacher draws a neutral charged sphere and demonstrates how it is said to be neutral.	Learners answering questions posed by the teacher	Learners answer questions - question and answer method. Question and answer method

45 min.	 Presentation stage: illustration of positive test charge and negative test charged spheres. Going deeper to the concept by stating Coulomb’s law of electrostatics, showing learners its mathematical expression. The force of attraction between two charged spheres is directly proportional to the product of the charges and inversely proportional to the square of the distance between their centres. Mathematical expression is: $F\alpha Q1.Q2$ and $F\alpha 1/d^2$ .combining the two relationships : $F=KQ1Q2/d^2$		Demonstration method

Expanded opportunities: homework given to learners and remedial work will be done.

APPENDIX D

Practical Experiment

Experiment: Coulomb's law of electrostatics

Figure 9: Charges transferred from an electroscope to another electroscope

1.1 Write down the aim of the experiment.

--- [2]

1.2 List all the apparatus used in the experiment.

---[3]

Procedure

2 Connect electroscopes with a fishing line using alligator clips.

Charge the first electroscope so that the aluminium strip is well diverted.

Observe what will happen.

2.1 Write down your observations.

---[2]

2.2 What causes the delay of the transfer of charge?

---[3]

2.3 What will happen to equilibrium if cans of different materials are used as electroscopes?

----
[3]

2.4 What conclusion can be drawn from this experiment?

-- [2]

3 Suppose the correct law of interaction between two point charges have the form

$F\alpha\ Q_1Q_2$ -------------------- (1)

$F\alpha 1/r^2$---------------------(2)

3.1 Write the mathematical expression of the law by combining the two relationships.

--[3]

If $k=9{,}0X10^9N.m^2.C^{-2}$ is called Coulomb's constant, write down the mathematical equation of the law

--- - [2]

[20]

APPENDIX E

Plausibility

Activity: Class Exercise   Date: ----------------

Instructions   Duration: 45 minutes

1 Complete the following table by calculating the magnitude of the electrostatic force given the sizes of charges and the distance between the charges:

Table 10: Coulomb's law of electrostatics

Experiment	Force in Newton	Charge Q_1 in C	Charge Q_2 in C	Distance r apart (m)
1		$5x10^{-5}$	$5x10^{-5}$	1
2		$5x10^{-5}$	$5x10^{-5}$	2
3		$5x10^{-5}$	$5x10^{-5}$	3
4		$10x10^{-5}$	$10x10^{-5}$	3
5		$20x10^{-5}$	$20x10^{-5}$	3
6		$20x10^{-5}$	$20x10^{-5}$	3
7		$20x10^{-5}$	$20x10^{-5}$	3

2 Two spheres with masses 200g each carry a charge of +3µC and +4µC respectively. Their centres are 300mm apart.

2.1 Calculate the electrostatic force between the two spheres.

2.2 Is the force in (2.1) a force of attraction or repulsion? Give a reason for the answer.

APPENDIX F

Fruitfulness
Class Activity **Date________________**

Answer the following questions:

1. Explain what causes lightning?
2. How does earth benefit from lightning?
3. List the most dangerous places to be during a thunderstorm.
4. Should you take a shower during a thunderstorm? Give a reason for your answer.
5. Name the safest places to be during a thunderstorm.
6. Describe the first aid measures you should take if someone is struck by lightning.

APPENDIX G
Post- test

Marks_____________Date____________

Name of learner_____________

<u>Instructions and information</u>

Answer the following questions by choosing the correct options. Do not write the statement, write the number of the correct answer next to the question number.

1. When the distance between two charges is halved, the electrical force between them.

A) quadruples. B) doubles. C) halves. D) reduces to one fourth.

2. If you comb your hair and the comb becomes negatively charged, ...

A) electrons were transferred from the comb onto your hair.

B) electrons were transferred from your hair onto the comb.

C) protons were transferred from the comb onto your hair.

D) protons were transferred from your hair onto the comb.

3. Which statement correctly describes how to charge something **negatively** by **conduction**?

A) Touch it with a positively charged object.

B) Touch it with a negatively charged object.

C) Momentarily ground it with a positively charged object nearby.

D) Momentarily ground it with a negatively charged object nearby.

4. If a neutral conductor is touched by a rubber rod with a negative charge on it, what will happen?

A) Electrons will flow from the conductor onto the rubber rod.

B) Electrons will flow from the rubber rod onto the conductor.

C) Protons will flow from the conductor onto the rubber rod.

D) Protons will flow from the rubber rod onto the conductor.

5. Protons and electrons...

A) repel each other. B) attract each other. C) have no effect on each other.

6. Coulomb's law says that the force between any two charges depends...

A) inversely on the product of the charges.

B) directly on the square of the distance between the charges.

C) directly on the product of the charges.

D) inversely on the square root of the distance between the charges.

7. In a good insulator, electrons are usually...

A) free to move around.

B) free to move around after an impurity has been added.

C) semi-free to move around.

D) tightly bound in place.

8. A leaf electroscope is neutral. As a negative charge is brought close to the electroscope, the leaves spread apart because the approaching negative charge...

A) attracts and pulls electrons away from them.

B) attracts and pulls protons away from them.

C) pushes electrons down onto them.

D) pushes protons down onto them.

9. The reason a pith ball will be attracted to a charged rubber rod is that...

A) the rod is positive and attracts electrons in the pith ball.

B) the rod is negative and repels electrons in the pith ball, attracting the nearer protons.

C) the rod is positive and repels electrons in the pith ball, attracting the nearer protons.

D) the rod is negative and attracts electrons in the pith ball.

10. Amy uses a piece of silk to rub a comb. The comb then becomes positively charged. This net positive charge accumulates because the comb:

A .gains electrons.
B. gains protons.
C. loses electrons.
D. loses protons. TOTAL=[20]

APPENDIX H

Interview Schedule

Name of school ______________________

Gender _________________**Grade** ______________

Interviewer __________________

Interviewee _________________

Date ___________________

a. Were your responses of your pre-test and post-test the same?
b. If they were not the same, what was the reason for the change?
c. Can you apply Coulomb's law in real life situation?
d. How will you apply that law to solve the problems in real life situation?
e. Do you understand the meaning of 'direct proportional'?
f. In what way will you use the concept of 'proportionality' in general?
g. Can you define an electric field? If yes, explain.
h. What is your overall comment on the experience you gained when the lesson was presented in your class?

6.2.9 APPENDIX I

Analysis of the pre-test scores

Names	Marks	Percentage
L1	4	20%
L2	10	50%
L3	4	20%
L4	12	60%
L5	10	50%
L6	8	40%
L7	6	30%
L8	6	30%
L9	12	60%
L10	8	40%
L11	4	20%
L12	4	20%
L13	8	40%
L14	2	10%
L15	4	20%
L16	6	30%
L17	4	20%
L18	2	10%
L19	4	20%
L20	6	30%
L21	6	30%
L22	8	40%
L23	4	20%
L24	2	10%
L25	4	20%
L26	4	20%
L27	4	20%
L28	6	30%
L29	6	30%
L30	6	30%
L31	4	20%
L32	4	20%
L33	4	20%
L34	2	10%
L35	2	10%
L36	4	20%
L37	2	10%
L38	4	20%
L39	2	10%
L40	4	20%
L41	2	10%
L42	4	20%
L43	4	20%
L44	4	20%
L45	4	20%

No. of learners: 45

No. wrote : 45

No. Passed :15

No. Failed :30

% Passed :33%

APPENDIX J

Question by question analysis of the pre-test

Name		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
L1	4	x	√√	x	x	x	√√	x	x	x	x
L2	10	x	√√	√√	x	√√	√√	x	√√	√√	√√
L3	4	x	√√	x	√√	x	x	x	x	x	x
L4	12	√√	√√	√√	√√	x	√√	x	x	√√	x
L5	10	x	√√	x	√√	√√	√√	x	x	x	√√
L6	8	x	√√	√√	x	√√	x	x	√√	x	x
L7	6	x	√√	x	√√	√√	x	x	x	x	x
L8	6	x	√√	x	x	x	√√	x	√√	x	x
L9	12	x	√√	x	√√	√√	x	x	√√	x	√√
L10	8	x	√√	x	√√	√√	x	x	x	x	√√
L11	4	x	√√	x	x	√√	x	x	x	x	x
L12	4	x	√√	x	x	√√	x	x	x	x	x
L13	8	x	√√	x	√√	√√	√√	x	x	x	x
L14	2	x	x	x	x	√√	x	x	x	x	x
L15	4	√√	x	x	x	x	x	√√	x	x	x
L16	6	x	√√	√√	x	x	√√	x	x	x	x
L17	4	x	x	√√	x	√√	x	x	x	x	x
L18	2	x	x	x	x	√√	x	x	x	x	x
L19	4	x	√√	x	x	√√	x	x	x	x	x
L20	6	x	√√	x	√√	√√	x	x	x	x	x
L21	6	√√	√√	x	x	√√	x	x	√√	x	x
L22	8	x	x	x	x	√√	√√	x	√√	√√	x
L23	4	x	√√	x	x	√√	x	x	x	x	x
L24	2	x	x	x	x	√√	x	x	x	x	x
L25	4	x	x	x	x	√√	x	x	x	√√	x
L26	4	x	x	x	x	√√	√√	x	x	x	x
L27	4	x	√√	x	√√	x	x	x	x	x	x
L28	6	x	√√	x	x	√√	x	x	x	x	√√
L29	6	x	x	√√	x	√√	√√	x	x	x	x
L30	6	x	x	x	√√	√√	x	x	√√	x	x
L31	6	√√	x	x	√√	√√	x	x	x	x	x
L32	4	x	√√	x	x	√√	x	x	x	x	x
L33	4	x	√√	x	x	√√	x	x	x	x	x
L34	4	x	√√	x	x	√√	x	x	x	x	x
L35	2	x	x	x	x	√√	x	x	x	x	x
L36	2	x	x	x	√√	x	x	x	x	x	x
L37	4	x	√√	x	x	√√	x	x	x	x	x
L38	2	x	x	x	x	√√	x	x	x	x	x
L39	4	x	x	x	x	√√	x	x	√√	x	x
L40	2	x	x	x	x	√√	x	x	x	x	x
L41	4	x	x	√√	√√	x	x	x	x	x	x
L42	2	x	x	x	x	√√	x	x	x	x	x
L43	4	x	x	x	√√	√√	x	x	x	x	x
L44	4	x	x	x	x	√√	x	x	√√	x	x
L45	4	x	x	x	√√	√√	x	x	x	x	x