

**Effect of Vee-diagramming on Grade 10 township
learners' understanding of some electrical concepts**

by

Khalipha Ramahlape

**A mini-thesis submitted in partial fulfilment
of the requirements for the**

degree of



M. Ed

University of Western Cape

2004

Supervisor: Prof. M. B. Ogunniyi

DECLARATION

I declare that **“Effect of Vee-diagramming on grade 10 township learners’ understanding of some electrical concepts”** is my own work; that it has not been submitted before for any degree or examination in any other university, and that all sources I have used or quoted have been indicated and acknowledged by complete references.

KHALIPHA DESRY RAMAHLAPE

SIGNED:



DATE: JULY 2005

ACKNOWLEDGEMENTS

The completion of this study came about through the support and encouragement of many individuals. I am grateful to all those individuals, but above all I would like to thank the Lord Almighty who gave me strength to carry on through the trying times that befell me during the study. Without His help I would never have made it. It has been a long and winding road.

My heartfelt gratitude and sincere thanks are expressed to Professor M.B. Ogunniyi, my supervisor for his guidance, patience, encouragement and faith in me. Not only has he enriched my knowledge in Science Education, I have also grown spiritually through him.

I am grateful to the NRF without whose support I would not have met the financial obligations that one incurs through studying. I would also like to thank the circle of friends who stood by me through thick and thin, especially my friend and mentor Brian Gray as well as Nomathemba Mpofu.



Juggling career, family and studies is not an easy task. Special thanks go to my loving husband Daniel Ramahlape for taking care of the family when I was busy, as well as for the major role he played in the production of this document. To our sons, Lorato and Katleho, thank you for your support and understanding, you are the best that a mom can wish for. To the Siyothula and Ramahlape families, especially my mother-in-law Anna Ramahlape, a big thanks to you for being there for me in the times of need.

Last but not least, I would like to dedicate this work to my late parents, Rev Abiatha Luvuyo Siyothula and Deliwe Felicia Siyothula for making me the person that I have become, as well as my late father-in-law Ben Ramahlape.

ABSTRACT

This study was based on the Scientific and Technology Literacy Project (STLP) study done between 1996 and 2001. It sought to determine whether Vee-diagramming (a pedagogic tool designed by Gowin in 1977) could help enhance grade 10 township learners' understanding of some aspects of electricity. The study was premised on socio-cultural constructivism which has arisen from the works of Piaget, as stated by Kitchener (1986) and Vygotsky (1962) and their associates as well as meaningful learning as espoused by Ausubel (1968). It also sought to find out whether age and gender influenced the learners' understanding of these concepts.

The study adopted a quasi-experimental design modified after Solomon-3-control-group design, in which three comparable groups were used. One was the experimental group, while the other two were the control groups. Both qualitative and quantitative research methods were employed in gathering data. The instruments used included a Modified Conceptions of Electricity (MCOET), which was adopted from STLP, a questionnaire, participant observation as well as selective interviews.

The findings of the study suggest that the subjects held misconceptions about some electrical conceptions. Although the subjects exposed to Vee-diagramming performed better than those not so exposed, they still held on to those misconceptions even after instruction. The gender of the learners seemed not to have a significant effect on their performance though the boys performed relatively better than the girls; and the younger learners performed better than older ones. It seems that Vee-diagramming offers a unique opportunity for promoting meaningful learning in electricity. Although this is the case, one acknowledges the fact that due to the very limited period and number of subjects involved, it is reasonable to suggest that further in-depth research into its effectiveness be carried out on a much larger scale and over a longer duration.

TABLE OF CONTENTS

DECLARATION.....	II
ACKNOWLEDGEMENTS	III
ABSTRACT.....	IV
ABSTRACT.....	IV
LIST OF TABLES	IX
LIST OF FIGURES	X
OPERATIONAL DEFINITION OF TERMS.....	XI
ABBREVIATIONS USED IN STUDY.....	XI
CHAPTER 1	1
INTRODUCTION TO THE STUDY	1
1.1 Introduction.....	1
1.2 Background of the school under study.....	8
1.3 Rationale for study.....	9
1.4 Theoretical framework	10
1.5 Border crossing	15
1.6 Problem statement and purpose of study	18
CHAPTER 2.....	21
REVIEW OF RELEVANT LITERATURE	21
2.1 Introduction.....	21
2.2 Theoretical considerations	24
2.2.1 Learning	24
2.2.2 Meaningful learning.....	26
2.2.3 Conditions for meaningful learning.....	26
2.2.4 Process of meaningful learning.....	27
2.2.5 Benefits of meaningful learning.....	28
2.2.6 Constructivism	28
2.3 Practical or pedagogic considerations.....	31
2.3.1 Concept mapping and Vee diagramming.....	32
2.3.1.1 Concept mapping	32
2.3.1.2 A Vee map on electric circuit	37

2.3.1.3 Benefits of Vee-diagramming	38
2.4 Problems with electrical concepts.....	39
2.5 Electric models.....	41
2.6 Analogies	42
2.7 Conceptual change	43
2.8 Studies using concept maps and Vee diagramming in electricity.....	47
2.9 Conclusion	50
CHAPTER 3.....	51
METHODOLOGY	51
3.1 Introduction.....	51
3.2 Research methods	52
3.2.1 Quantitative research methods.....	52
3.2.2 Qualitative research.....	52
3.2.3 Case studies: The strengths and limitations	53
3.3 Research design.....	55
3.3.1 Description of research design.....	57
3.4 Class demographics.....	58
3.5 Instrumentation	60
3.5.1 Pre-test and post-test	60
3.5.2 Classification of questions	63
3.5.3 Questionnaires.....	64
3.5.4 Interviews.....	65
3.6 Classroom observation.....	66
3.7 Data analysis	67
3.8 Instructional methods	68
3.9 Ethical issues.....	71
3.10 Summary.....	72
CHAPTER 4.....	74
RESULTS AND DISCUSSION	74
4.1 Introduction.....	74
4.2 Demographic profile of learners	75
4.2.1 Comparison of the family background of learners in each group.....	75
4.2.2 Comparison of home support in each group	77

4.2.3 Comparison of attitude towards Science and Technology.....	77
4.2.4 Summary.....	78
4.3 Pre- test results on the MCOET	80
4.3.1 Learners’ performance on the MCOET according to sex.....	80
4.3.2 Learners’ performance on the MCOET according to age.....	81
4.3.3 Further exploration of pre-test results	83
4.3.4 Discussion.....	86
(i) Attenuation model.....	86
(ii) Sharing model.....	88
(iii) Clashing model	88
(iv) Misconceptions	89
4.4 Post-test results	90
4.4.1 Post test statistical summary.....	91
4.4.2 Post-test statistics according to gender in each class	92
4.4.3 Post-test performance according to age	93
4.4.4 Further exploration of post test results.....	94
4.4.5 Discussion.....	96
(i) Attitudinal change	96
(ii) Attenuation model.....	97
(iii) Language issues	100
(iv) Link between school and home	102
4.5 Comparison of pre and post-test	104
4.6 Opinions on Vee diagramming	108
4.7 Summary of findings.....	110
4.8 Conclusion	111
CHAPTER 5.....	113
CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS.....	113
5.1 Introduction.....	113
5.2 Findings.....	114
5.3 Limitations	118
5.3.1 Area or Location	118
5.3.2 Time of the year	118
5.3.3 School culture	119

5.3.4 Time allocation	119
5.5 Implications of the findings	120
5.5 Conclusion	121
5.6 Recommendations	122
BIBLIOGRAPHY.....	125
APPENDIX A	140
PERMISSION LETTER TO SCHOOLS	140
APPENDIX B	141
QUESTIONNAIRE	141
APPENDIX C	144
MCOET.....	144
APPENDIX D.....	149
LESSON OVERVIEW FOR INTRODUCTION OF THE CONCEPT MAP.....	149
APPENDIX E	150
CONCEPT MAP BY SOME OF THE LEARNERS	150
APPENDIX F.....	151
LESSON OVERVIEW ON VEE-DIAGRAMMING	151
APPENDIX G	152
LEARNERS' VEE-DIAGRAM.....	152
APPENDIX H.....	153
INTERVIEW ITEMS.....	153

List of Tables

Table 1 : The 1989 South African comparative education statistics.	3
Table 2 : Grade 8 learners' performance in electricity according to gender, language, age and career interest.	4
Table 3 : Grade 9 learners' performance in electricity according to gender, language, age and career interest.	5
Table 4: Class distribution of learners with valid test results	59
Table 5 : Summary of MCOET	62
Table 6 : Process skills implied by the items in MCOET.	63
Table 7 : A bibliographical profile of the learners in percentages.	76
Table 8 : Learners' pre-test performance on the MCOET on account of sex.	80
Table 9 : Learners' pre-test performance on the MCOET on account of age.	81
Table 10 : Process skills in percentages used by the learners to perform cognitive tasks on the MCOET at the pre-test stage.	84
Table 11 : Learners' performance on the MCOET at the post-test stage	91
Table 12 : Performance on the MCOET according to gender	92
Table 13 : Performance of the learners on the MCOET according to age.....	93
Table 14 : Process skills in percentages used by the learners to perform cognitive tasks on the MCOET at the post-test stage.	95
Table 15 : Performance on the MCOET at the pre- and post-test stages.....	107

List of Figures

Error! Bookmark not defined.

Figure 1: An example of concept map on electrical circuits.....	35
Figure 2 : ... An example of a Vee dagram on an electrical circuit (modified after Ebenezer & Connor, 1998:59)	37
Figure 3 : Research design	58
Figure 4 : Learners' attitude towards Science and Technology	77
Figure 5 : Learners' performance on the MCOET at the pre- and post-test stage.....	105
Figure 6 : Graph showing the change in performance on the MCOET by groups E and C ₁ at the pre- and post-test	106



OPERATIONAL DEFINITION OF TERMS

1. Learners - School going children
2. Township - Resident areas that were formerly designated for black during apartheid times in South Africa.
3. Grade 10 - Learners in their 10th year of schooling
4. Social constructivism - States that people acquire knowledge of higher process of mental life through social relationships (Vygotsky, 1962, 1978).
5. Concept mapping – is a schematic device for representing a set of concept meanings embedded in a framework of propositions (Novak and Gowin, 1984).
6. Vee-diagramming – is a heuristic device the helps people understand the structure of knowledge and the process of knowledge construction. It is both a teaching and a learning tool (Novak and Gowin, 1984).
7. Electrical concepts – These are concepts that are associated with electricity.
8. Outcomes Based Education - The education system introduced in South Africa post apartheid. This system is outcomes driven versus the old system which was content driven.

ABBREVIATIONS USED IN STUDY

RDP	-	Reconstruction and Development Project
COET	-	Conceptions of Electricity Test
MCOET	-	Modified Conceptions of Electricity Test
STLP	-	Scientific Technology and Literacy Project

- STAP - Science Through Applications Project
- SEP - Science Education project
- OBE - Outcomes Based Education
- DACST - Department of Arts, Culture, Science and Technology
- FRD - Foundation for Research and Development



CHAPTER 1

INTRODUCTION TO THE STUDY

1.1 Introduction

South Africa is a country with a long history of colonialism and the dehumanising apartheid system of government. In 1652 this territory now called South Africa was colonised by the Dutch, and later on by the British in 1806. During the apartheid period i.e., from 1948 to 1991 (Fataar, 1997; World book, 2002) when the National Party came into power, people were segregated on racial lines. Different races lived in different areas and were not allowed to mix due to the then called “Group Areas Act”. At that period, blacks could not own assets like land and "pass laws" were implemented. The blacks could not move freely in the areas designated for whites unless they carried an identity document called “pass”. Also, the blacks were prohibited from moving freely in the country as they had to carry the “pass” at all times. They were arrested if caught without one in their possession. This saw a lot of blacks being thrown into jail unnecessarily. There was “job reservation” – the better jobs, as well as jobs that required specialised skills were reserved for the whites. The blacks were made inferior and did inferior jobs, as they were not skilled like their white counterparts (Badat, 1991; Levy, 1991; Swainson, 1991). The most common type of employment that blacks could get was in the gold mines, as unskilled migrant labourers. This meant that men had to leave their families to work in the gold or diamond mines.

Apartheid in South Africa did not only imply people staying separately because of their race, but also in terms of education as well. Although racially segregated schooling system was introduced in 1902, it took firmer shape in 1948 when the National Party won the only white based election (Fataar, 1997; World book, 2002). A number of laws governing the apartheid education system were consolidated between the 1950s and 1960s. Several laws were promulgated including: the Bantu Education Act of 1953; the University Extension Act of 1959; the Coloured Persons Education Act of 1963; the

Indian Education Act of 1965 and the National Education Policy Act of 1967 (Fataar, 1997; Sono, 1999; Unterhalter, 1991; Wolpe & Unterhalter, 1991). Compulsory and free access to school for white children was introduced but not for blacks. Blacks were given Bantu education that was of inferior standard to that of whites. According to Fataar (2000):

Education was meant to inspire blacks with an unquestionable sense of social place as inferior subjects in the unfolding racial hierarchy that had begun to constitute public life in South Africa. (p. 5)

Blacks were only educated to serve the whites and never to be equal to them. The president of Cape African Teachers' Union (CATU) is cited by Sono (1999) as saying that the system of Bantu education would make the African child "a docile servant who will accept his backward slavery as a creation of God"(p.53). Even the per capita spending on black children was far less compared to white children (Unterhalter,1991). The situation of only skilling the whites and leaving the majority of the population unskilled had had serious implications for the economy because only a few skilled personnel had been produced. The consequence has been the paucity of skilled personnel who could have contributed to the economic growth of the country (Statistics South Africa, 1996).

The late 1970s and mid-1980s saw an increase in secondary school children in urban areas. This was due to urbanization caused by people leaving the rural areas to seek a "better life" in townships that were built by the apartheid regime at the time. New schools were built but could not accommodate the large numbers of black children. As a result, classrooms in black schools were overcrowded. This led to youth uprisings due to their dissatisfaction with the whole system of education. Amongst other reasons cited for the uprising was the fact that learners were against the use of Afrikaans, the language used by their oppressors as the medium of instruction, poor conditions at schools, unavailability of resources e.g. laboratories, poorly qualified teachers, etc. (Hofmeyer and Buckland 1992; Sono, 1999). The following table shows disparities in teacher qualification, per capita spending in education as well as the pass rate in standard ten for the different racial groups in 1989.

Table 1 : The 1989 South African comparative education statistics.

	White Education	Indian Education	Coloured Education	African Education (DET)
Pupil – Teacher Ratio	17:1	20:1	23:1	38:1
Under-qualified teachers (less than Std. 10 plus a 3-year teachers' certificate)	0%	2%	45%	52%
Per Capita expenditure	R3 082,00	R2 227,01	R1 359,78	R764,73
Std 10 pass rate	96.0%	93.6%	72.7%	40.7%

Source: Jane Hofmeyer and Peter Buckland (1992).

All the problems mentioned above i.e., overcrowded classrooms, lack of laboratories, poorly qualified teachers and others, definitely impacted on the performance of learners. Matriculation results in black schools were poor with mathematics and science being the worst subjects. Teachers taught learners how to answer examination questions rather than understanding science concepts and principles. Due to lack of resources, no experiments were ever done; children only saw science equipment in diagrams. This resulted in learners who were not interested in the subject and therefore, performed poorly. Even after the newly attained democracy in 1994, some of these historical problems still persisted although the present government has been trying to eradicate them. There is still a big shortage of qualified science teachers in the black schools. The legacy of the past still looms large over the education system. There are still unqualified or under-qualified teachers teaching matriculation science. According to Osborne et al (1998), “teachers who lack confidence, resort to a more closed and constrained pedagogy and do not understand the salience of any given topic” (p. 31). The under-qualified teachers do not usually do justice to the subject and hence, the results of the black learners in science still leave a lot to be desired.

For students to perform well in science at high school, they must have strong background in the subject. Primary school educators therefore, play a major role in this regard as they supposedly lay the foundation for high school science. The unfortunate thing perhaps, is that many educators at both primary and high school levels are not only deficient in the

discipline and pedagogical content knowledge required to perform their instructional tasks, they lack the necessary confidence and hold a congeries of misconceptions as well (Shallcross et al, 2002; Muwanga-Zake, 2000). According to Shallcross et al (2002) confidence is a central component of effective science teaching. This lack of confidence results in learners reaching high school with a shaky science background. Therefore, school science poses a serious challenge to the learners. The Scientific and Technology Literacy Project (STLP) based at the University of the Western Cape carried out a study whose main aim was to diagnose the problems encountered by South African primary and secondary students in science and to implement necessary instructional strategies to solve such problems (Ogunniyi: 1999). The results arising from a battery of assessment instruments developed to diagnose grade 7 – 9 learners’ cognitive, psycho-motor and affective readiness for the interim syllabus show that less than one-third of the learners scored above 40% in all topics covered in that syllabus (see Tables 2 and 3). Considering this poor performance (of less than 50% average), it seems that only a small percentage of the learners are cognitively ready to pursue science in further education.

Table 2 : Grade 8 learners' performance in electricity according to gender, language, age and career interest.



	Average score
Male	42 %
Female	38 %
English	49 %
Xhosa	28 %
Afrikaans	46 %
13 years	53 %
14 years	47 %
15 years	31 %
16 years	25 %
Over 16 years	28 %
Medicine	41 %
Technology	54 %
Business	44 %
Service	35 %

Source : Ogunniyi, M.B. (1999). Assessment of grade 7 – 9 pupils’ knowledge and interest in science and technology

Table 3 : Grade 9 learners' performance in electricity according to gender, language, age and career interest.

	Average score
Male	30%
Female	34%
English	46%
Xhosa	14%
Afrikaans	34%
14 years	42%
15 years	33%
16 years	25%
Over 16 years	17%
Medicine	34%
Technology	26%
Business	48%
Technical	31%
Service	21%

Source : Ogunniyi, M.B. (1999). Assessment of grade 79 pupils' knowledge and interest in science and technology



As can be seen from Tables 1 and 2, the average percentage scores are low. Even the learners who would like to choose careers that are in the line of Science and Technology have scored low marks hence the low averages.

Electricity is one of the topics in the physical science in which students tend to underperform (e.g. see TIMSS, 1996). An examination of the tables and figures above shows that learners are encountering serious problems in this topic. While the grade 8 boys perform better than their female counterparts, the reverse is the case among grade 9 learners. However the differences between the two gender groups are not statistically significant (Ogunniyi; 1999:52 & 80). In view of the importance of this topic in science, the learners' underperformance in it impacts negatively on their achievement in science in general. This in turn has serious implications for scientific and technological human power development which, as is well known, plays a significant role in the socio-economic development of a country (Ogunniyi, 1998).

After the first democratic election in South Africa, in 1994, the government introduced a new curriculum known as the “Outcomes Based Education” (OBE) which was seen as an alternative to the “content laden, often ideologically distorted, examination oriented” apartheid curriculum (Christie, 1999;282). According to Christie, the new curriculum emphasises “learning by doing, problem-solving, skills development and continuous assessment and allows greater space for educator involvement in curriculum construction” (Christie, 1999; 282). Although the new curriculum seems to have good intentions, its implementation has been problematic. Likewise, though the government provided educators with crash training programmes, these programmes were inadequate in preparing educators for an outcome based pedagogy and continuous assessment entailed in the new curriculum. Compounding this problem was the introduction of educator redeployment aimed at addressing the inequitable distribution of qualified educators in the schools. This exercise led to massive dislocation of experienced science educators who were forced to take severance packages or got transferred to under-staffed schools (Chisholm, 1997). In the midst of the uncertainties, many experienced science educators left the school system creating a vacuum difficult to fill. This has resulted in the downward spiralling of performance in science. This appalling performance is seen in the results of the Trends in International Mathematics and Science Study (TIMSS, 1996) conducted amongst grade 8 learners, involving 41 countries, in which South Africa came last in Mathematics and last but one in Science. Learners’ poor performance in science has been attributed to gaps in fundamental knowledge, reasoning skills and methods. Asmal, the former Minister of Education was cited in a report of the Discovery Centre (2000 – 2001) as stating that:

By comparison with other middle-income countries, our learners perform very badly in internationally standardized tests in Science and Mathematics. School leavers become job seekers or enter high education with serious gaps in fundamental knowledge, reasoning skills and methods of study. (p3)

The issue of under-achievement in science by South Africa students, particularly in the previously disadvantaged schools, and the problem of unqualified or incompetent science educators who employ ineffective instructional methods have attracted much public

concern. The Science Through Applications Project (STAP) at the University of the Western Cape was initiated in April 1995 as a curriculum research and development project aimed at addressing some of these concerns. The project has developed learning programmes and curriculum materials that support a Science and Technology for Society (STS) approach. It presents learners with science that is more contextually relevant and which involves them more actively and collaboratively in the learning process (Gray, 1999).

My involvement with the STAP and the STLP has created in me an awareness of the seriousness of the situation, especially the prevalence of under-achievement across the entire education system. Therefore, it is against the background of under-achievement in science that this study was undertaken. Research internationally has shown that electricity is one area in science that is problematic to both students and teachers in which alternative conceptions have conspicuously manifested (e.g. Arnold and Miller, 1988; Shipstone, 1988; Smit, 1993; Smith, 1994; Stanton, 1989; Wesi, 1997).



Poor teaching methods employed by teachers due to various reasons, especially inadequate training (Muwanga-Zake, 2000; Tyobeka, 2000) and weak knowledge of the discipline have contributed to learners' under-performance in science. This study therefore, seeks to investigate how 'Vee-diagramming' as a pedagogic tool could help enhance township students' understanding of some aspects of electricity. The study was conducted in a township school because the learners in the school have consistently under-performed in physical science, particularly electricity. The underlying assumption was that if learners in Hope High School could be made to improve their performance in physical science through an instructional strategy, then the chances for using the same strategy to upgrade the performance of similar township schools would be much higher. Hence, the study can be regarded as a case study in which an instructional strategy was used to ameliorate grade 10 learners' conceptual difficulties in electricity.

1.2 Background of the school under study

From an interview with some of the teachers at the school, the high school involved in the study was established in 1992 as a “finishing school”. Finishing schools in South Africa were established as a response to a call by the former President, Nelson Mandela after he was released from prison in 1990, for all the people who missed the opportunity of studying due to political and apartheid reasons to go back to school. The Finishing High School (fictitiously named, “Hope High School”) derived its name from a Xhosa word which when translated means “our future”. People who for one reason or the other missed schooling or terminated their education were provided the opportunity to re-build their future by going back to school. Most of the learners accepted at the establishment of the school were adults and the school offered only matriculation classes. However, since 2001, finishing schools have been phased out. The feeling has been that finishing schools have outlived their primary objective. Hope High School did not escape this, and since 2003 the school has been declared a normal high school thus losing its "finishing school" status. This has meant that all grades, i.e. grade 8 – 12 have had to be accepted at the school. The majority of the learners are still grade 12, followed by grade 10. Learners in the school come from all over the Cape Flats townships while others are from the Eastern Cape rural areas. Their parents who work in the Western Cape brought them into the province when the school opened doors for all grades.

The school encounters typical township problems of poverty, crime, drug abuse among learners and lack of the culture of learning. Education is not taken seriously. This is evident from the fact that some learners do not do home assignments.

On the positive side, there is at least one science laboratory and two biology laboratories at the school. The staff members are also well qualified with education degrees and diplomas and each teacher teaches the subject that he/she is qualified to teach.

1.3 Rationale for study

Science is taught because it is believed to have a lot to offer to people, better job opportunities and a better quality of life. This belief is also reiterated in the South African White Paper on Science and Technology, which states that science is considered to be among the requirements for creating wealth, and improving the quality of life (DACST, 1996; 8). When asked to give justification for teaching science, scholars have proffered two main justifications, i.e. science teaching for “intrinsic” and “extrinsic” values (Shayer and Adey: 1982). The intrinsic value argument stresses the importance of science as an educational activity, including such things as exploring the world, process skills development and making empirical judgment. The extrinsic value argument on the other hand stresses the role and use of science in society including such things as using scientific knowledge to improve our lives, improving the economy of a country and taking up scientific careers. The South African government’s White Paper on Science and Technology (1996) states:

To survive and prosper, that is, to achieve a high standard of living for its members, a society must...(amongst other things) ... ensure that its members develop and continually update knowledge, competencies, abilities and skills that are required to produce innovative products and services. (DACST, 1996: 10)

If students are under-performing in, or shying away from science, they are not likely to be scientifically literate, and by implication they may not have the needed knowledge or skills to contribute meaningfully to scientifically and technologically driven economic activities.

It is interesting to note that in South Africa out of a work force of approximately six million, only 4% are involved in Science and Technology activities and 95% of the 4% is white while 5% is black (FRD, 1996). Considering that about 75% of the total population is black, there seems to be a vast amount of untapped talent that could have been utilized in science and technology. To make use of this untapped talent implies that science will be taught in a way that will make learners interested in the subject, and in turn, will remain within the scientific field. From the studies done so far by various groups, (e.g.

Davies, 2000; Mphahlele, 2000; Muwanga-Zake, 2000; Sanders & Mogodi, 2000) it is obvious that something is definitely not going right in the teaching and learning of science in South Africa. If there could be a way of reversing this situation, it would be beneficial not only to the learners in terms of intrinsic values but also for the country at large in terms of the extrinsic values.

1.4 Theoretical framework

Debates about the content of education are of interest to various stakeholders: educators, politicians, academics, etc. However, before we can look at what is to be learned, it is even more important to look at how learning takes place. Different learning psychologists have given theories about how this happens. Behaviourists, who are in direct opposition to cognitivists see a learner as a blank page (i.e. having no previous knowledge) on which the teacher writes and the learner relies on memory for learning. This would be measured against the behaviour the learner exhibits afterwards (Nye, 1996). Cognitivists, especially the constructivists on the other hand, acknowledge the fact that learners come to school already having their patterns of thinking and ideas about many things in the world (e.g. see Ausubel, Novak and Hanesian, 1978, Piaget, 1970). As science teachers we are expected to expand on these ideas and even add new ones. On the whole, the student is central to the instructional process. Driver et al (1994:5) states that, "knowledge is not transmitted directly from one knower to another, but is actively built up by the learner."

This study is premised on socio-cultural constructivism, which has arisen from the works Vygotsky and their associates as well as meaningful learning by Ausubel. When talking about socio-cultural constructivism, one cannot overlook the work of Piaget, a personal constructivist, whose work was a precursor to the social or socio-cultural constructivism. His views have some impact in the development of socio-cultural constructivism.

Piaget uses "schema" to explain the ideas held by children. At school, children are introduced to the culture of science, that is, the way scientists observe and understand

natural phenomena. These children will probably have come across these phenomena in their everyday life but may have other explanations or understanding about them. This previous commonsense knowledge and beliefs have been designated by certain scholars as “traditional worldviews” (e.g. Aikenhead, 1996; Cobern, 1993; Jegede, 1995; Ogunniyi, 1988). According to Piaget when learners come across new information they try to fit it within their existing schemata. Sometimes the two worldviews, science and traditional worldviews may clash. This could happen in a science class when the learner is introduced to the scientific worldview, which in the main, does not coincide with what he/she has always held to be true. The success or otherwise of accommodating the new worldview into the existing worldview in his/her cognitive structure to a large extent will depend on the effectiveness of the instructional process.

Most learners first come across electricity at home; even those households which do not use electricity might have a radio or a torch. Those who have electrified homes have come across electricity while using electrical appliances. They might have some myths about electricity but may not necessarily hold valid conceptual understanding of it. Basically, children come across electrical concepts at school. As they proceed from one grade to another, they construct knowledge based on their previous knowledge or schemata. In Piaget’s view accommodating the new experience warrants that the learner creates room for the new experience while assimilation implies the incorporation of the new experience into the existing schemata. He uses the term “equilibration” to refer to a state where the student has gone through the process of assimilation and accommodation and has finally reached a state of cognitive balance or stability. Learning is produced by the act of seeking equilibrium and new knowledge derived from the learner’s internalization of his/her own action (Piaget, 1986). This results in a changed viewpoint due to alterations to existing knowledge and modification of existing mental structures to incorporate the new aspects assimilated (Urevbu, 1990). According to Driver et al (1994):

Learning comes about when the schemes change through the resolution of disequilibrium. Such resolution requires internal mental activity and results in a previous knowledge scheme being modified. Learning therefore involves conceptual change. (p. 6)

Vygotsky (1962, 1978) argues that learners acquire knowledge of higher process of mental life in the course of social relationships. Learners take part in collective activities in which new knowledge is mediated to them by other people who have better understanding of it. They do not construct their own mental complexes independently; they therefore need support of others. This support is especially needed in the case where there is a gap between the level where the learner is (in terms of cognitive development) and where the learner should be. Vygotsky refers to this gap as the zone of proximal development. In order to bridge the gap, “scaffolding” of subject matter is provided by the more experienced partner to support the student’s evolving understanding. This partner could be a teacher or adult who is seen as the expert in the field or a fellow student who is more knowledgeable.

The gap between a learner’s intuitive knowledge and school science is largely created by the distinctly different ways in which phenomena are construed by both worldviews. In deed, in many instances science is “counterintuitive”, “unnatural” and “uncommonsensical” (Good and Shymansky, 2001:61). Misconceptions that learners have are based on incorrectly formulated ideas, which they hold before encountering school science. Whenever they are confronted with school science a conflict is likely to arise. In this setting the learner either accepts the scientific view and discards his/her own or holds both simultaneously. Aikenhead and Jegede (1999) explain this in terms of collateral learning where two or more conflicting schemata are held simultaneously in the long-term memory. They mention four types of collateral learning i.e., parallel, secured, dependent and simultaneous collateral learning. Parallel collateral learning is defined as the type of collateral learning whereby the conflicting schemata do not interact at all – the learner accesses each schema as the need arises, depending on the context. Secured collateral learning is defined as that form whereby the two schemata interact with one another but the learner is able to resolve this conflict. Dependent collateral learning occurs when two schemata from different domains of knowledge challenge each other to the extent that one schema gets modified but without radically restructuring it. Simultaneous collateral learning occurs rarely and usually coincidentally whereby

learning a concept in one domain of knowledge can facilitate the learning of a similar concept in another domain (Aikenhead and Jegede, 1999).

According to Arnold and Millar (1988):

Even successful science students may have learned an “official” set of ideas for use in tests and examinations, overlaying alternative beliefs which are resorted to in “ everyday “ contexts or in novel or difficult situations (p.149).

An example of what Arnold and Millar are saying is in static electricity whereby some learners believe that it is man made, while science has its own explanation of how it comes about. These learners know how to answer questions at school and they know how to engage in debates at home about these issues using the traditional perspectives. In a study carried out under the auspices of the STAP Clark (1998) indicated that learners did well in class tests but when discussing lightning they still believed, amongst other things that lightning came about due to ancestors conveying a message about something that made them unhappy in the family. The inference drawn by Clark on this is that “in terms of its usefulness, the scientific explanation has made little or no impact to many students’ everyday beliefs thereby, confirming the power of students’ ‘lifeworld knowing’. To Clark (1998) it seems “as if students have had a little more than a fleeting and unmemorable excursion into the sub-culture of science” (p.114). Driver, Guesne and Tiberghien (1985) allude to this when they assert that:

It is often noticed that even after being taught, students have not modified their ideas in spite of attempts by a teacher to challenge them by offering counter evidence. (p. 3)

Waldrip and Taylor (1999) also seem to agree with this notion of holding to two worldviews at a time when they mention a professor of geology who discussed his work in terms of evolution but in church affirmed special creation. This is in line with Aikenhead and Jegede’s theory of parallel collateral learning. Although it is possible for some people to think diversely in different cultures, it is a problem for others especially if

the cultures are too different and in some instances such a dichotomy could even hinder learning.

Learners perhaps hold on to both traditional and scientific worldviews in order to be acceptable at school and their home environment (Aikenhead and Jegede, 1999). The need for social identity is human as no one wants to be ostracised from his/her own society or group. At the same time, the challenge is even greater for those learners who attend multi-racial schools where they fear being ridiculed by other learners who do not hold the same beliefs.

There is an overlap between personal and social constructivism, namely, the important role of the learner actively constructing his/her knowledge (in accordance to Piaget's view) and the teacher being the mediator in accordance to Vygotsky's point of view. Educators need to consider that learners actively acquire existing human knowledge as their own systems of knowledge by actively constructing their novel ways of knowing in the face of familiar problems. Therefore, learners must be given the opportunity to engage the problems themselves, make mistakes, interact with others, engage in minds-and-hands activities. We must always remember that knowledge cannot be transmitted from the teacher to the learner in a naked wholesale form but that it is de-constructed and re-structured by the learner engaged in the culture of learning at school (W.C.E.D., 2001). Our role as educators is to mediate scientific knowledge for learners, to help them make personal sense of the ways in which knowledge claims are generated and validated. Vee-diagramming can play a role in the process of de-constructing and reconstructing knowledge in that it gives the learner and educator to look into how their existing concepts are related and how they influence the new knowledge. After they have performed experiments they are guided to establish knowledge claims and value claims from the experiment. It thus purports to promote meaningful learning.

1.5 Border crossing

In the process of a student constructing his/her own knowledge, he/she has to move from the everyday world into the world of school science. He/she holds certain worldviews about basically everything. Sometimes these worldviews hinder or promote the learning of science. If the two worldviews are in agreement with each other, assimilation of the new knowledge becomes easy. Ogunniyi (2002) refers to Ogawa's "conflict model" which is about mental conflict that results due to the two views clashing (e.g. the beliefs that African children bring to school about lightning and its causes versus the scientific theory or the unipolar model of electricity that originates from home versus the dipolar model in science). Aikenhead (1999) speaks of four types of border crossing namely, smooth, managed, hazardous and impossible border crossing. Smooth border crossing occurs when the learner is able to cross without difficulty from the beliefs held at home into the scientific world since the two worldviews are similar. Managed border crossing occurs when the learner's worldview is somewhat different from the scientific worldview but not too different to the extent of hindering crossing thus making border crossing to be managed. This is seen through a learner who knows how to respond to his/her science teacher and how to respond to his peers or cultural group. Hazardous border crossing occurs when the learner's worldview are diffused resulting in the learner's crossing hazardingly between the two views. A learner who is able to pass a test or a course without really understanding the content shows this. Lastly, impossible border crossing occurs when the student's worldview and that of science are "highly discordant" i.e., so different that the two clash with one another and therefore, causing learners to resist crossing from one worldview to the other.

Electricity is a topic universally known for its difficulty (Cohen et al, 1983; Fredette & Lochhead, 1980; Heller & Finley, 1992; Millar, 1993; Ogunniyi & Taale, 2004; Webb 1992) in both teaching and learning due to many reasons. Arnold and Millar (1988) cite the following reasons:

- (1) Prior conceptions which may conflict with view promoted by formal science teaching that can result in confusion or rejection of the scientific perspective;
- (2) The abstract nature of the concept of electricity e.g. ampere, current, voltage, etc.
- (3) Concepts involved are not directly observable but are theoretical ideas used to explain a range of observations;
- (4) Simplified circuits commonly used in the introductory course of study are remote from the child's experience of everyday electrical applications and may fail to serve as adequate models for students thus preventing any effective linkage between school and everyday knowledge (p. 149).

The appliances that learners use at home are so complicated that they hardly get to see the circuits in them. Even if they happen to cut wires open, there is no single wire going to one side and another going to another thus completing the circuit. The wires are either twin wires or three wires, yet when they get to school they are required to light a bulb by using one or two wires. Even the learners from rural areas who might be familiar with a torch lacking wires might not perceive the concept of a circuit in such a small device. For the same reason, the conceptions needed to understand electricity are not readily understood because the appliances learners see are quite different from what make them to function the way they do. As Shipstone (1985) and Arnold and Millar (1988) have argued, the underlying concepts of electricity are difficult for the learners to understand.

Posner et al (1982) argue that for an idea to be acceptable it must be “intelligible (understandable), plausible (reasonable) and fruitful” (p. 214) and for conceptual change to occur in the learner, the learner must first understand the limitations of his/her current views and recognize the need to replace them. Hodson and Hodson (1998) allude to Posner et al by stating that:

A learner will be dissatisfied with an existing idea if the idea “fails to predict correctly and cannot control events beyond its previous restricted context – that is, it is no longer fruitful in the new situation which the learner has to confront or if

the new view meets the conditions of intelligibility and plausibility more satisfactorily than the existing idea". (p.34)

It seems that learners will stay with their traditional worldviews for as long as they still see value in them i.e., as such views seem appropriate to explain phenomena. It is only when they are perceived as not being useful that they will consider changing them. According to Hodson and Hodson, educators therefore, need to "lower the status of the existing idea and raise the status of the new idea" (Hodson and Hodson, 1998: 34) through giving students problems that will challenge the old idea which in return, will force students to use the new idea and thus hopefully decide to stay with the new one. Driver et al (1994) agree with this view and assert that:

Teaching approaches must focus on providing children with physical experiences that induce cognitive conflict and hence encourage learners to develop new knowledge schemes that are better adapted to experience. (p. 6)

As educators, we need to consider each learner as an individual who is at a specific level of cognitive development. We tend to generalize in mixed ability classes and assume that everyone is at the same level. In the process we make those who are behind feel inferior and incompetent, and inadvertently hinder their progress. According to Shayer (1981):

If we understand the difficulties of different learners, and take that understanding into consideration when doing lesson planning we show respect for the learners as people and increase the rate at which they are able to learn and the breadth of knowledge and skills that they can achieve. (p.40)

Urevbu (1990) goes further to suggest that educators must provide the learner with the opportunity to gain information and skills at a level appropriate to his/her state of mental development, through his/her own direct experience and through social interactions with other children.

1.6 Problem statement and purpose of study

As indicated earlier and from my experience as a matriculation science teacher, I have realized that my learners struggle with the topic electricity, and consequently, perform poorly in Physical Science of the Matriculation Examination Paper 1. Looking at the fact that students do electricity for four years at high school, one would expect them to have a better understanding of it at the end of their high school years, especially in the Matriculation Examination. Presently, in the matriculation syllabus, electricity weighs about 24% in Standard Grade (SG) and 29% in Higher Grade (HG) of the total mark distribution of the physics paper (National Examinations, 2002). If the section on electric fields is included, then the percentage is 29 % (SG) and 41% (HG) (National Examinations, 2002). This suggests that learners' poor performance on electricity is most probably one of the contributing factors to the high failure rate of black students in matriculation examination in physical science. Other related factors include such things as

- Ineffective teaching methods due to teachers not understanding how children learn.
- Textbooks, which are not accessible to students who are second language users.
- Historical issues e.g. poorly qualified teachers or under-qualified teachers teaching courses in which they lack competence.
- The chaotic state of many township schools.
- Socio-economic factors e.g. poverty, crime, lack of interest, lack of resources e.g. laboratories and other facilities.

All of the above and perhaps other factors do contribute in one way or the other to students' poor performance in the examinations. Even those who manage to pass and go to higher institutions are not completely free from the deficits they carry into such institutions. Due to the complexity of some of the factors mentioned above, a small study as this one cannot address all of them. It is for this reason that I opted to explore the effectiveness or otherwise of an instructional and learning tool known as "Vee-

diagramming” in enhancing grade 10 learners’ conceptions of electricity in this study. In pursuance of this problem, this study attempted to:

- Assess grade 10 students’ understanding of some electrical concepts.
- Determine the relationship between the learners’ performance on selected electrical concepts and their age or gender.
- Determine the effectiveness or otherwise of “Vee-diagramming” in enhancing the learners’ conceptions of selected electrical concepts.
- Determine whether or not the use of Vee-diagramming was more beneficial to learners’ learning of electricity than the traditional lecture method.

Two reasons, amongst others, why Vee-diagramming was selected as opposed to other teaching methods were that: (1) it supports meaningful learning; and (2) it also enables the teacher to tap into the learner’s existing knowledge thereby allowing an opportunity for educator to identify misconceptions and gaps (Novak & Gowin, 1984; Wandersee, 1990).



The vee-diagram (to be discussed in more detail in chapter 2) consists of a v-shape. At the centre of the v is the focus question with the “event” at the bottom. On the left is the “my understanding” side and the right is the “my doing” side. The focus question is at the core of the activity and the learners work on answering or solving the problem by performing an activity or an “event”. As they work on the activity they tap into their existing knowledge of related concepts and link them to the current situation, in the process form concept maps. This leads them to drawing conclusions, referred to as “knowledge claims” and establishing the value of the knowledge gained (“value claims”). This instructional tool was seen as suitable for addressing these learners’ problems with electricity in that it moves them away from the lecture method which may not have benefited them substantially in terms of enhancing understanding of concepts is concerned.

1.7 Research questions

In pursuance of the aims of the study answers were sought to the following questions:

- What conceptions of selected electrical concepts do grade 10 township learners hold?
- Are students' performances on the selected electrical concepts influenced by their age or gender?
- Will the students exposed to "Vee-diagramming" perform better on selected electrical concepts than those taught through the traditional lecture method?

1.8 Hypothesis

To answer the questions above, the following null hypotheses were posited for testing:

- Grade 10 learners at Hope High School do not hold valid conceptions of selected electrical concepts.
- The learners' performance on electricity will not be influenced by their age or gender.
- There is no significant difference between learners exposed to Vee-diagramming and those not so exposed.

1.9 Significance of study

It is hoped that the findings of the study will:

- Contribute to efforts aimed at identifying the difficulties that learners have on electricity
- Identify some of the alternative conceptions about electricity that learners hold thus providing the necessary platform for remedial instruction.
- Provide useful information about the effectiveness or otherwise of Vee-diagramming in ameliorating students' misconceptions about electricity

CHAPTER 2

REVIEW OF RELEVANT LITERATURE

2.1 Introduction

Learners come to science classes having experiences of the world around them and therefore, have views about a variety of topics in science from a young age. These experiences become an integral part of each learner and his/her society. Common sense knowledge and gut feeling or intuitions are part of these experiences which help the learner to perceive the world in a certain way and consequently, the way he/she learns science (Osborne & Wittrock, 1985). Learners' knowledge about diverse natural phenomena is accumulated over the years and is sensible and useful to them. But as the British biologist, Lewis Wolpert has argued, "science is counter-intuitive and even unnatural. Any experienced science teacher is well aware of the multitudes of pre-scientific conceptions that learners bring into the classrooms" (Good & Shymansky, 2001: 61). Because science often goes contrary to commonsensical and intuitive notions of the world (Cobern, 1994), learners' worldviews tend to clash with what they are exposed to in the science classroom. The tenacity with which they hold to these pre-scientific notions or what has been variously referred to as alternative conceptions, misconceptions or children's science has been reported in a plethora of studies in the last two decades or so (eg Bradley & Stanton, 1986; Driver & Erickson, 1993; Fler, 1999; Millar & King, 1993; Phelan, Davidson and Cao, 1991; Shipstone, 1985).

The existence of alternative conceptions held by learners tend to hinder them from acquiring valid scientific conceptions because of the mismatch between what they already know and the new knowledge presented to them in the classroom. Osborne and Freyberg's (1985:12) investigation showed that these ideas that learners have are "strongly held" and because they are "sensible and coherent from the children's point of view, they often remain uninfluenced or can be influenced in unanticipated ways by

science teaching.” Novak and Gowin (1984) also agree to the fact that these ideas are remarkably stable and may persist for years. This, therefore, makes the aim of science education of “enabling learners make better sense of their world by helping them restructure their ideas into useful and usable ways” (Freyberg and Osborne, 1985: 85) quite a difficult one for the educator. Nussbaum and Novick (cited by Freyberg and Osborne 1985:86) state that the "more we appreciate the complexities of the learning process the more amazing it becomes that we can teach anybody anything."

As educators our role is to mediate as the learner constructs his /her own knowledge. We must know what conceptions the learner brings with him/her in order to facilitate smooth crossing-over between his/her worldview and the scientific worldview. Also, we need to employ teaching and learning methods that will help elicit these conceptions so as to build on them. Osborne (1985:41) suggests that these methods should:

- a) Help children exchange, evolve or extend their existing ideas with respect to a particular topic.
- b) Present new ideas so that they appear intelligible, plausible and useful to the learner.
- c) Offer teaching which will order the topics of the curriculum better to take into account the learner's intuitive and/or developing ideas.



According to Ausubel’s theory of Meaningful Learning, relevant concepts held in a learner’s cognitive structure are the most important factors influencing the learning of new material (Ausubel, Novak & Hanesian, 1978). To Ausubel (1968):

Potentially meaningful material is always learned in relation to an existing background of relevant concepts, principles and information which provide a framework for its reception. It is only in this way that interactional cognitive products are formed and that new meanings emerge and are retained. (p. 76)

As indicated in Chapter 1, electricity is a topic universally known for its difficulty to both teaching and learning due to many reasons. Different scholars have done extensive research and published papers on electricity to determine why the concept has been

particularly difficult for learners (e.g. Adams, 1990; Arnold and Miller, 1988; Fler, 1994; Fredette and Loghead, 1980; Liegeois et al, 2002; Millar and Beh, 1993; Millar and King, 1993; Psillos, Koumaras & Tiberghien, 1988; Rozenkwajg, 1992; Shipstone, 1988; Shipstone et al, 1988; Solomon, 2001; Stanton, 1989; Tasker and Osborne, 1985; Wesi, 1997) to name but a few. Most of these studies were conducted in countries outside South Africa and the researchers mostly concentrated on identifying problems associated with the learning of electrical concepts. Very few studies investigated practical methods that can be employed to solve or alleviate the problem. According to Shipstone (1988):

There has been many studies worldwide of children's understanding of basic electrical concepts so that we now have quite a clear picture of many of their difficulties. By contrast, the work on remediation is in its infancy. (p. 92)

Even those studies that have investigated instructional methods look at the effect of a single method e.g. concept mapping alone on student conception of electricity. A review of a vast literature in the area, shows that only a few of the studies had employed Vee-mapping (which is a combination of concept mapping and other aspects) in enhancing understanding of electrical concepts by learners. A study conducted by Ogunniyi and Taale (2004) using a combination of instructional methods, examined the effect of a remedial instructional model on grade seven learners' understanding of electrical concepts. Their findings show that although there is a shift or improvement in the learners' understanding as a result of remedial instruction, a substantial number of alternative conceptions encountered at the pre-test stage still persisted even after the intervention. This implies that there is still a gap for a method that can yield better results in as far as enhancing understanding and ameliorating misconceptions in this topic. But before considering this practical issue, it is apposite to first examine certain theoretical considerations surrounding the use of Vee diagramming as an instructional tool for enhancing learners' understanding of science concepts.

2.2 Theoretical considerations

One of the most important steps in any study is to find an appropriate theoretical framework or context in which to situate that study (Adam, 2003). The theoretical framework controls the methods or procedures adopted in a study as well as the type of data set that is collected. This study is underpinned by Ausubel's (1968) Theory of Meaningful Learning and uses two instructional strategies: concept and Vee mapping compatible with, or inspired by that theory (e.g. see Novak & Gowin, 1984). But before going into details about these two instructional strategies, it is critical to consider what in Ausubel's (1968) view constitutes "learning" and "meaningful learning"

2.2.1 Learning

People learn in order to gain knowledge. Unlike gold or oil, knowledge is constructed and not discovered. Learners, therefore, construct their own knowledge as they learn. "Learning is personal and idiosyncratic" while "knowing is public and shared" (Novak & Gowin, 1984: 5). Different scholars e.g. Ausubel, Novak, Gowin to name a few, have always been concerned about how learners learn. The argument for this interest has been that if we know how learners learn, then we can teach them accordingly, and this will hopefully yield a better understanding for the learners. Ausubel (1963), talks about the different kinds of learning, namely, reception learning, discovery learning, meaningful reception learning, meaningful learning as well as rote learning. These different forms of learning are summarized as follows:

- Reception learning – can be rote or meaningful. The entire content of what is to be learned is presented to the learners in its final form. The learners do not need to discover anything. Rather, they are required to internalize the material presented so that it is available and reproducible in future. In this regard, learners are just passive and their minds are like a "blank page" on which the educator writes. Unfortunately, this has been the most common way of learning in schools.

- Discovery learning – The essential feature of discovery learning is that the content of what is to be learned is not given but must be independently discovered by learners before they can internalise it. The learners are actively involved in the learning process. This kind of learning takes a very long time and is hardly used in schools.
- Meaningful reception learning – New knowledge is presented in final form. However, the learners must first judge the relevance of the new knowledge and decide under which proposition to catalogue it. After that, they must reconcile it with the existing knowledge they hold and then the new propositions are customarily translated into personal frames of reference consonant with their experiential backgrounds, vocabulary and the structure of ideas. Ausubel (1963) warns against this kind of learning stating that:

The main danger in meaningful reception learning is not so much that the learner will frankly adopt a rote approach, but that he will delude himself into believing that he has really grasped precise intended meanings when he has only grasped a vague and confused set of generalizations and no real meaning whatsoever. (Ausubel, 1963: 21)

- Meaningful learning – Although meaningful reception learning seem close to meaningful learning, they are not the same. The key feature of meaningful learning as a process is that it presupposes that the learner employs a meaningful learning set and that the material he/she learns is potentially meaningful to him/her. This kind of learning will be covered in more detail in the paragraphs that follow.
- Rote learning – the learner incorporates new materials to be learned as discrete, self-contained entities that are isolated from the his/her established conceptual systems into his/her cognitive structure. Due to the fact that this knowledge is arbitrarily put into memory, anchorage to established conceptual systems is not achieved concomitantly and as a result the retention span is relatively brief.

Another reason for this brief retention span is that the knowledge is retained in conformity with the laws of association, and is primarily influenced by the interfering effects of concurrently acting similar rote materials.

2.2.2 Meaningful learning

Most of my attention in this and subsequent sections will be paid to the notion of meaningful learning as it promises to be more beneficial than the other kinds of learning. According to Ausubel (1968), “The most important single factor influencing learning is what the learner already knows; ascertain this and teach him accordingly”(Epigraph). Freyberg and Osborne (1985) quote Driver (1980) as referring to how the following scholars interpret this statement:

- Gagne and White (1978) – emphasise the need to find the sub-skills that a learner has, and then develop the learner sequence from these sub-skills.
- Shayer and Adey (1981) – reiterate the same point by urging the educator to find the logical structures of thought the child is capable of and match the logical demands of the curriculum to them.
- Wittrock (1974) – educators should find the meanings and concepts that the learner has generated already from his or her background, attitudes, abilities and experiences and determine ways so that the learner will generate new meanings and concepts that will be useful to him or her.

2.2.3 Conditions for meaningful learning

According to Ausubel (1968), in order for meaningful learning to occur, the following conditions must be satisfied:

- The existence of a cognitive structure that is hierarchically organized, with highly inclusive concepts at the top and less inclusive sub-concepts subsumed under. He further argues that:

If this cognitive structure is “stable, clear, suitably organized, valid and unambiguous meanings emerge and tend to retain their individuality or dissociability. If on the other hand, cognitive structure is unstable, ambiguous, disorganized or chaotically organized, it tends to inhibit learning or retention. (Ausubel, 1963:26)

- The new knowledge must be relevant to existing knowledge in the cognitive structure. Schollum and Osborne (1985:55) take this notion further when they state, “if relevance can enhance pupil’s understanding of science, then lack of relevance can certainly hinder it”.
- The new knowledge must be potentially meaningful to the student.

2.2.4 Process of meaningful learning

Freyberg and Osborne (1985) refer to Wittrock’s (1974,1977) view of learning with understanding that focuses on the proposition that the learners themselves must actively construct, or generate meaning from sensory input, e.g. sights, sounds, smells, etc. I concur with this statement as I view sensory input as the point where learning of new knowledge begins. After a given sensory input, a learner can judge the relevance or otherwise of a potentially meaningful new knowledge in terms of the existing knowledge in his/her cognitive structure (e.g. see Ausubel,1968). According to Ausubel (1968), if the new knowledge is relevant, to extant knowledge it becomes subsumed by the latter. However, where subsumers are absent e.g. in the case where a learner has had no encounter with a given phenomenon, thus lacking the necessary experience, the teacher can use an advance organiser to facilitate the learning process. To Ausubel (1968) the function of an advance organiser is to “bridge the gap between what the learner already knows and what he/she needs to know before he/she can successfully learn the task at hand” (p. 148). To thrive, the new knowledge “must adapt to the organizational principles governing the learning and retention of the system in which it is incorporated” (p. 108).

2.2.5 Benefits of meaningful learning

The benefits that have been associated with meaningful learning include:

- Knowledge has more meaning: This occurs because the new knowledge is linked to existing knowledge in the cognitive structure. If the two do not clash then the learner is able to accept new knowledge and make better sense of it. If the two do clash, the learner tries to modify the existing knowledge such that it is in line with the new knowledge.
- Knowledge is retained for a long time: This happens because new knowledge is not stored in a haphazard way. It is stored hierarchically within the cognitive structure and therefore lasts for longer periods. This is in opposition to short-term storage (memorisation) whereby knowledge is arbitrarily stored and there is no sense attached to the process.
- Knowledge is easily accessible for recall purposes as it was retained in an orderly, efficient and stable way.
- Learning is easy because it has meaning and the learner sees the purpose in what he/she is doing. (Ausubel,1963; Novak & Gowin, 1984; Ausubel, 1978; Heinze-Fry & Novak, 1989; Novak, Gowin & Johansen, 1983)



2.2.6 Constructivism

As indicated earlier, one main aspect of constructivism as a conceptual framework is that learning is a process in which the learner actively constructs new ideas or concepts based upon his/her current or past knowledge (Bruner, 1966). However, as Jenkins (2001) has pointed out, the notion of “active” or “passive” learning is rather equivocal in that all learning requires some form of active intellectual engagement with what is to be learned.

He argues further that:

If, as constructivism requires, learning presupposes the active engagement of the mind of the learner, then the notion of 'passive learning' lacks meaning. As any teacher knows, it is possible to engage the minds of learners by a wide variety of teaching strategies, some of which might be described as formal and didactic, rather than informal and exploratory. In deed, selecting a strategy that is more, rather than less, likely to interest students and promote their learning is central to a teacher's professional competence. (p. 157)

However, relevant as Jenkins' (2001) contention above is to the debates surrounding constructivism as an instructional theory, limitation of space would not permit further elaboration. Despite the validity of Jenkins' contention, it is still helpful to explore some of the insights that constructivism has provided about how science can be taught or learned in a meaningful and effective way.

Although different cognitive psychologists have contributed to the theory of constructivism, the focus in this study is on Ausubel's and Piaget's contributions to the theory.

Ausubel's contribution to constructivism perhaps is his advancement of a theory that contrasted meaningful from rote learning. Ausubel's idea of meaningful learning suggests that in order to learn meaningfully, learners must relate new knowledge to what they already know. His theory reaffirms the important role played by current or past knowledge in learning new material as well as the active role the learner will be engaged in as he/she tries to link new knowledge to existing knowledge. He proposed the notion of an advanced organiser as a way of helping students link new material to ideas that they already have (Ausubel, 1968:148). These organisers are expository as well as comparative in nature. Expository organisers are used to provide anchorage for the new learning material if it is unfamiliar to what the learner already knows by providing relevant proximate subsumers. Comparative organisers are used to provide anchorage if new learning material is familiar and similar to what the learner knows. They help the

learner to discriminate between the new and existing idea so that he/she does not confuse the two since they are very similar.

Piaget's contribution to constructivism is also the reaffirmation of the learner's active involvement in the learning process. According to Piaget, whatever structure knowledge has is due to the subject's creative activity of constructing it. Piaget, cited by Kitchener (1986) states that "knowledge is not a copy of reality", "knowing an object does not mean copying it – it means acting upon it" (p.103). He further explains that construction does not have the sense of arbitrary creation out of nothing as an act of fancy or imagination, but in order to construct, one builds by combining parts or elements in a certain way.

Piaget, like Ausubel stresses the important role played by previous knowledge in the learning process. He also contributed the theory of assimilation, accommodation and equilibration. According to Piaget, previous knowledge exists in the form of cognitive structures or schemes. When a learner encounters new knowledge, he/she first judges it in relation to existing cognitive structure. He refers to this process as assimilation. Assimilation therefore is the incorporation of the cognitive environment into cognitive structures of the organism (Kitchener, 1986). Accommodation is a process in which the cognitive structures are modified to match more closely the new knowledge. This modification and adaptation leads to a state of balance or equilibrium between the learner and the new knowledge, which Piaget refers to as equilibration.

2.3 Practical or pedagogic considerations

The use or application of various instructional tools such as concept mapping and Vee diagramming has been one of the ways in which theory has been put into practice. The theory of meaningful learning proposed by Ausubel (1968) like other cognitive theories focuses on the cognitive processes involved in learning rather than how knowledge should be taught or learned. Although Ausubel's (1968) theory of meaningful learning emphasizes the importance of knowing what the learner already knows in order for meaningful learning to take place, he did not give educators tools, so to speak, for ascertaining what the learner already knows. Novak, therefore, provided a concept map as such a tool. Novak and Gowin (1984) describe a concept map as an educational tool that will tap into a learner's cognitive structure and externalises it for both the learner and the educator to see what the learner already knows. Once this information is available to the educator, he/she will be able to plan the lessons accordingly. He/she will establish whether or not there are any misconceptions in the learner's cognitive structure. If they do exist, the educator will have to deal with them first, before introducing the learners to the new knowledge, otherwise the misconceptions can hinder the acquisition of the new information.

A concept map can be used independently or in conjunction with a Vee-diagram. Details of this are provided in the sections that follow. Vee-diagramming invented by Gowin in 1977, is a heuristic device that has been found to be useful in helping people understand the structure of knowledge and processes of knowledge construction. A Vee-diagram is both a teaching and a learning tool. According to Novak and Gowin (1984) concept mapping and Vee diagramming help educators and learners to construct new ideas and meanings about scientific concepts and generalizations.

2.3.1 Concept mapping and Vee diagramming

Concept mapping and Vee-diagramming as instructional tools are underpinned by Ausubel's (1968) theory of meaningful learning. According to Ausubel:

A substantive and non-arbitrary incorporation of a learning task into relevant portions of cognitive structure, so that a meaningful relationship is established, implies that the learning material becomes an organic part of a particular, hierarchical organized conceptual system. It becomes imbedded within the latter system in a relational sense that is independently both of the verbatim integrity of the material and of specific, arbitrary connections within the material. This type of ratability and incorporability into the learner's cognitive structure has two principal consequences for learning and retention. First, the newly acquired knowledge is anchored to a stable conceptual system. Second, the newly learned material becomes subject to the organizational principles governing the learning and the retention system within which it is imbedded. (Ausubel 1968:42)



Based on Ausubel's theory of Meaningful Learning, Novak and Gowin invented two knowledge construction tools called concept mapping and Vee mapping as visual lenses for promoting learners' understanding of scientific concepts (Ebenezer & Connor, 1998). These tools have been applied worldwide not only in science but virtually in all school subjects.

2.3.1.1 Concept mapping

Just as a map can provide a visual road representation of some pathways one may take to connect places, so does a concept map. Wandersee (1990) refers to it as a "map of cognition". It provides us a visual road that one takes to connect meanings of concepts in propositions. They are 'tools for negotiating meaning'. Wandersee (1990) argues further that 'to map' has always meant 'to know' because one cannot draw an accurate map of what he/she does not know. One can tell how much a student knows from the kind of concept map that he/she draws.

Although concept mapping was originally developed for Biology education by Novak (Novak and Gowin, 1984), it has been a useful tool in science education and other learning areas as well. Novak and Gowin (1984) define a concept map as a schematic device for representing a set of concept meanings embedded in a framework of propositions. Nicole (2001) describes a concept map as an invaluable tool for representing what knowledge students have acquired over a period of time. Concept maps are intended to represent meaningful relationships between concepts. When concept mapping is done, the broader, more general and more inclusive concepts are placed at the top and the less general concepts follow. Links are then made between related concepts. Concept maps can be used as both a teaching and a learning tool. When concept maps are done before new knowledge is learned, the educator can establish what conception students have and whether or not they make the correct links between concepts. In this way, misconceptions can be picked up and addressed.



When concept maps are drawn after a learning task has been completed, the various concept maps drawn by the learners provide schematic summaries of what has been learned as well as clarifying to both the learner and educator the key ideas that must be focused on in a specific learning task or require additional attention. This makes revision much easier to the learner. Learners are first encouraged to draw their own concept maps rather than memorize those drawn by the educator. The danger of memorizing the one drawn by the educator is that it reduces what has the potential of being a meaningful learning experience to become a rote learning experience. Novak and Gowin (1984) have warned educators that it would be disastrous if they expected learners to memorize concept maps and be able to reproduce them in content, structure and detail precisely as they were shown in class. To them, it is only when learners do these maps conscientiously that the organization of the student's cognitive structure is revealed.

Concept mapping has benefits to both the learner and the educator. The learner gets to know the key concepts to be learned, actively understands relationships among concepts and linkages between new knowledge and what the learner already knows. The benefits

to the educator are that he/she knows what conceptions learners bring to class and this informs him/her on how to structure the lessons. As Novak (1990:946) puts it, “concept mapping has become an important tool to help students to learn meaningfully and to help teachers become more effective teachers.” If a learner has misconceptions, the educator cannot introduce the new knowledge without first correcting these and helping the learner restructure the existing knowledge such that new knowledge will not clash with it. If concept maps are done before and after learning new knowledge, the educator can establish whether or not there has been a change in conceptual understanding by comparing the concept maps prior to, and after the learning experience. Changes in maps reflect changes in understanding. Prior knowledge influences the type of map one draws (Wandersee 1990). When constructed by educators/experts, concept maps enable learners to identify and explore the structure and nature of knowledge in a domain. Another benefit of concept mapping is in curriculum planning. When planning the curriculum, planners should choose examples that are in the learners' experience. This will make new knowledge to have more relevance to the learners as they will likely see the need for learning the new knowledge, as well as its meaning or relevance in their daily lives.



2.3.1.2 Vee diagramming

The challenge faced by educators is knowing how to organize better instructional materials and how to help learners learn this material (Novak, 1990). Educational value of any learning situation according to Novak and Gowin (1984), is:

Determined by what the learners do with lessons, not by the exact fit between a lesson and its replication on a test. Educational value is a transformation of the quality of experience that empowers students to give meaning to themselves and to their world, and the value of education can only be judged by its power to bring about educational consequences. (Novak and Gowin, 1984:111)

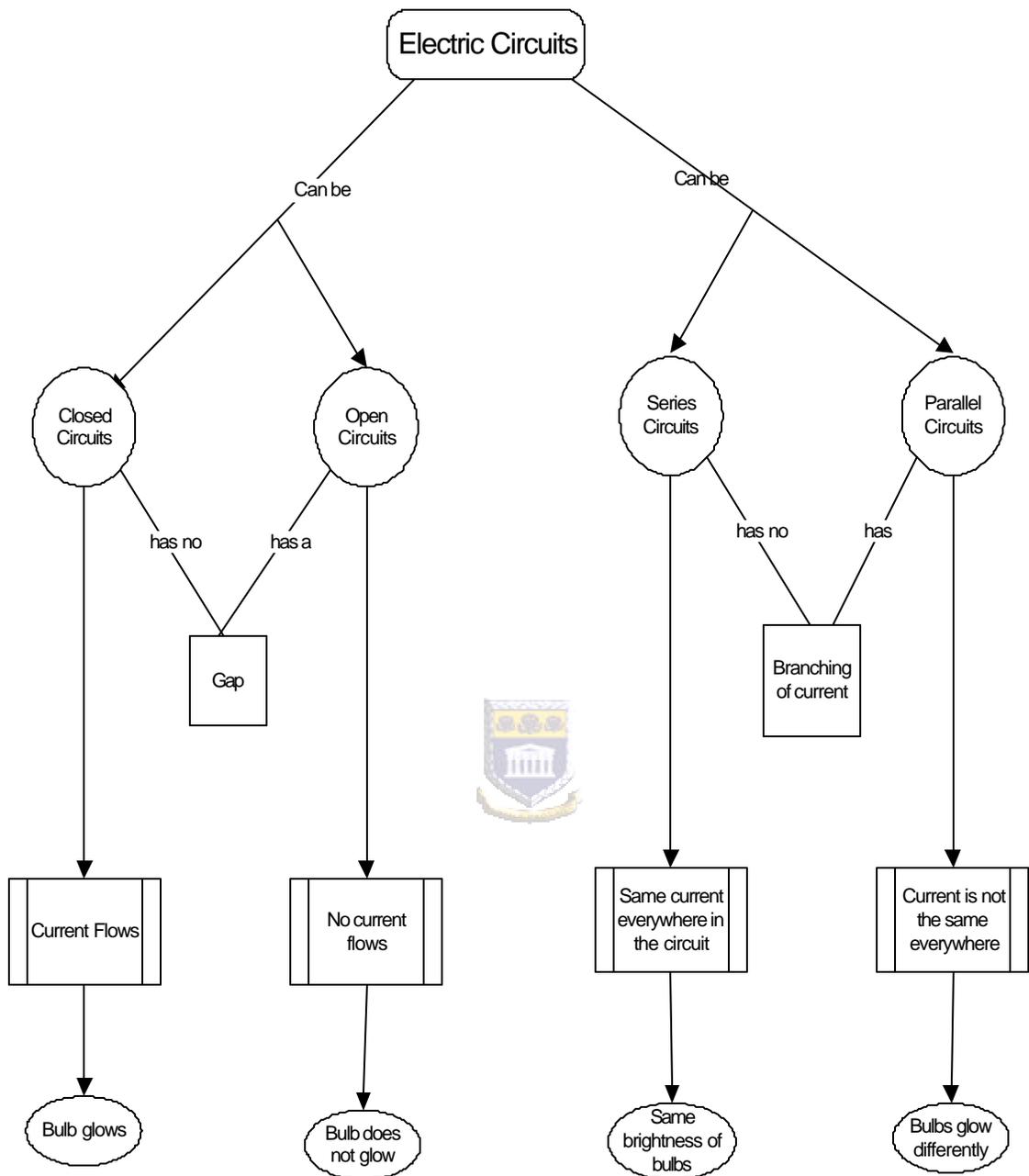


Figure 1 : An example of concept map on electrical circuits

Novodorsky (1997) seems to be in agreement with the statement above when she says that, “learning is less a function of what the teacher tells the students and more a function of what the students do in the classroom” (Novodorsky, 1997:242). As educators, we must employ instructional methods that will lead to meaningful learning and be of educational value to learners. Different instructional methods have been used and some of them have fallen short in helping learners learn meaningfully. An example of such a method is the chalk-and-talk or lecture method, which encourages rote learning rather than high-order thinking skills such as the application of concepts, critical thinking and decision-making skills needed to solve problems. In rote-learning, existing knowledge has hardly been considered, and therefore, learners have never made real links between existing and new knowledge and consequently, the learning cannot be regarded as meaningful.

The Chinese saying "I hear and I forget, I see and I remember, I do and I understand" (Confucius) has often been misunderstood by educators. Educators have so much faith in laboratory work ('hands on approach') that they think that because the learners have done and seen something, they have therefore gone through meaningful learning and they will understand what is required to perform a given task. How often have learners done practical work and yet not understood what they were doing or why they did what they did? Learners often find laboratory work frustrating as there is hardly any interplay between what they are thinking and what they are doing. Most often, it would be a case of hands-on but minds off affair. They would not be thinking about what they are doing or why they are doing it. Vee diagramming instructional method seems to eliminate this tendency among learners.

2.3.1.2 A Vee map on electric circuit

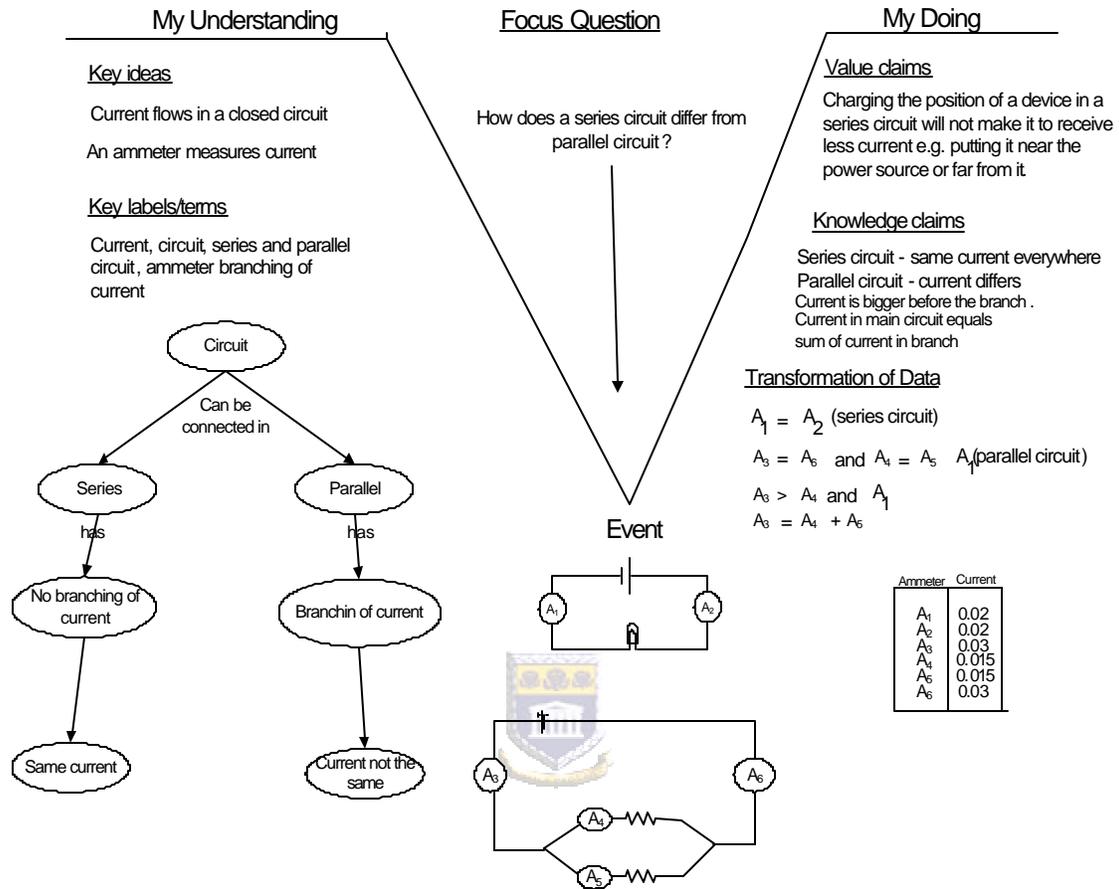


Figure 2: ... An example of a Vee diagram on an electrical circuit (modified after Ebenezer & Connor, 1998:59)

The Vee diagram is v-shaped, not for any particular reason but it points to the events or objects that are at the root of all knowledge production and it is crucial that learners become acutely aware of the events or objects that they are experiencing. As Wittrock (1974) argues, learners must generate meaning from sensory input, the event provides that input. Specific events in the environment are used to make observations and records.

As learners make these observations, concepts already known help/influence what they observe and record.

On the left side of the Vee is the 'my understanding' side which involves the development of a concept map. At the bottom of the Vee is the 'event' (the actual experiment/ event to be investigated) while on the right side is the 'my doing' side. The 'my understanding' side consists of the theories and concepts learners need to know in order to handle the event or new knowledge to be learned. Fig. 2 illustrates various activities connected to the concept of electrical circuits.

The 'my doing' side involves learners recording observations and manipulating data so that they are able to draw valid / logical conclusions based on their findings. They are then in a position to make knowledge and value claims based on what they have learnt from the event. In other words, knowledge claims deal with generalizations learners arrive at after conducting an investigation, whereas value claims relate to the application of the knowledge in novel situations (Ebenezer & Connor, 1998; Novak & Gowin, 1984; Novak, Gowin & Johansen, 1983)



2.3.1.3 Benefits of Vee-diagramming

A review of the literature reveals that Vee-diagramming has been found to be beneficial to the teaching-learning process in the following ways:

- It supports meaningful learning.
- Through concept maps that are within the Vee-diagram, these concepts are mapped thereby organizing meaning in a more coherent and comprehensive way.
- Existing knowledge structure is tapped into, misconceptions are picked up and gaps in knowledge are identified.
- According to Novak and Gowin (1984:110), "thinking based on understanding leads to actions that are better controlled (more efficient, more effective). Being able to act with such confidence makes us feel better about ourselves and the world." It is believed that through Vee mapping learners will be more confident of themselves as

they go through the learning process and they will feel good about themselves because what they are doing is more meaningful to them, and as such these learners are able to organize their thinking in a coherent way.

- Once learners are able to draw their own Vee maps, they are in a better position to reorganize new information using what they already know. This process is creative and idiosyncratic and requires that the understanding be expressed through a variety of ways of thinking and doing.
- A study conducted by Novak and Gowin showed that Vee-diagramming helped learners do better in tests requiring problem solving skills and their performance increases with time as they get more experienced in using the Vee map.
- It is instrumental for revision purposes (Novak & Gowin, 1984; Wandersee, 1990).

2.4 Problems with electrical concepts

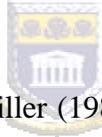
A review of the extant literature reveals that learners encounter all sorts of difficulties in their study of electrical concepts. The specific areas that have been pointed out in this regard include:



- Prior conceptions which may conflict with view promoted by formal teaching that can result in confusion or rejection of the scientific perspective
- Language of electricity – the technical terms used in electricity such as ampere, current, voltage.
- Concepts involved are not directly observable but are theoretical ideas used to explain a range of observations
- Circuit diagrams
- Simplified circuits commonly used in the introductory course of study are remote from the learner's experience of everyday electrical applications and may fail to

serve as adequate models for learners thus preventing them from effectively linking what is learnt at school with everyday experience.(e.g. see Arnold and Millar, 1988; Cohen et al, 1983; Fredette & Lochhead, 1980; Heller & Finley, 1992; Millar, 1993; Ogunniyi & Taale, 2004; Webb 1992) in both teaching and learning due to many reasons.

The appliances that learners use at home are so complicated that they hardly get to see the circuits in them. Even if they happened to cut the wire open, there is no single wire going to one side and another going to the other side thus completing the circuit. The wires are either twin wires or three wires, yet when they get to school they are required to light a bulb by using one or two wires. Even the learners from rural areas who might be familiar with a torch lacking wires, might not perceive the concept of a circuit in such a small device. For the same reason the conceptions needed to understand electricity are not readily understood because the appliances students see are quite different from what makes them to function the way they do.



As Shipstone (1985) and Arnold and Miller (1988) have argued, the underlying concepts of electricity are abstract and difficult to understand. According to Smit (1993) this difficulty is not only experienced by secondary school learners, but also final year prospective science educators in universities as well as practising science educators. Smit goes further to assert that the misconceptions about models in electricity held by science educators are passed on to learners. In their studies Cohen et al (1983), Heller and Finley (1992), Webb (1992), as well as Wesi (1997) encountered conceptual difficulties in electricity among practising educators. If educators who have gone through high school as well as tertiary training in physical science still find electrical concepts difficult and still have misconceptions, what more should be expected of high school learners they teach? In the South African context, perhaps one can blame it on the system of education that these educators went through, but Cohen et al (1983) found that the same problem existed in Israel as well. Other studies have confirmed the universality of the same problem and the fact that a considerable number of educators do not fully understand physics conceptions or hold alternative conceptions. Heller & Finley's (1992) study done

in Minnesota (USA); Nyagura's (1995) study done in Zimbabwe; Ogunniyi and Yandila's (1994) study done in Botswana and Nigeria; Pardhan and Bano's (2001) study done in Pakistan; Pardhan also cites Kruger and Summar's (1988,a, b, c) study done in UK; Webb's (1992) study done in South Africa and Australia; Muwanga-Zake's (2000) study done in South Africa; etc. are a few examples of studies showing science educators' poor conceptions of electrical concepts.

2.5 Electric models

Due to the complexity of scientific concepts, including electrical concepts, models are created in order to try and explain or describe these complex concepts. Although models are representations of the real thing, they are not, and there is no one-to-one correspondence between a model and the real thing. A review of the literature indicates that learners generally have the following models about electricity:

- Unipolar model – learners with this model believe that only one terminal of the battery is active in making the bulb glow. This creates the misconception that current only flows in one direction, i.e. from the terminal to the bulb and is consumed there and does not flow back to the other terminal.
- Clashing current model – learners believe that there is a flow of something from both terminals of the battery. The bulb glows due to the two things clashing and then current comes out.
- Attenuation or consumer model – the current flows around the circuit in one direction. It leaves the battery by one terminal and some current is “used up” in the bulb so that less or no current may return to the battery. Where the current passes through a number of identical components in series, each successive one will receive less current.

- Sharing model – learners believe that current is shared between components in a circuit. Where a series circuit is made up of a number of identical components, the current will be shared equally between them. Identical lamps in series are predicted to be all the same brightness, for example, but the current is not regarded as conserved. They believe that there is more current at the positive terminal and less current goes back to the cell or battery (Arnold & Miller, 1987; Borges, Herizante & Gilbert, 1999; Osborne, 1983; Shipstone, 1984, 1985).

All of the models mentioned above are flawed and lead to serious misconceptions about electric current.

2.6 Analogies

Analogies are also used in trying to simplify complex concepts, including electrical concepts. There are good and bad analogies that have been used to enhance students' understanding of electrical concepts. Even the good ones will have limitations too and at times they may also lead to alternative conceptions. The analogies commonly used in high school for electric current are the “water circuit” and the “movement of some imagined particle” (Black and Solomon, 1987). The most common one is the “water circuit analogy”. The problem with this analogy is that the pipe is hollow while the conductor is not. This difference, although irrelevant may cause students to concentrate on features that are not significant rather than on the relevant ones. Shipstone (1985) argues further that:

The problems with analogies are that learners tend to divorce the essential features that we are aiming to convey from the often irrelevant and sometimes troublesome ancillary attributes of any single concrete model.(Shipstone, 1985:44)

Although the study carried out by Black and Solomon (1987) reveals that learners learn better by analogy, educators must teach these analogies carefully so as to avoid confusing learners, since as stated before analogies do not have a one-to-one correspondence with

the real thing. Sometimes learners will unintentionally misinterpret a model as lending support to their ideas (Freyberg and Osborne, 1985). So, educators need to be careful not to use a model that will reinforce or support a learner's present idea that is faulty.

2.7 Conceptual change

After learners have gone through a learning process, whether meaningful or not, they are normally assessed or evaluated to see what impact the learning process has had on their cognitive structure. Amongst other things that the educator wants to ascertain is whether or not the learners have fully comprehended what they were learning, and whether or not their conceptions have changed from those previously held. It is often a disappointing reality to educators that most of the time, they do not get the desired results.

Novak (1990) paints the whole scenario quite succinctly by asserting that:

The challenge has been not only to help students elaborate the conceptual understanding they already possess, but especially to modify those knowledge structures that contain misconceptions or alternative conceptions or frameworks.

(Novak, 1990: 946)

Learners' conceptions do not undergo major transformations, even after science teaching. Different scholars agree to this (e.g. Arnold and Miller, 1988; Clark, 1998; Clough, Driver and Wood-Robinson, 1987; Cobern, 1994; Driver, Guesne and Tiberghin, 1985; Waldrup and Taylor, 1999).

Clough et al (1987) attribute the resistance of learners' conceptions to change to the fact that the ideas that these learners have are 'viable' to them. They are viable in that they enable learners to make sense of the world in a way that is acceptable to them. Besides the viability of these ideas, I also believe that cultural or traditional beliefs also play a role in making these ideas resistant to change. The reason for this belief is that even after spending some months teaching static electricity some African (i.e. Black South African) learners would still believe that witchdoctors cause lightning and they would still follow certain rituals when a thunderstorm comes e.g. there are small sticks called "abafana" that

are placed above the door post (within the thatch of a in rural hut). It is believed that these sticks will protect the house from being stuck by lightning. The idea is that one would rather be safe than sorry. They would still believe that it is those rituals that save them from lightning. These are beliefs that have been passed on from generation to generation. These students have faith in their parents and the elders in their communities, and do not want to be seen as being in opposition to them. Cobern (1994) quotes a story narrated by Gunstone whereby a learner did not believe what the educator told him about electricity and only believed in a theory given by his father who was an electrician. Osborne, Bell and Gilbert (cited by Osborne, 1985:48) indicate that learners' conceptions do not change because the scientists' viewpoint appears to children to be less intelligible, plausible and fruitful than their own view".

The conceptual change model as espoused by Posner, Strike, Hewson and Gertzog (1982) suggests that conceptions have status depending on the degree of commitment an individual has to that conception. According to this model, an individual will have a greater degree of commitment if the conception is intelligible (has meaning), plausible (is believed to be true) and is fruitful (is useful). According to Hewson and Hewson (as cited by Beeth, 1988), instruction consistent with the principles of conceptual change is associated with the following actions of a teacher:

- a) Diagnose the learners' thought on the topic at hand.
- b) Learners must clarify their own thoughts.
- c) Ensure that there is a direct contrast between the learners' views and the desired view. This will lead to learners being dissatisfied with the existing ideas learners hold, thereby justifying the need for them to change such ideas which otherwise would have lost their status.
- d) Provide immediate opportunities for the desired view to be used in explaining a phenomenon.

My teaching experience accords with the notion that when a theory that a learner has, fails to explain certain phenomena, the learner will be dissatisfied with that theory and look for another one. When educators want to introduce new knowledge, scientific

knowledge to be more specific, they need to first explore the content of the learner's cognitive structure e.g. by using a concept map in conjunction with a Vee map as an instructional tool. Afterwards, if there are still misconceptions that might hinder the meaningful learning of the new knowledge, they need to be addressed. Once this new knowledge is in line with the existing cognitive structure, it is expected that the learner will easily assimilate the new knowledge, and finally it is expected that conceptual change would have taken place. Also, if there is evidence of clashing views between what learners know and the new knowledge, the teacher must challenge the existing ideas so that the learners see such ideas as not being fully fruitful. The status of the existing knowledge will then be lowered. The educator should also make sure that the new knowledge is intelligible, plausible and fruitful or else, it will not replace the existing knowledge. According to Beeth (1998:58):

Change in students' conceptions rests squarely under their own control but is intimately linked to the role of the teacher in facilitating and supporting discourse that can lead to change.

Although learners are responsible for changing their perceptions, our actions as educators will either promote or hinder the change.



Cobern (1994) on the other hand disagrees with the conceptual change model. He feels that it is too narrow in that it does not consider the socio-cultural environment of the learner. He is against what he calls the "isolation" caused on the learner by this model as it emphasises that the learner "breaks away with long held concepts steeped in meaning for alien concepts newly encountered" (p.5). These long held concepts are representative of the way he/she understands his/her world yet the alien scientific concepts that we expect him/her to accept are counterintuitive. He goes on to say that the conceptual model gives science a superior status to other conceptions held by the learner. Tobin as cited by Cobern (1994) supports the same view pointing out that, "a classroom is a complex socio-cultural environment". We must therefore, consider this socio-cultural environment of the learners when we teach and we must be sensitive to their beliefs because we do not want to belittle any cultural group. In a multicultural classroom, we do not want to be seen as promoting one subculture over another as the group that aligns

itself with that subculture will become elevated and see themselves as superior to the other group.

The importance of Cobern's (1994) contention about isolating or drawing away the learner from his/her understanding of his/her world cannot be over exaggerated in any teaching-learning situation. An instructional method aimed at conceptual change should not be a haphazard way of making learners break away from previously held ideas, but it rather should facilitate negotiated meanings between the educator and learner. In other words, the educator must assist the learner through the process by making him/her realise that there are gaps in his/her existing knowledge and that the old knowledge is not adequate enough to cope with demands of the task at hand.

The problem with the conceptual change model is that it is rather simplistic. How easy is it for a learner to become dissatisfied with what he/she tenaciously hold? Gunstone and White (2000) suggest that instead of teachers aiming at the replacement of one belief by another, they should rather aim at promoting co-existence:

The issue now appears to be not one of abandonment and replacement, but one of addition, so that the earlier belief and the scientific belief co-exist. The learner's task is to learn the scientific belief, and to become clear about when it is appropriate to apply one belief or the other. (Gunstone & White, 2000, p. 289)

A plethora of studies have shown that although learners might give the right answer at the right time, they still hold tenaciously to a host of alternative ideas (e.g. Cobern, 1994; Driver, Guesner & Tiberghien, 1985; Freyberg & Osborne, 1985). Learners tend to hold more than one view about the world around them. For instance, they respond to questions in the scientific way at school, the traditional way at home and the spiritual way in church. Freyberg and Osborne speak of a view for living and the other view as being for examination and that no attempt is made to perceive or reduce contradictions inherent in holding the two opposing views. Cobern (1994) refers to this, as cognitive apartheid whereby students create a compartment for scientific knowledge from which it can be retrieved on special occasions but in everyday life has no effect. The compartment wall

holds as long as there is pressure e.g. pending examinations, afterwards the walls go and the concepts revert to forms more consistent with the students' worldviews or deteriorates for lack of significance. The point he is making is that it would be a mistake to assume that the accumulation of science concepts by conceptual change leads to a change of worldview. One may well reject a concept that he/she fully understands.

2.8 Studies using concept maps and Vee diagramming in electricity

As mentioned earlier, a lot of studies have been conducted in the area of electricity. Although this is the case, the studies that I have perused happened to fall under the following categories:

- a) Those that investigated learners' understanding of electricity including the mental models they have as well as misconceptions (e.g. Andre and Ding, 1991; Borges et al, 1999; Cohen et al, 1983; Fler, 1994; Fredette and Lochhead, 1980; Liegeois and Mullet, 2002; Millar and Beh, 1993; Rozencwajg, 1992; Shipstone et al, 1988; Ogunniyi, 1999; etc.).
- b) Those that investigated ways of improving learners' understanding of scientific concepts as well as electricity (e.g. Anderson et al, 2000; Arnold and Millar, 1987, 1988; Lee and Law, 2001; Ogunniyi and Taale, 2004; Shipstone and Cheng, 2001; etc.).

Various studies on learners' understanding of electricity have suggested different kinds of instructional methods that were believed could yield better results. Braund (1999) conducted a study that looked at the effectiveness of drama in improving understanding of electric concepts. Although they found positive results in their study, they admitted that the method was one form of teaching that a lot of educators would shy away from. Shipstone and Cheng suggested box diagrams. These also proved successful but some learners did not like the diagrams in that they seemed not very useful for problems that were not sophisticated (Shipstone and Cheng, 2001).

Other studies took a constructivist approach e.g. the study by Anderson et al (2000) looked at how learners constructed knowledge about electricity by drawing on their experiences during a school visit to a science museum. Although this and other studies which used a constructivist approach, yielded positive results in learners' performance, they did not succeed in removing completely the alternative conceptions of electricity or other concepts for that matter, held by the learners at the pre test (e.g. Ogunniyi and Taale, 2004).

The use of concept mapping as an instructional tool has been investigated in a plethora of studies in physical, biological and earth science. For instance, Dinie (2002) investigated the effectiveness of concept mapping in improving science (Biology) writing for English second language grade 12 learners at a school in Langa. In his study, he found that there was considerable improvement in the learners' writing as well as in their understanding after concept mapping intervention. Roth and Roychoudhury (1992) also used concept mapping in their study of in which they were investigating the use of concept mapping as a “conscriptio device for social thinking amongst high school science learners.” They found that concept mapping gave learners an opportunity to engage in “sustained discourse” over long periods and through this, they learned the language patterns of science, and with it constructed scientific knowledge. Although this was the case, they also reported on communication drawbacks brought about by concept mapping whereby language is reduced to uttering short sentences or single words. This, somehow, seemed to be in conflict with Dinie's findings where in fact there was an improvement in the learners' writing.

Novak (1990) describes the genesis and development of concept mapping as a useful tool for science educators. He reports on studies conducted by other researchers which showed that learners using concept mapping compared with a group using conventional lecture/expository instruction, received significantly higher mean scores on an achievement tests. He cites a study conducted by Jegede, Alaiyemola & Okebukola as a good example of such studies. He further highlights the use of concept mapping in

various aspects of teaching and learning, e.g. for exploring changes in meaning framework; in instructional design; etc.

Unlike the studies mentioned above which employed only one instructional method, Ogunniyi and Taale's (2004) study investigated the relative effects of a remedial instruction on grade seven learners' conception of electricity amongst other concepts. The remedial instruction included concept mapping as well as two other instructional models. The findings were that learners who went through the remedial instruction benefited more than those who went through the conventional instruction. But despite the improvement in the former, alternative conceptions that existed before were still present among the learners even after the intervention.

Novak et al (1983) conducted a study that investigated if grade seven and eight learners could learn to use concept mapping and Vee mapping strategies with existing programmes. Their findings showed that the learners could use these learning tools. They also found that concept mapping and Vee mapping were helpful in changing learners' knowledge about science, and in problem solving skills.

From the foregoing, it seems obvious that despite the merits and demerits of concept mapping and Vee mapping in enhancing understanding of electrical concepts there are also instances where the findings were neither definitive nor conclusive. Besides, most of the studies using both instructional tools were carried out in the developed world. A survey of journals in the sub-region and conference proceedings reveals a paucity of studies in the area and hence it is hoped that the present study would contribute towards efforts directed at filling up this conspicuous research lacuna.

2.9 Conclusion

According to Clough et al (1987):

If we are to influence children's conceptions in the long term we may need to take account of the ideas which they bring with them to the teaching/learning situation. Encouraging students to make ideas explicit in writing or in discussion enables the teacher to understand the students' conceptions and may in itself help students to begin to resolve some of the inconsistencies in their thinking. (p. 266)

A review of the literature shows that Vee mapping method of teaching and learning lends itself to the exposition of the learners' conceptual structure. Likewise, the concept maps, which they draw, do help them to discover the links between concepts and to discuss pertinent issues, be it in the scientific language or mother tongue about these concepts. By intellectually engaging the concepts, the learners are able to bring to the fore their understandings, misconceptions or concerns. This context provides the educator to address areas warranting attention in the learner's conceptual development. It was therefore hoped that using this methodology for teaching electrical concepts might provide more insight into learners' understanding of such a concept. However, whether or not learners' conceptual change will last must await future studies in the area. It would of course, be preposterous on my part to assume that this study would, once and for all, solve all the problems surrounding learners' understanding of electrical concepts. Nevertheless, it is hoped that the findings would not only provide baseline data but also contribute towards attempts directed at ameliorating the negative effects of alternative conceptions on learners' understanding of electricity and perhaps other science concepts as well.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The objective of this chapter is to discuss the methods and procedures used in carrying out the study. As mentioned earlier, although the problem of learners' poor understanding of electrical concepts is universal, it is perhaps worse in South African townships. This study focuses on the relative effectiveness of Vee-diagramming (including concept mapping) in enhancing grade 10 township learners' understanding of electrical concepts. Hope High School in a township in Cape Town was chosen as the study site for the following reasons:

(i) It is a typical township school faced with the usual challenges of poverty and inadequate human and material resources that most township schools face. According to Patton (1990), "when the typical site sampling strategy is used, the site is specifically selected because it is not in any major way atypical, extreme, deviant, or intensely unusual" (p.62).

(ii) The school had not covered the topic in grade 10 at the time of the research.

Due to the fact that the study was conducted during teaching time, the normal school timetable had to be followed and classes had to be intact. Random sampling could not be done and for ethical reasons all the grade 10 science learners were involved in the study. Hope High School has three grade 10 classes doing science namely, 10A1, 10A2 and 10A3.

Before the study was conducted at Hope High School, a pilot study was done at a comparable High School in another Township in Cape Town. The purpose of the pilot study was to familiarize myself with using a Vee diagram as an instructional tool before the main study as well as to develop the instruments to collect the data.

3.2 Research methods

This study applies both qualitative and quantitative research methods. The reason for this was to strike a balance between the two since each has something to contribute to the study. Burges (1985) states that a researcher who utilizes a range of research methods can bring distinct advantages to a project. The use of both research methods has afforded me the opportunity to collect a more holistic data set that would not have been the case if I had used only one method. It has also provided me a greater insight into the issues at stake.

3.2.1 Quantitative research methods

Social science enquiry, like scientific enquiry, has its own logic. When conclusions are drawn, this must be done in a logical manner and the researcher must give explanation for these conclusions reached in a study. Quantitative research requires evidence that is observable and testable (Balnaves and Caputi, 2001). It is this evidence that enables the researcher to draw logical conclusions about a variety of quantifiable variables. Similarly, the evidence or data can be organized, described and interpreted using statistics. In this regard, both descriptive and inferential statistics were used in the study. While descriptive statistics has enabled me to describe the characteristics of the sample, inferential statistics has allowed me to make inferences about the sample and to some extent the population from which the sample was drawn (Salkind, 2000:180).

3.2.2 Qualitative research

In a qualitative research, the researcher works in the natural setting, he/she attempts to observe people and events as they are and happen. Lynda Measor (cited by Burges, 1985) states that this method “stands in opposition to methodologies which create artificial conditions for experiments and observations claiming that artificial results will be gained” (p.67). Smith (1975) alludes to the same point by asking a rhetorical question: "Aren't experiments rather superficial and artificial creations of real-life scenarios?" He

argues further that these manipulations are frequently distorted and that larger social groups, organisations and processes are often inadaptable to the confines of controlled laboratories.

The end product of qualitative research is characterized by rich descriptions (Merriam 1978). These descriptions may lead to a thorough understanding of the subjects and their behaviours in their natural settings. This study was a case study since only one township school was used and the researcher became a participant observer. The advantage of being a participant observer is that learners get used to the researcher with time and accept him/her as part of the team and even tend to forget that he/she is doing research. This helps to minimize artificial behaviours that they might display when an outsider comes to observe them. As Patton (1990) puts it, "People may behave quite differently when they know they are being observed compared with how they would behave if they were not aware of being observed" (p.209). Foster (1993) states that being a participant observer helps build a rapport and relationship of trust and openness, which will help to reduce reactivity. The other side to this is that there can be tension between being a teacher and an observer. The researcher may lose the sense of detachment and adopt an over-sympathetic view of the subjects and this may lead to the researcher presenting a one-sided and therefore, an inaccurate account (Foster, 1993). Of course, by being located in a particular site, there is no need to generalise beyond the locale of the study. For the same reason, the findings of this study specifically were to :

- (i) Provide insight into the nature of conceptual difficulties on electric circuits that learners in a typical township school experience and
- (ii) Seek for an effective instructional method that is more compatible with such a school setting than the traditional chalk-and-talk approach.

3.2.3 Case studies: The strengths and limitations

According to Bacon (2001:225), "Case study methods involve systematically gathering of enough information about a particular person, social setting, event, or any group to permit the researcher to effectively understand how it operates or functions." Case studies are

useful in that they offer insights and illuminate meanings that expand readers' experiences (Merriam, 1978). A case study is a particularly appealing design for applied fields of study such as education. Its appeal in education comes from the fact that educational processes, problems, and programmes can be examined to bring about understanding that in turn can affect and perhaps even improve practice. Merriam (1978:41) states further that case studies have proven particularly useful for studying educational innovations, for evaluating programmes and for informing policy.

Since this study is about evaluating the usefulness of an instructional tool in a township school setting, I felt that this method could be of great value. Another strength of case studies, besides the fact that they can inspire insights, is that they can even be a breeding ground for hypotheses that may be pursued in subsequent studies. The scientific benefit of case studies is that they offer information that can be seen as useful beyond the individual case provided the procedure did not involve too many subjective decisions made by the investigator (Bacon, 2001).

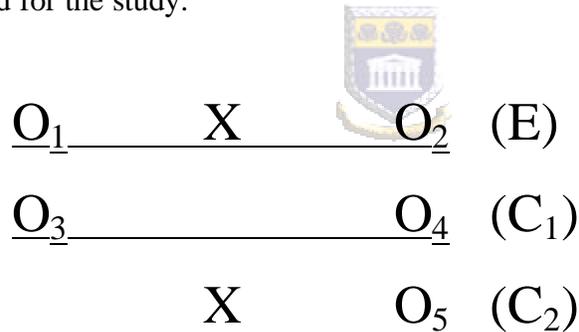


On the other hand, case studies can be too lengthy. Readers may also think that case studies are accounts of the whole as they masquerade as a whole when in fact they are only a part of the whole. Guba and Lincoln in Merriam (1978) warn that the researcher can over-simplify things or exaggerate a situation leading to erroneous conclusion about the actual state of affairs. Although this may be the case, I was sensitive to Smith's (1975) statement that the "social scientist, as scientist is supposed to be objective. Hence, he ought to describe not as he wishes things were, but rather as they are" (p.3). Hence, I tried as much as possible to be objective and to avoid an over-simplification or exaggeration of situations in which I found myself during the study.

3.3 Research design

The research design employed for the quantitative aspect of the study is a quasi-experimental design based on a modified Solomon-3-Control Group Design. Unlike the actual randomized Solomon-3 group design, which follows a true experimental design, the three groups used in the study were intact classes. The subjects, were therefore, not randomly selected.

The objective of an experimental design “is to establish a causal relationship between an independent and a dependent variable” (Ogunniyi, 1992:81). The independent variable in this study is the instructional tool namely Vee diagramming (including concept mapping) and the dependent variable is the student’s understanding of electrical concepts. By manipulating the independent variable, one is able to observe its effect on the dependent variable (Balnaves & Caputi, 2001:61). The following represents the quasi-experimental design adopted for the study:



O1 and O2 stand for the pre- and post-tests for the experimental group (E), while O3 and O4 stand for the pre- and post-test for the true control group (C1). O5 is the post-test for the second control group (C2) correcting for the pre-test effects. X stands for the treatment, i.e. the instructional method. One group, 10A₃ served as the true experimental group (E). A second group 10A₁, served as the true control group (C₁) and a third 10A₂ was the second control group (C₂). The lines indicate that intact rather than randomized groups were used (Ogunniyi, 1992:91). The E group and C₂ received treatment (X) in form of Vee diagramming as an instructional tool whilst C₁ did not. Although the same

concepts covered in E group were also covered in C₁ group, C₁ was taught through the usual/traditional lecture method. C₁ was therefore, used as the control for the effect of the treatment. The horizontal observations O₁ and O₂; O₃ and O₄ represent two subsequent assessments or observations. Vertical observations O₁ and O₃ represent the same pre-test administered simultaneously to both groups E and C₁ while O₂, O₄ and O₅ are post-tests, which were also administered simultaneously to all three groups. C₂ without a pre-test as indicated above was used to control for the effect of pre-test.

Both the experimental and control groups are comparable. This was evident from the mean of pre-test scores of both groups which was the same as well as socio-economic background which was very similar as evident from the questionnaire administered (see chapter 4 for more details). C₂ is assumed to be comparable to E and C₁ because Hope High School does not practise streaming.

Doing research whereby the control and experimental groups are in the same school poses a threat to the validity of the results, as there could be contamination amongst the different groups – whereby information could be shared between the groups and that might influence the outcome at the end of the study. In this study as well, although all these groups were in the same school, I realized that contamination was not likely to take place since the learners hardly shared any information between themselves. In a school day, learners could share information during break time or after school, but I noticed that with Hope learners, that this does not occur as they would all leave their books and look for something to eat during break time. The culture of learning was virtually absent among these academically weak and poorly motivated learners. Even after school there were no study groups whereby they could share information. Once the bell rang, it was a big rush for the gate. Amongst the learners used in the study, no two learners were from the same family. Despite this, one cannot gainsay that interactions of some sort had not taken place even if they were based on extraneous matters other than science.

3.3.1 Description of research design

Figure 3 below, shows an overview of the study. The study was comprised of three phases, i.e. preparation phase, pilot phase as well as the main study. The questionnaire and the MCOET were developed during the preparatory phase. The pilot study was undertaken with the purpose of the researcher to get familiarity with Vee-diagramming as an instructional tool prior to implementing it in the main study. Data in the main study was collected through quantitative and qualitative methods. Once data had been collected, it was analysed and conclusions drawn. Data for the quantitative aspect of the study has been collected through the implementation of the MCOET test as well as questionnaires administered to the learners. Further discussion on these instruments is available in sections to follow. Data for the qualitative aspects was collected through participant observation as well as interviews conducted at the end of the study. The collected data was then analysed and findings communicated with implications thereof suggested. Fig. 3 below presents the overall design of the study.



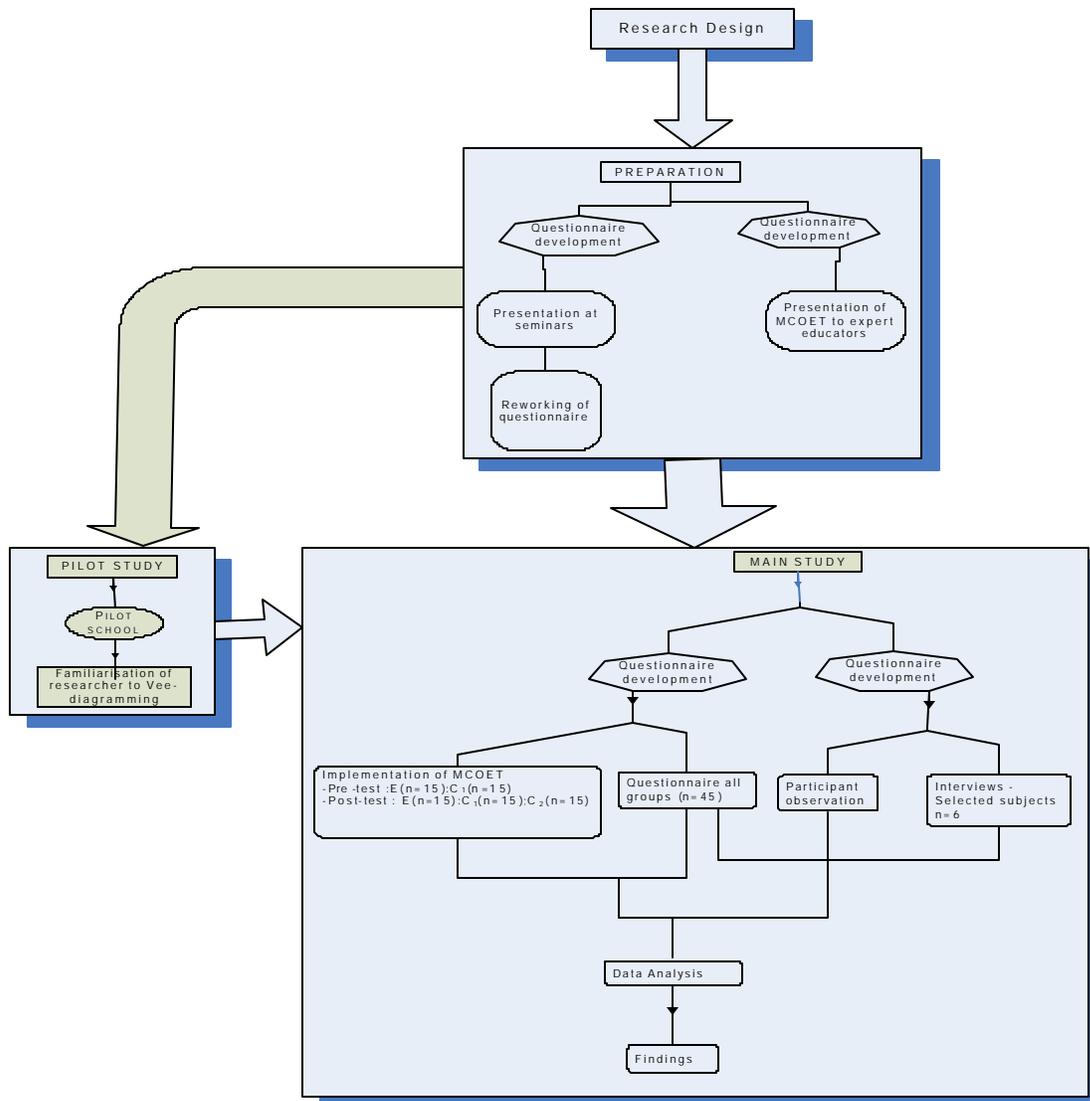


Figure 3: Research design

3.4 Class demographics

On the average, a grade 10 class at Hope has 50 learners. In some cases a science group was mixed with a non-science group with the aim of making a total of 50 learners in the class. This therefore, meant that when the science group goes for science their number would be slightly less than 50. The E and C1 groups were examples of such classes, and hence E group had 40 science learners. The ages of the learners ranged from 14 to 20. C2 consisted of 42 science learners. The age of the learners ranged from 15 to 24. C1 or what

can be considered the pure science group consisted of 50 learners. Unlike E and C1, the learners were not mixed. The age of learners ranged from 15 to 22. In all the three groups, the majority of the learners were between 16 and 19 years of age.

Although all the grade 10 learners took part in the study, the analysis focused on the pre- and post-test responses of only 15 learners per class. The reason for limiting the number to fifteen is that some learners wrote either the pre- or post-test only, not both. This therefore, rendered their tests unusable for comparison purposes and hence were discarded. In other words, only those that wrote the pre- and post-test were deemed useful. This loss of about 2/3 of the original sample posed a threat to reliability of statistical inferences drawn from these data, but these issues are some of the realities of the research environment, which researchers must face. The 15 learners were selected on the basis of stratified sampling to reflect the male and female ratio (Table 4).

Table 4: Class distribution of learners with valid test results

<u>Class</u>	<u>Boys</u>	<u>Girls</u>	<u>Total</u>	<u>Age range</u>
E group	9	6	15	14 – 20
C1 group	6	9	15	15 -22
C2 group	9	6	15	15 – 24

As can be noticed from the table, learners in township schools tend to be much older than the normal age for a specific grade. This is sometimes due to economic reasons whereby parents are not able to afford school fees, uniform, etc and the learner is forced to stay at home that year.

The majority of the learners in all the three classes came mainly from Langa as well as the neighbouring townships including the informal settlements. The furthest distance that learners have to travel to school is from Khayelitsha which is about 30 km to school. Most of the learners walk or travel by train to school. Very few use the bus. The learners in all the classes come from economically disadvantaged communities. This conclusion is

based on their responses to the questionnaire (See Appendix B). All the learners are Xhosa speakers.

3.5 Instrumentation

3.5.1 Pre-test and post-test

As stated in chapter 1, this study was based on the Scientific and Technology Literacy Project (STLP) study done nationally between 1996 and 2001 on learners' understanding of electrical concepts. I decided to use a modified grade 9 STLP Conceptions of Electricity Test (COET) and administered it as the pre- and post-test. The reasons for using a grade 9 test for a grade 10 class were:

- (1) Most learners in the grade 10 class had recently relocated from Eastern Cape and after discussing with them at the onset of the study; it became apparent that they last did electricity in grade 8.
- (2) Due to the huge demands of Outcomes Based Education (OBE), the previous year's grade 9 educator could not cover electricity in great detail, this implied that the learners were not at a grade 10 level in as far as electrical concepts were concerned.

The use of the same test as pre- and post-tests as well as one person doing the research helped to eliminate the problem of instrumentation threat. Instrumentation threat occurs when a different test from pre-test is used as a post-test and the levels of difficulty for the two tests are not the same (Trochim & Land, 1982).

The original STLP electricity test (COET), like other STLP instruments went through "copious reviews to establish validity and reliability" (Ogunniyi, 1999:6). The same instruments were also tested in a study in Norway, thus increasing the scope of its applicability. The original test consists of 40 items. The modifications were done on numbers 1 to 5 which were left out since static electricity was not part of this study. These questions were replaced by question 1 of the grade 8 STLP electricity test. Although these questions are from a grade 8 test, they are in fact applicable to any grade because they test the basic knowledge of symbols used in electric circuits. Lack of

knowledge of these symbols is bound to hinder the understanding of circuit diagrams. The purpose of including this question was to make learners comfortable with the test rather than starting with a complicated question that requires application of knowledge. Although this was the case, there were still some learners who could not answer this question.

Some items of question 7 of the COET were also removed and replaced by a question on voltage. This question (on voltage) was taken from an instrument developed by Duit et al, used by Shipstone in a study conducted in 1988 on students' (aged between 15 and 17) understanding of electricity in five European countries. The modified test consists of 17 items, with the maximum possible marks of 29. Since the test was modified, it had to be subjected to some form of evaluation. To attain face, content and construct validity, five experienced grade 10 science educators from two schools were asked to appraise the suitability and appropriateness of test for grade 10 learners before the test was administered to the learners. The educators were asked to rate the items in terms of relevance of content and clarity of language. They were quite comfortable with this, as they were not required to answer the question, which could have led to embarrassment for some if they did not do well in the test. This rating in terms of relevance of content and language was crucial, as the learners involved in the study are second language users. The scale for rating, ranged from 1 to 5 whereby each represented the following:

- a) 5 - strongly agree that the question was relevant and clear
- b) 4 - agree that the question was relevant and clear
- c) 3 –not sure that the question is relevant and clear
- d) 2 –disagree that the question is relevant and clear
- e) 1 –strongly disagree that the question is relevant and clear.

The average correlation coefficient was determined using a modified Spearman's Rank-difference formula based on the rating by the judges. The average correlation coefficient based on their ratings stood at 0.82.

Construct validity was difficult to establish since the questions tested process skills of recall, understanding and application. A question might be categorised as an

“application” question, but if some learners have seen the question before, then it becomes more of a recall than application to them, while to others it will be application. These challenges posed a threat to construct validity. As far as I was aware, the learners were not exposed to the questions before and therefore the assumption is that they were new to them but this claim could warrant further attention.

The COET was administered according to the design as discussed earlier. A summary of the modified COET (MCOET) is shown in Table 5 below, but the actual test is available in Appendix C.

Table 5 : Summary of MCOET

Question	Summary
1.	Learners to identify symbols in a given electric circuit.
2. 1	Learners to identify a symbol in a given circuit.
2.2	Learners state what an instrument in a given circuit measures.
2.3	Learners state the unit for current.
2.4	Given a series circuit with two ammeters, as well as the reading in one ammeter, learners state what the reading in the other ammeter will be.
2.5	Given a series circuit, what happens to the ammeter reading if a second cell is added to the circuit?
2.6	Given a series circuit with two cells, learners must say what the effect of adding an extra cell would have on the brightness of bulbs.
3	Given a parallel circuit with two bulbs and three ammeters as well as reading of the main current and the other ammeter reading, learners were asked to predict what the reading on the remaining ammeter would be.
4.1	Learners state the unit for measuring charge.
4.2	Given the ammeter reading, learners are asked how much charge will pass through the ammeter in 1 second.
5.1	Given a circuit diagram with a voltmeter reading across the cell. Learners are asked what the voltage will be at various points in the circuit.
5.2	A second bulb is added to 5.1. Learners must predict what the ammeter reading will be at the same points after this change is made.
6.1	Name one use of a resistor.
6.2	Name the four factors affecting resistance.
7.1	Given a circuit diagram with readings, learners calculate the value of the resistance.
7.2	Given a circuit with a cell, ammeter reading, a resistor and voltage across it, learners state what would happen to the current if voltage was increased to 20 (doubled).
7.3	Learners state how the change done in 7.2 would affect resistance.

3.5.2 Classification of questions

The questions on the MCOET were classified into three main categories of process skills namely, those that required recall of information, those that tested conceptual understanding and those that required application of knowledge gained. The following table shows where each question fits:

Table 6 : Process skills implied by the items in MCOET.

Question	Summary	R	C	A
1.	Learners identify symbols in a given electric circuit.	X		
2. 1	Learners identify a symbol in a given circuit.	X		
2.2	Learners state what an instrument in a given circuit measures.	X		
2.3	Learners state the unit for current.	X		
2.4	Given a series circuit with two ammeters, as well as the reading in one ammeter, learners state what the reading in the other ammeter will be.		X	
2.5	Given a series circuit, what happens to the ammeter reading if a second cell is added to the circuit?			X
2.6	Given a series circuit with two cells, learners must say what the effect of adding an extra cell would have on the brightness of bulbs.		X	
3	Given a parallel circuit with two bulbs and three ammeters as well as reading of the main current and the other ammeter reading, learners were asked to predict what the reading on the remaining ammeter would be.		X	X
4.1	Learners state the unit for measuring charge.	X		
4.2	Given the ammeter reading, learners are asked how much charge will pass through the ammeter in 1 second.		X	X
5.1	Given a circuit diagram with a voltmeter reading across the cell. Learners are asked what the voltage will be at various points in the circuit.		X	X
5.2	A second bulb is added to 5.1. Learners must predict what the ammeter reading will be at the same points after this change is made.		X	X
6.1	Name one use of a resistor.	X		
6.2	Name the four factors affecting resistance.	X		
7.1	Given a circuit diagram with readings, learners calculate the value of the resistance.			X
7.2	Given a circuit with a cell, ammeter reading, a resistor and voltage across it, learners state what would happen to the current if voltage was increased to 20 (doubled)?		X	X
7.3	Learners state how would the change done in 7.2 affect resistance.		X	X

R = Recall; C = Conceptual understanding; A = Application of concepts.

There are 7 recall questions whose weighting is 11 out of 29 possible marks, thus making 38% of the test. The rest of the questions, as can be seen from Table 5, test conceptual understanding only; both conceptual understanding and application; or application only.

3.5.3 Questionnaires

A questionnaire is a "self-administered interview", that "requires particularly self-explanatory instructions and question design since there is often no interviewer or proctor present to interpret the questionnaire to the subject" (Smith, 1975:170). It is the most common form of data collection in social science, reasons being that they are cheap to administer. The subjects have more freedom than in a face-to-face interview since anonymity is maintained in questionnaires. According to Cannel and Kahn (1975) one must be aware of the following when drawing up a questionnaire: language, frame of reference and conceptual level of questions. If the vocabulary used is not understandable to subjects, then the questionnaire is useless. If the researcher and the subjects do not share the same meanings and the questions asked are beyond the level of conception of the subjects, this also renders the questionnaire useless.

In this study the admonition by Cannel and Kahn (1975) were taken into consideration when drawing up the questionnaire. The purpose of the questionnaire was to collect information on the socio-economic background of the learners as well as their attitude towards electricity and science in general. It consisted of 16 items, most of which were closed-ended questions and only the last question was open-ended. The items on the questionnaire can be classified into four groups:

- A. Questions that deal with residential area
- B. Questions that deal with socio-economic background
- C. Questions that deal with home support in schoolwork
- D. Questions that deal with attitudes towards science and electricity.

The questionnaire was presented for scrutiny at a number of seminars whereby attendants commented and suggested changes on some questions as they saw fit. It was also given to five township educators, who were to rank the items in terms of its quality based on a five-point scale ranging from very unsuitable to very suitable. Using Spearman's Rank-difference formula, an average correlation of their ratings stood at 0.99 which suggests that the questionnaire was judged to be of good quality. Only after this scrutiny had been

carried out that the questionnaire was administered to all the grade 10 learners (see Appendix B).

3.5.4 Interviews

The purpose of an interview is to find out what is in someone else's mind (Patton, 1990,270). According to Maccoby and Maccoby cited by Smith (1975), an interview is a peculiar verbal interactional exchange in which one person, the interviewer, attempts to elicit information or expression of opinions or belief from another person or persons. The problem with interviews is that they are "unnatural interactions" (Measor, 1985). This unnaturalness sets off something in people that make them a little uncomfortable and this can have an effect on the information they will give you as an interviewer. This problem can be minimised by building a relationship of trust with the interviewee. Goode and Halt as well as Moser cited by Measor, (1985) warn that whilst building this relationship, the interviewer must still try and maintain a proper distance with the interviewee in order to avoid bias. Sometimes the researcher becomes too involved in this relationship that it raises questions of data validation bias and scientific standpoint (Measor, 1985).

Interviews may be structured, unstructured or standardised (Patton, 1990). In structured interviews questions are pre-set and rigidly followed. The respondent is restricted by the questions. In an unstructured interview, although there is a plan, questions are asked as they come to the interviewer's mind and the respondents can be as broad as they feel like in answering the questions. In Patton's (1990) view, an unstructured interview is more like an informal conversation. Smith (1975) refers to unstructured interviews as "depth interviewing"(p.189). Questions asked in an interview can be either open-ended or closed (also known as fixed response questions). In an open-ended interview (unlike a closed-ended one), the respondents are not limited by choice; they express themselves in their own words. In a way this is good because the interviewee gets to open up and to express himself/herself freely on a subject matter.

Semi structured interviews seem to strike a balance between the two extremes. Patton refers to these as an "interview guided approach". Questions or issues to be covered are specified in advance in an outline form but the interviewer will decide on the sequence or wording of the questions in the course of the interview. The guide will be kept as a checklist of issues to be covered but there will still be room for the interview to become fairly conversational and situational and logical gaps can be closed (Patton, 1990).

Semi-structured interviews were employed to elicit more information from the learners. Six learners consisting of two from the experimental group, two from control group-1 and two from control group were interviewed. The interviews were only conducted at the end of the study to obtain information on whether or not learners held any misconceptions after the study; what their attitude towards electricity was after being taught; their emotional responses to their experience of Vee-mapping as well as whether or not their attitude towards electricity had changed at all. The items of interview are presented in Appendix 3.



3.6 Classroom observation

Classroom observations were done but not in a structured manner. A tape recorder was used to record discussions within groups while the learners were doing experiments. The purpose of these observations was to establish the following:

- i) The attitude of learners in class with respect to electrical concepts.
- ii) Whether learners had any misconceptions about electrical concepts and if so, what sort of misconceptions?

The full details of the findings of the observations are discussed in chapter 4. Although at the end of the study all groups had covered the same concepts, it is worth mentioning though that by virtue of the nature of the lecture method, one took less time to cover concepts than when using vee-diagramming. All groups had an opportunity to use equipment or watch an experiment in progress. Due to shortage of equipment, not every learner received a chance to connect up equipment. Refer to Appendix F for a description of an example of one of the lessons using vee- diagramming.

As stated earlier, it is essential during research to control factors that could affect the study e.g. the socio-economic background, facilities at the school, the teacher, level of learners' ability, etc. Since the study was an evaluation of a teaching method, i.e. vee-diagramming, I had to try and control the effect of the teacher as the other factors had been established to be uniform amongst all the groups involved in the study through the demographic analysis discussed in chapter 4. In order to control the effect of teaching I had an option of either using two other teachers or teaching all the groups myself. The advantage of the former is that it controls for the effect of the researcher biasing the outcome whether consciously or unconsciously by putting more enthusiasm into the experimental group than the control group. In this case, time constraints did not allow enough training and poor training would in turn introduce new sources of error. Also other differences come into play which are linked to the personalities of those teachers etc. This was therefore avoided. The advantage of the researcher doing all the teaching is that it saves time but the disadvantage is that possibility of researcher bias. I was conscious of this all the time but cannot claim that it could never have happened even at subconscious level.



3.7 Data analysis

The data set was analyzed using Excel. The illustrations of data were in form of tables, graphs, etc. Descriptive statistics (e.g. frequencies, means and standard deviations and percentages) were used to “organize and describe characteristics of a collection of data” (Salkind, 2000:9). Inferential statistics in the form of t -test and f -test calculations were also employed so as to “make inferences from a smaller group of data to a possibly larger one “ (Salkind, 2000:10), in this study no generalisation beyond the school was intended, though the lessons learned could be found useful in a larger study.

In addition, the quantitative analysis was supplemented with qualitative descriptions to provide a fuller picture of the findings, especially in areas that are not easily amenable to

quantification. The qualitative descriptions used in the study were based on analytic categories such as:

- (i) noting patterns or themes;
- (ii) seeing possibilities;
- (iii) subsuming of particulars under broader categories;
- (iv) comparing;
- (v) clustering; etc.

Also, quotations of the respondents' viewpoints in form of excerpts were used to supplement the quantitative and qualitative descriptions.

3.8 Instructional methods

The instructional method adopted in this study was Vee diagramming in conjunction with concept mapping. The aim of this instructional approach as indicated earlier, was to support meaningful learning through organization of concepts in a coherent and comprehensive way. This approach acknowledges the existing knowledge that learners have and builds on it as well as picks up misconceptions and knowledge gaps if they exist.

Due to the complexity of Vee diagramming, and the fact that learners had never been introduced to it before, I decided to introduce learners to concept mapping first. Wandersee (1990) as well as Novak et al (1983) also suggest that this is the best way to introduce Vee diagramming. Discussions around whether concept maps made learning easier or not took place and learners seemed to prefer concept maps to bulky notes. Although the initial concept maps were done with my assistance, the learners were later given the opportunity to develop their own concept maps. It was a struggle at first for most of them, Wandersee alludes to this by saying that, "Despite their uncomplicated appearance, concept maps are, initially difficult to construct" (p 928.).

Once they showed confidence with concept mapping, it was then that Vee diagramming was introduced. Learners were taken through a process of explaining this teaching and

learning tool as well as what it hoped to achieve. Initially, the construction of Vee diagrams involved the whole class and the diagrams were drawn step by step as the lesson proceeded. At the end of the lesson, the diagram was revisited to see whether or not all the necessary aspects had been covered. Later on, the learners were required to generate the various aspects of the Vee diagram as the lessons continued both as groups and individually until the diagram was complete. This posed some challenges both for learners and me. Some of these challenges are in line with Wandersee's (1990) findings i.e.:

- i) Learners were not used to this method of learning/teaching and found it demanding as they were used to being spoon-fed and now they had to be actively involved in all sorts of ways in the lesson.
- ii) Due to the fact that the subjects for my research are English second language users, they encountered problems in formulating meaningful propositions such as appropriate linking words to write on the lines that connect concepts. Initially, they preferred leaving them out these linking words or phrases.
- iii) It was time consuming; sometimes it took two periods to complete one Vee diagram.
- iv) Undergoing the necessary mind shift from the learners' side from just doing things to reflecting upon actions was a challenge. Normally, after learners had done an experiment they would only be concerned about the results but the Vee diagram forced them to put everything into perspective from the existing knowledge to value claims.

Other challenges were to do with the running of the school e.g. change in class periods (by management without knowledge of staff) due to the fact that matriculation class was writing the final examinations. There were instances of confusion about periods and sometimes periods were cut short or cut out completely. Educators would at times not attend to their classes because they were busy completing portfolios. All of this created a chaotic situation. This chaos unfortunately also impacted on the instructional method as well. Once the matriculation class had finished writing for each day and vacated the school premises, the internal classes (non matric classes) also wanted to leave although

their periods for the day were not over. This impacted on the concentration levels of the learners involved in the study.

Since Vee-diagramming was being tested in this study for its effectiveness or otherwise, it is viewed as the exemplary teaching and learning material applied in the study. The term “exemplary” in this instance does not imply excellence, but a prototype interactive teaching and learning tool, specifically designed to engage learners actively in the learning activities such as drawing their own concept maps, vee-diagrams, conducting investigations and making knowledge or value claims. Novak and Gowin (1984) have well documented the process or stages involved in teaching learners how to do Vee-diagrams. They give advice that it is easier to first introduce learners to concept mapping before introducing them to Vee-diagramming. Mention is also made of the fact that there is no one best way of introducing concept mapping as each method will depend on the setting. In the study I therefore followed this advice of starting with concept mapping. Appendix D gives an overview of the lesson in which the learners were introduced to concept mapping. The lesson overview is adopted from Novak & Gowin (1984: 33). Appendix E shows an example of a concept map drawn by the whole class. After the learners had done the concept map as a class, they were divided into groups and were given another opportunity to develop a concept map as a group. This helped to give them some confidence so as to enable them to work on concept maps individually at a later stage. It was only after this that the learners were introduced to Vee-diagramming. Appendix F gives an overview of a lesson in which learners were introduced to Vee-diagramming, while appendix G shows an example of a Vee- diagram done by the whole class. It took the groups about two lessons to complete the Vee-diagram. As Wandersee (1990) and Novak et al (1983) have stated, Vee-diagrams are difficult if people are not used to them, a number of Vee-diagrams had to be done as a class before the learners could attempt doing them in smaller groups.

To overcome the challenges already mentioned above, I avoided rushing the learners through the learning episodes having realised that this was not a familiar territory for them. I also had to leave out some of the electrical concepts that I would have liked to

handle, and cover just enough given the time available. The programme therefore, had to be condensed in as far as concepts were concerned and the period extended. Due to the fact that the learners disappeared after lunch, I always asked educators who had morning periods to offer me their periods so as not to miss out on those learners.

3.9 Ethical issues

Researchers in the social science arena, like those in science also have an obligation to maintain ethical standards when conducting research. Social scientists have been moving towards some consensus on basic ethical guidelines for conducting research involving human subjects (Smith, 1975). The guidelines are there to protect subjects from exploitation by researchers. These guidelines include informed consent, confidentiality, the rights and welfare as well as subject risk/potential benefits ratio (Smith, 1975). Cognisant of these ethical issues, permission to conduct the study was sought from the management of the school, which includes principal, school governing body members, science head of department as well as the science educator for grade 10. The role of a school governing board is to oversee the smooth running of a school. It has a parent component which gives the board the mandate to make decisions on its behalf on various issues. Receiving the school governing board's permission to carry the study forward therefore, meant that parents in general also agreed to the study. Their agreement to the study implied that the rest of the staff be informed about this as the researcher was going to be a participant observer and would thus be a member of the staff for the period of the study. No deception or covert research took place. Although Patton puts forward the argument that "covert observations are more likely to capture what is really happening than are overt observations" (Patton, 1990:275). However, despite the merit of his argument I could not, for ethical reasons conduct covert observations. The learners were therefore well briefed about the purpose of the research. Foster (1993) mentions that many researchers have grave concerns about ethical acceptability of deception, particularly when it involves covert research or gross misrepresentation of the purpose of the research. This concern derives from the value of honesty as well as the fact that

subjects should be fully informed about the nature of any research in which they are involved.

Learners were assured that their names would not be mentioned in the study and therefore, they should be relaxed and answer questions freely. When responding to the questionnaires, they were told not to write their names to give them the liberty to express their true feelings whilst confidentiality was maintained. Also, it was explained to them that the purpose of the tape recorder was to keep track of what was said in class as it would be impossible for me to write or remember all what they said. The tape recorder was therefore openly used in class sessions and during the interviews.

3.10 Summary

This chapter looked at research design and methodology applied in carrying out the study. The main study was conducted after a pilot study was undertaken to better equip the researcher for the main study. Through this the researcher had some sense of what to expect in the main study and how to overcome some problems if they arose. The main study was a quasi-experimental design based on Solomon-3-Control Group Design. The three groups used comprised an experimental group (E) and two control groups (C₁ and C₂). C₁ controlled for the treatment effect while C₂ controlled for the pre-test effect. The MCOET and the questionnaire provided data for the quantitative aspect of the study while the interviews and classroom observations provided data for the qualitative component of the study.

Due to the robust nature of the procedure employed it was expected that the results obtained would offer good insight into the problems at hand and contribute to the pool of knowledge as we grapple with ways of making learners learn meaningfully. The findings are discussed in chapter four while the conclusions reached and their implications are presented in chapter five.



CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This study attempts to determine the effect of Vee-diagramming in enhancing grade 10 township learners' understanding of some electrical concepts. As explained in chapters 2 and 3, Vee-diagramming is a visual device that relates and connects a learner's view to a scientific mode of inquiry. It shows how a scientist's conceptual knowledge may be used as a lens to view the processes in a scientific investigation (Ebenezer & Connor, 1998). As a reminder, the study sought answers to the following questions:

- What conceptions of selected electrical concepts do grade 10 township learners hold?
- Are the learners' performances on the selected electrical concepts influenced by their age or gender?
- Will the learners exposed to "Vee-diagramming" perform better on the selected electrical concepts than those taught through the traditional lecture method?

As explained in chapter 3, the Modified Conceptions of Electricity Test (MCOET) was administered both as pre-test and post test to grade ten learners at Hope High School. Other instruments used in the study were the questionnaire as well as interviews. Although all the grade tens were involved in answering questionnaires and writing the pre- and post- tests, only the results of fifteen learners in each class are analysed and discussed in this chapter. Also, as indicated in chapter 3, the analysis reported in this chapter is based on the data collected from 15 learners per group who completed the pre- and post-tests.

This chapter examines the data obtained in the study and discusses findings under specific sub-headings. In addition to the qualitative descriptions, the learners' responses to interviews are used to elaborate on their performance in both tests.

4.2 Demographic profile of learners

As indicated in chapter 3, an aspect of the questionnaire was to collect a demographic profile of the learners to determine possible influence of such a profile on the learners' understanding of the selected concepts. This index was used to determine the comparability of the three groups in terms of the tasks they were given to perform during the period of the study. Table 7 shows four main features constituting the demographic profile of the learners. The four features are: areas where the learners reside; their family background; their home support and their interest in science.

Although the factors above are assumed to impact on the learners' achievement in science, they are construed only in a probable rather than a causal sense in that many intervening and extraneous factors are involved. As can be seen in Table 4.1, over 80% of the learners in all three groups reside in townships. With the exception of the learners' responses to items 6 and 9, it was evident that the majority came from similar backgrounds.



4.2.1 Comparison of the family background of learners in each group

The learners' responses to items 2-5 show generally a very close resemblance in the status of all the three groups in terms of their family backgrounds. From interviewing the learners it became apparent that most learners come from single parent homes. Likewise, they live with at least five other people. They mostly reside in apartments that are four roomed or smaller. The smaller houses were mostly single-roomed shacks or the two-roomed Reconstruction and Development Project (RDP) houses built after the 1994 elections. Having more than five people in these small dwellings renders the place not conducive to learning due to space problems.

Q6, which was about having someone, employed in the home, shows similar situations in groups E and C₂, but not in C₁. Although C₁ seems to have more unemployment, one could question the kind of employment people E and C₂ have. If they work as domestic

employees, they would not be making much income. In talking to the learners from the C₁ group, it was discovered that although there could be no one employed in some households, some members of the family ran small businesses such as vegetable stores, ‘spaza’ shops, etc, and in that case, most probably make more income than the domestic employees (from E and C₂ group), even worse if the domestic employees work in the townships. Although there is a big difference in the responses to Q6, more than 50% of the learners in all groups have someone employed in their families. It is worthy to note however, that a 53% percentage employment indicated by C₁ casts a bleak picture on the homes of learners in that group.

Table 7 : A demographic profile of the learners in percentages.

	E %	C ₁ %	C ₂ %
A. Residential area :			
Q1. Those that reside in townships	87	93	100
B. Family background :			
Q2. Learners that reside with either one parent or both	67	67	73
Q3. Those with families of more than five people	67	73	73
Q4. Those that reside in a 4 roomed house or smaller	60	73	73
Q5. Those that walk, use bus and train to school	93	100	93
Q6. Someone employed at home	87	53	87
C. Home support in school work :			
Q7. Those who have space to study at home	80	80	93
Q8. Those who are given time to study at home	80	93	80
Q9. Those who have people to help them at home	73	87	47
Q10. Someone at home has high school education	47	53	53
D. Attitude towards science and electricity :			
Q11. Those who like science	93	80	73
Q14. Those who like the way electricity was taught	100	93	93

E=Experimental group; C₁ = Control group 1; C₂ = Control group 2

4.2.2 Comparison of home support in each group

With respect to home support, the three groups show a close resemblance with respect to the availability of space for study in the home (Q7), the opportunities learners have to study at home (Q8) and Q10 indicating that some members of the family having a high school education. Q9 shows that more learners in C₁ and E respectively receive help from home in as far as homework is concerned compared to learners in C₂. Although this may be the case, one would question the quality of the assistance they get in science from family members who themselves have no high school education in science. In most township schools, the number of learners doing non-science subjects tends to out number those who do. Since educational qualification is related to employment and consequently, the availability of learning facilities, it may not be far-fetched to assume that the conditions for learning science in the home environment of a considerable number of the learners are anything but conducive. Although most of the learners indicated having study space and study time at home, the environment might not encourage much learning due to noise, overcrowding and other forms of disturbance.



4.2.3 Comparison of attitude towards Science and Technology

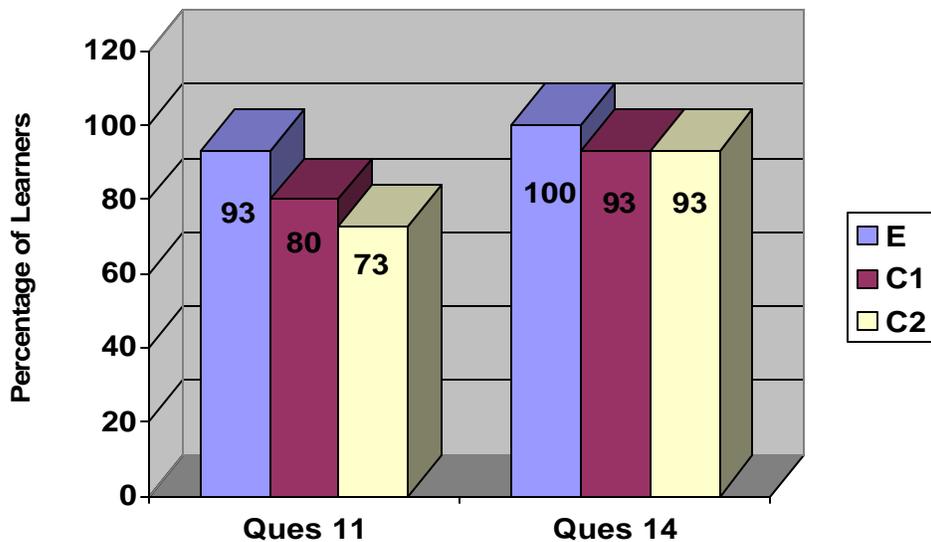


Figure 4 : Learners' attitude towards Science and Technology

Question 11 was about whether they liked science or not while Question 14 was about whether they liked the way electricity was taught or not. Fig 4 shows positive responses to these questions in each group. It is also evident from Fig. 4 that all the three groups display similar or very close attitudes towards science. For instance, 73 % and above of the learners indicated that they liked science (Q11), and above 93% indicated that they liked the way electricity was taught (Q14). Based on their responses, it is safe to say, in general, that most of the learners are favourably disposed to the study of science and technology and the way electricity was taught during the study.

4.2.4 Summary

Although the questionnaire was rigorously evaluated by a number of people and experts for validity and reliability, it became apparent at the stage of analysis that language and ability to follow instructions by the learners was still a major problem. This problem was most pronounced in questions 12 and 13 as well as 15 and 16. In these questions, the learners had to answer either question 12 or 13 and either 15 or 16. It was noted that most learners did not follow the instructions properly and answered all the questions. This rendered these questions invalid for analysis and has therefore been discarded in the analysis (see appendix B for actual questions).

The problem of not being able to follow instructions is attributed to the language problem as well as being careless when reading instructions. In the last question (general comments), the learners had to express their general opinions/experiences about science. Although the learners were encouraged to express themselves in their mother tongue, most of them left this section blank i.e. 80% in section C₂, 73% in section E and 47% in section C₁. All who responded seemed to either prefer English rather than their home language or were embarrassed to answer in mother tongue when the questionnaire was in English. Although these learners preferred to express themselves in English, their English grammar and spelling was appalling for grade ten learners. Sometimes it was difficult to make sense of what they had written whilst others would just decide to rewrite the question instead of answering it. Considering the fact that grade ten learners are only left

with one year to be in their final year at school, it is worrying when their language proficiency is so low yet the rest of their studies will be in English, even beyond matriculation. One is concerned about what the future holds for them in an English dominated world as far as academic work is concerned.

Some learners mentioned that English was the major problem to their understanding of science. This problem of lack of understanding of English by second language users cannot be underestimated. It hampers their understanding of scientific concepts as they must first contend with the English language itself through translation to their native language and then make connections between what they already know and the new knowledge. This process is time consuming especially due to the fact that the day to day use of English is different to the scientific use. Tobin (2000) alludes to this by stating that learners with limited proficiency in the use of English face a challenge of making sense of instruction while at the same time building understanding of science. Setati (1997) also highlights the important role that language plays in learning by stating that language is a tool for thinking and communication, it is used to transform experience into cultural knowledge and understanding.



These learners did not only face a problem of lack of understanding, they also faced a problem of not being able to articulate what they did not understand or formulate questions about what they did not understand. This is why even during teaching time, when they were given an opportunity to ask questions, no one did and that would give false impressions that they understood what was being taught. It is perhaps interesting to note that some of the learners suggested in the questionnaire that the educator uses code switching time and again. I agree with this as a way of counteracting the effect of “limited proficiency”, meeting these learners halfway and thus ensuring that concepts are well understood. Although this is the case, teachers should guard against swinging the pendulum to the other extreme end and conduct the full lesson in the learners’ native language when the learners are expected to express themselves in English during examinations. This will by no means have helped prepare them for their examinations. But the whole question of whether we teach for passing exams or for knowledge is

another debate on its own. Educators must therefore, try and strike a balance between ensuring that the English language is not a barrier to learning and at the same time give learners enough practice in the language so that they are able to answer questions comfortably using it.

4.3 Pre- test results on the MCOET

As mentioned in the methodology section, the E and C₁ groups responded to the MCOET at the pre-test stage. The null hypothesis posited for testing was that there would be no significant difference between the means of the two groups on account of sex or age. Table 8 below shows the learners' performance on the MCOET on account of sex at the pre -test stage.

4.3.1 Learners' performance on the MCOET according to sex

Table 8 : Learners' pre-test performance on the MCOET on account of sex.

Group	Sex	Mean %	Mean	SD	t test
E	All	20.3	5.9	2.1	t = 0.0
C ₁	All	20.3	5.9	2.6	
E	Males	19.9	5.7	2.5	t _{obs} (-0.61) < t _{crit} (1.77)
	Females	22.0	6.4	0.6	
C ₁	Males	19.0	5.5	1.9	t _{obs} (-0.51) < t _{crit} (1.77)
	Females	21.4	6.2	2.9	

Table 8 shows the average performance of both groups in the pre-test. It includes the average performance of all the learners in each group as well as the average performance of males versus females in each group. The mean percentages are also included so as to give a better picture in terms of the overall performance of each group. The table seems to suggest that each group has achieved a mean of 5.9 against a total mark of 29. Given this low achievement one can conclude that both groups had a poor understanding of the concepts tested by the MCOET. The close values for standard deviations (2.05 and 2.6

for E and C₁ respectively) indicate that the scores in the two groups are very similar. Based on the demographic profile of the learners, their level of performance at the pre-test stage and close standard deviation values, one can conclude that both groups are comparable.

Table 8 further shows that the girls' mean score is slightly higher than that for boys in both groups. However, the t-value obtained indicates that the difference is not statistically different thus, further corroborating the notion of comparability of the two groups at the pre-test stage. A t-test was employed to determine whether or not this difference was significant. This implies that the null hypothesis cannot be rejected, as the observed t-value (-0.61 in the E group, and -0.51 in the C₁ group) is far less than the critical value (1.77) needed to reject it. Hence, it is safe to assume that the boys and girls performed similarly on the MCOET at the pre-test stage. This finding is similar to what Ogunniyi (1999) found in a large scale study in the Western Cape. In another study conducted by Habte (2003) in Eritrea, again the same conclusion with regards to sex was drawn. This is somehow against expectation since one would have expected boys to perform significantly better than girls in electricity as they are the ones who normally are more inclined to be working with electric devices than girls.

4.3.2 Learners' performance on the MCOET according to age

Table 9 : Learners' pre-test performance on the MCOET on account of age.

Age range	N	Mean %	Mean	SD
14 – 15	2	22.4	6.5	0.5
16 – 17	13	26.0	7.4	2.6
18+	15	19.0	5.5	2.5
Total	30	21.0	6.0	6.0

($F_{(2, 27)} = 1.06$ at $p = 0.05$)

An exploration of the learners' performance on account of age is rather mixed (Table 9). In other words, no clear pattern on account of this variable is discernible. Under normal

conditions, most of the learners in grade 10 should be between 16 and 17 years of age. However, for various socio-economic factors, the ages of the learners involved in this study are quite varied. An examination of Table 9 indicates that although none of the groups passed the MCOET test, the mean of the 16 – 17 age range was the highest of the three and that of the 18+ range was the lowest. The age range of 14 -15 has been discountenanced because only two learners belong to this age group. However, when ages 16-17 are pitched against 18+ year olds, the latter obtained a lower mean score compared to the former, though the F-value shows that the difference was not statistically significant ($F=1.06 < F= 3.32$ at $p=0.05$).

These findings are similar to those of Adams (1990), Habte (2003), Solomon (2001), and Ogunniyi (1999) in which there was no significant difference in performance of older learners to that of the younger ones although the younger groups performed better than the older counterparts. This phenomenon of younger learners performing better than older learners is rather contrary to expectation. It is generally expected that older learners will perform better than younger learners because they are supposed to have undergone more intellectual development and reached certain levels of maturity which is required to perform certain functions. However, various studies have revealed that age alone does not contribute to better performance, other factors come into play e.g. perhaps these learners are slow learners naturally, they may be repeating the grade. Also, due to the fact that poor performance is sometimes caused by the clash of ideas between those perpetrated by school and those from home particularly if the two worldviews are different. Also, if a learner is much older, it may be argued that the ideas he/she holds are engrained more than in their younger counterparts, thus making it even more challenging to try and eradicate them. However, this requires further investigation before any firm conclusion can be reached. As Ausubel (1968) has argued, familiarity or exposure to a learning material rather than age alone might provide a much more fruitful explanation to the anomaly encountered in this and similar studies.

4.3.3 Further exploration of pre-test results

In order to facilitate discussion around the various test items in the pre test, the questions in the pre-test have been grouped into the following categories of “process skills”. The term “process skills” as used by Ogunniyi and Mikalsen (2004) refers to the learner’s cognitive activity of creating meaning and structure from new information and experiences. These are seen as “building blocks from which suitable science tasks are constructed” (D.O.E, 2002 p. 9 cited by Ogunniyi and Mikalsen, 2004). The process skills that the learners employed to solve the problems probably include:

- recall only process skills
- conceptual understanding only process skills
- application only process skills
- conceptual understanding and application process skills.

In this study, the process skills are viewed as the intellectual tools or strategies deployed by the learners to perform specific cognitive tasks. Some of these tasks require one type of skill while others require a combination of skills.



A close examination of the Table 10 indicates that the learners have a poor knowledge of the electrical concepts tested. Only about 21% of all the questions were answered correctly by all the learners in E and C₁. Looking at the E group, its highest performance is in the recall category whereby learners could answer 31.4% of the questions, followed by application only with 22.2%, then conceptual understanding and application with 7.3% and lastly conceptual understanding only with 6.7%. In the C₁ group, their highest performance was not in the recall category but conceptual understanding only category with learners being able to answer 33.3% of the questions in this section, followed by recall with 27.1%, then application only with 20% and lastly conceptual understanding and application with 8.7%.

Table 10 : Process skills in percentages used by the learners to perform cognitive tasks on the MCOET at the pre-test stage.

Category	Question and summary	E	C ₁
1. Recall	1 (Identifying symbols in a circuit) [75]	62	53
	2.1 – 2.3 (Identifying symbols, stating use of instrument, stating unit of current) [45]	1	4
	4.1 (Unit for charge) [15]	0	0
	6.1–6.2 (Stating use of resistor; Naming factors affecting resistance) [75]	3	0
Sub-section average		31.4%	27.1%
2. Conceptual understanding only	2.4 (Deducing the ammeter reading in a given circuit) [15]	1	5
	2.6 (Deducing the effect of adding an extra cell to the brightness of the bulb in a given circuit) [15]	1	5
Sub-section average		6.7%	33.3%
3. Application only	2.5 (Determining the effect of adding a cell to the ammeter reading in circuit) [15]	0	1
	7.1 (Calculation of resistance) [30]	10	8
Sub-section average		22.2%	20%
4. Conceptual understanding and application	3 (Predicting an ammeter reading in a parallel circuit) [15]	0	2
	4.2 (Determining amount of charge given ammeter reading) [15]	0	0
	5.1 (Determining voltage at various points in a circuit) [45]	8	8
	5.2 (Determining the effect of adding a bulb to the ammeter reading) [45]	1	1
	7.2 (Determining the effect of doubling voltage on current) [15]	1	2
	7.3 (Determining how doubling voltage would affect resistance) [15]	1	0
Sub-section average		7.3%	8.7%
Grand Total		20.5%	20.5%

N.B. [] indicates the total possible score for the whole group

Question 1 in the recall category was well done by both groups with over 70% of the learners in each group knowing the correct answer to this question. This means that both groups are generally well familiar with circuit diagrams and circuit components required in the grade 8 syllabus. In other words, they were able to mobilise the recall process skills and get the questions right. However, it is disturbing to note that hardly did the learners recall what they should have done at grade 9 level pertaining to electric circuits. There seemed to be a gap in the learners' knowledge of grade 9 work on electric circuits. Most of the learners had never seen an ammeter before; some were seeing some components for the first time in grade 10. Through interviews and general class discussions, quite a number of learners mentioned that they had never done experiments at school on electric current at all.

When the “conceptual understanding only” category is considered, it will be noted that the C₁ group performed much better than the E group. Although this was the case, none of the groups received an average of at least above 40 % in this category. This poor performance is a result of the misconceptions that the learners had about the flow of current in a circuit. These misconceptions will be discussed in the subsequent section.

The fact that the E group performed better in the “application only” than in “conceptual understanding only” process skill seems odd. The reason for this is that the process skill involved in solving the “application only” question was that of applying a given formula to solve the problem and then make inferences about how changing one factor would affect the answer. Most learners were able to work out the first part of the problem but not the latter. This therefore caused inflation in the application only performance. Poor performance in the combination of the two process skills shows that learners lacked understanding of the actual concept being tested even if they could manipulate mathematical formulae.

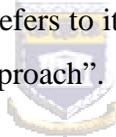
4.3.4 Discussion

The poor performance of learners in the pre-test as well as their responses to questions during interviews indicated evidence of misconceptions that can be categorised in the following ways:

- Existence of the attenuation model
- Existence of the sharing model
- Misconception about the role of conductors in a circuit that could be related to the effect of a resistor in a circuit

(i) Attenuation model

Osborne (1983) describes this model as the one in which the current flows around the circuit in one direction; it leaves the battery by one terminal and some current is “used up” in the bulb so that less or no current may return to the battery. Where the current passes through a number of identical components in series, each successive one will receive less current. Shipstone (1984) refers to it as the “sequence model” while Liegeois et al (2002) refer to it as the “localist approach”.



The following excerpts from the recordings made during classroom observations as well as interviews give evidence of the existence of the attenuation model in Hope High School learners. The excerpts also give some insight into the learners’ poor performance at the pre- test stage, especially in questions 2.4, 2.5, 2.6 and 5.2. These were mainly questions that tested conceptual understanding only, application only as well as conceptual understanding and application. In most of these questions, learners have scored less than 10% and even 0% in some (see Table 10). The following excerpts reflect the attenuation model held by the learners.

Excerpt 1 (learners from the C₁ group)

After learners had connected a series circuit, they were asked to show / trace the path of current flow in the circuit:

Teacher : Can you trace the path of the current flow in this circuit?

- Learner 1 : It goes from positive to negative terminal (showing the path from positive terminal of cell straight to negative without going via the circuit then only goes to the rest of the circuit from the negative terminal)
- Teacher : If I were to measure current here (pointing out next to a cell) and there (away from the cell), is there a place that would have more current?
- Learner 2 : Yes there is a place (where there will be more current)
...Here, because it is near the battery.
- Teacher : Do you all agree in the group? Is there anyone with a different view?
- Learner 3 : I think this side will have more current because it has two wires (two wires were connected in order to make the wire longer as they were too short) while the other has only one wire. You see this one is shorter whilst this one is longer. Because the wire is longer, it takes more time to get here.
- Learner 3 : (When asked if he thinks there are places where the current will be equal) From here to there, it is equal with here to there because the wires are equal in these places. (This student saw the length of the connecting wires as having a major role in the amount of current at different points in the same series circuit.

Excerpt 2 (learners from the E group)

The learners in this group were also asked the same questions as those in the C1 group, i.e., after they had connected a series circuit, they were asked to show / trace the path of current flow in the circuit. The views below are representative:

- Teacher : If I were to measure current here (pointing out next to a cell) and there (away from the cell), is there a place that would have more current?
- Learner 4 : The current in this circuit is not the same everywhere, it starts big

here (from the cell) and gets smaller there....It is because the connector makes the current smaller just before it gets to the bulb.

Learners 5 and 6 shared the same sentiments as learner 4 in terms of current not being the same in a series circuit although they differ fundamentally in what causes the current not to be the same. Whilst learner 4 believes the connecting wires are the cause for this difference, learners 5 and 6 believe that the bulb is the main cause. This is what learners 5 and 6 had to say:

Learner 5 : There is more current in some places than others...Here, next to the bulb.

Learner 6 : I think there will be more current before it enters the bulb, so it comes out less on the other side of the bulb.

(ii) Sharing model

When learners hold this model they believe that identical components share the current equally between them but the current is not regarded as conserved (Arnold and Miller, 1987; Borges, Herizote & Gilbert, 1999; Osborne, 1983; Shipstone, 1984;). In this study, the learners seemed to move between the attenuation and sharing models. It was interesting to note a strong presence of the idea that not only are the bulbs consuming and sharing current but so are the connecting wires. This was evident from some of the statements made by some of the learners, e.g. learner 7 in C₂ asserted that:

Learner 7 : This side there is only one wire and that side two (*two wires connected in series on the other side of the bulb*). So the wires share it, which is why it gets less.

(iii) Clashing model

According to Tasker and Osborne (1985) and Arnold and Millar (1987), the clashing model exists in learners if they believe that “something” leaves from the positive pole of the battery while another leaves from the negative terminal. When the two things meet at the bulb, they clash and this results in the formation of the current and the bulb glows. During class observation, there was evidence that a few learners had this model.

(iv) Misconceptions

Some of the learners seemed to confuse the connector with a resistor. They seemed to confuse what they learned in grade 9 about the factors affecting resistance. They looked at the connecting wires as resistors, which would “consume” the current and thus lead to less current on the other side of the resistor. The statement “the longer the resistor, the higher the resistance” made by learner 4 was therefore used by this learner to draw the following conclusion:

I think this side will have more current.... because this side has two wires (*two wires were connected in order to make the wire longer as they were too short*) while the other has only one wire. You see this one is shorter whilst that one is longer. Because the wire is longer it takes a long time to get here (*the other side of the wire*)... From here to there it is equal with here to there because the wires are equal in these places. (Learner 4, from the E group)

This group saw the length of the connecting wires as playing a crucial role in the amount of current in the circuit, not the cells and not the bulb. They failed to appreciate the fact that the connectors were made of copper, which has very low resistance and should therefore have very minimal effect on current. If these learners were to study electronic circuits, they would have a problem as they see the size of the components having an effect on the circuit and not what the components are made of.

Further more, Learner 2 from the C1 group stated that “the current is not the same. It starts big here (*from the battery*) and gets smaller here... It is because the connector makes the current smaller just before it gets to the bulb” while learner 3 from the same group contended that this difference in current in the same series circuit is due to the fact that the wires share the current and in the process result in some places having more current than others. The following statement bears witness to this:

Learner 3 : This side there is only one wire and that side two (*two wires*)

connected in series on the other side of the bulb). So these two wires share it, which is why it gets less.

Not only were these learners stuck in the consumer model way of thinking but they also tended to be reasoning “locally” instead of “globally” in the way they thought about the effects of changes in an electric circuit. According to them, some feature in a series circuit would have an effect on the amount of current at that point and not the whole circuit in a series circuit. This localised perspective about current will create problems as the learners continue with their studies of electricity. Of course, these findings are not peculiar to these groups of learners; they are consistent with other findings in the area e.g. Millar and King (1993), Riley et al. (1981), Shipstone (1984), etc.

4.4 Post-test results

As mentioned in chapter three, the post-test was given in order to try and establish whether or not Vee-diagramming as an instructional tool would enhance the learners’ understanding of electrical concepts. E, C₁ as well as C₂ group wrote the post-test test after they had been exposed to a period of instruction. E and C₂ were exposed to the combined instructional model involving Vee-diagramming, experiments and exemplary learning materials. C₁ on the other hand was exposed to the same instructional protocol but was denied of Vee- diagramming. Instead of Vee-diagramming it was exposed to an expository lecture method. All the three groups wrote the test at the same time. The null hypothesis posited for testing was that there would be no difference in the performance of the learners exposed to Vee-diagramming and those no so exposed. The learners’ performance at the post-test on the MCOET is displayed in Table 11.

4.4.1 Post test statistical summary

Table 11 : Learners' performance on the MCOET at the post-test stage

Group	Sex	N	Mean %	Mean	SD	t test
E	All	15	43	12.5	2.9	t_{obs} for E & C ₁ (2.57) > t_{crit} (1.70)
C ₁	All	15	30	8.7	5.0	
C ₂	All	15	39	11.3	5.5	t_{obs} for E & C ₂ (0.76) < t_{crit} (1.70) t_{obs} for C ₁ & C ₂ (1.38) < t_{crit} (1.70)

Table 11 represents the average performance of groups E, C₁ and C₂. Looking at the overall picture, although no group achieved a mean % of above 50%, the group that performed the best was E with a mean of 43% followed by C₂ with a mean of 39% and finally C₁ with a mean of 30%. The t-statistic for E and C₁ groups is 2.57, which is higher than the critical value of 1.70 at p=0.05. In other words, the null hypothesis suggesting no performance difference between the two groups is rejected. There is therefore, a difference in performance between the learners taught by Vee-diagramming and those taught by traditional method.

When E and C₂ groups, which were both taught by Vee diagramming were compared, it is noticed that although the mean of E was greater than that of C₂, the observed t-value (0.76) for the two groups was less than the t critical value at p=0.05. This leads to the conclusion that the difference between the performances of the two groups is not statistically significant. One can therefore, further conclude that although E wrote the pre-test, it did not influence their performance in any significant way. Otherwise E would have performed much better than C₂. The comparable performance can thus be attributed to similar instructional model to which both groups were exposed, i.e., Vee-diagramming.

When C₁ and C₂ groups were compared there was no significant difference between the two groups although C₂ was exposed to Vee-diagramming as E. Also, the fact that C₁ was

exposed to the pre-test did not give it an advantage over C₂ denied of the pre-test. In other words, pre-test did not seem to play a major role in performance of C₁. The attenuation of the effect of the Vee-diagramming in C₂ might well be either that the group was not as comparable to the other two groups as was assumed to be the case or it might be the result of extraneous variable such as the so called “classroom culture” and associated factors making each group to differ somewhat from the other groups but not powerful enough to neutralize the effect of the treatment. However, this would warrant a closer inquiry beyond the scope of the present study.

Finally, the F-test for the three groups (C₁, C₂ and E) gives a value of 2.84 which is less than the critical value of 3.23 at p=0.05 needed to reject the null hypothesis. In other words, the differences amongst the three groups are not statistically significant. This however, is not to state that the treatment has not been effective. As would be seen later, the differences between the pre- and post-tests are actually statistically significant (Fig. 5 & 6 and Table 15).



4.4.2 Post-test statistics according to gender in each class

An examination of Table 12 below shows that unlike in the pre test, the boys have performed slightly better than girls in the E and C₁ groups. Although this is the case, the difference is not statistically significant at p=0.05 in both groups.

Table 12 : Performance on the MCOET according to gender

Group	Sex	N	Mean %	Mean	SD	t test
E	Male	10	47	13.6	2.76	$t_{obs} (0.69) < t_{crit} (1.77)$
	Female	5	43	12.4	3.91	
C ₁	Male	6	36	10.5	6.75	$t_{obs} (1.19) < t_{crit} (1.77)$
	Female	9	26	7.4	3.32	
C ₂	Male	7	49	14.3	6.34	$t_{obs} (1.84) > t_{crit} (1.77)$
	Female	8	30	8.6	5.7	

With the exception of C_2 where the boys outperformed girls, the difference is neither significant in E nor C_1 . In C_2 , the mean difference between the boys and the girls is statistically significant ($t=1.84 > t_{crit}=1.77$) at $p=0.05$ i.e. the null hypothesis suggesting no significant difference has not been confirmed.

4.4.3 Post-test performance according to age

Table 13 shows the performance of the learners in the post test according to the different age groups. Unlike in the pre test where the highest mean score was obtained by the 16-17 age group, in the post test the highest mean score (40.3%) obtained by the 14 -15 age group, i.e. the youngest age group. The 16-17 year olds achieved the lowest mean score (37%). Although there are differences in performance according to age, the differences are not statistically significant ($F = 0.02 < F_{crit} = 3.32$ at $p = 0.05$). Once again, at post test, just like in the pre test, age differences do not seem to influence the performance of learners in electricity in a significant way.



Table 13 : Performance of the learners on the MCOET according to age

Age range	N	Mean %	Mean		SD
14 – 15	3	40.3	11.7		4.5
16 – 17	18	36.0	10.4		3.5
18+	24	38.0	11.0		5.5
Total	45	37.0	10.8		4.7

($F_{(2,42)} = 0.2$ at $p=0.05$)

It will be noted that like in the pre-test, the oldest group (18+ year olds) have under achieved as compared to the youngest group (14 – 15 year olds). Although as mentioned earlier, this is against expectation and yet a number of studies do corroborate these findings e.g. Adams (1999), Habte (2003), Solomon (2001), and Ogunniyi (1999). This shows that age alone does not just lead towards better understanding, there are other

extraneous factors contributing to this underachievement of older learners as compared to the younger ones.

4.4.4 Further exploration of post test results

Looking at table 14, it is evident that in the “recall category”, learners in the E and C₂ groups could answer more questions correctly than in the C₁ group, with E scoring 62.9 %, C₂ scoring 61.4% and C₁ scoring 43.8%. The next section in which the learners achieved better was in the “application only” process skill category with E scoring 55.6%, followed by C₂ with 37.8% and lastly C₁ with 28.9%. The “Conceptual understanding only” section was badly done by all three groups with no group reaching at least a 40% mark followed by “conceptual understanding and application” subsection where all groups scored less than 15%. Generally, the same pattern in performance as that on pre- test is noted at post- test.

It is normal to expect learners to perform poorly in application questions than recall and conceptual understanding type of questions. This is so because application types of questions require the learner not only to recall concepts but to show a good understanding by applying the knowledge gained. It is noted that in this study learners performed better at “application only” than in “conceptual understanding”. This interesting phenomenon is due to the fact that the learners sometimes find it easier to do mathematical manipulation whereby they substitute values and obtain the correct answer. If the same learner is asked to respond to the same question qualitatively, one would find a lot of misconceptions. Cohen et al (1983) state:

Our experience in the teaching of electricity shows that even after a systematic and fairly advanced study of the topic in high school or college, in which students become quite efficient in carrying out complicated algorithms (e.g. Kirchoff’s laws), they are still incapable of qualitatively analyzing simple circuits. (p. 407)

This then explains why when the two categories ‘application only’ and ‘conceptual understanding only’ are put together the learners performed poorly because the conceptual understanding category weighed more than the application only.

Table 14 : Process skills in percentages used by the learners to perform cognitive tasks on the MCOET at the post-test stage.

Category	Question and summary	E	C ₁	C ₂
1. Recall	1 (Identifying symbols in a circuit) [75]	67	62	62
	2.1 – 2.3 (Identifying symbols, stating use of instrument, stating unit of current) [45]	17	17	24
	4.1 (Unit for charge) [15]	0	2	2
	6.1 – 6.2 (State use of resistor; Name factors affecting resistance) [75]	48	11	41
Sub-section average		62.9 %	43.8%	61.4%
2. Conceptual understanding only	2.4 (Deducing the ammeter reading in a given circuit) [15]	6	6	3
	2.6 (Deducing the effect of adding an extra cell to the brightness of the bulb in a given circuit) [15]	3	3	5
Sub-section average		30.0%	30.0%	26.7%
3. Application only	2.5 (Determining the effect of adding a cell to the ammeter reading in circuit) [15]	5	4	5
	7.1 (Calculation of resistance) [30]	20	9	12
Sub-section average		55.6%	28.9%	37.8%
4. Conceptual understanding and application	3 (Predicting an ammeter reading in a parallel circuit) [15]	1	1	1
	4.2 (Determining amount of charge given ammeter reading) [15]	0	0	0
	5.1 (Determining voltage at various points in a circuit) [45]	6	7	2
	5.2 (Determining the effect of adding a bulb to the ammeter reading) [45]	5	4	4
	7.2 (Determining the effect of doubling voltage on current) [15]	7	4	6
	7.3 (Determining how doubling voltage would affect resistance) [15]	2	0	2
Sub-section average		14.0%	10.7%	10.0%
Grand Total		43%	30%	39%

N.B. [] indicates the total possible score for the whole group

Educators should therefore, guard against automatic mathematical manipulations which are actually meaningless to the learners as this might give false impressions that learners fully understand the concepts at hand whereas this is not the case.

4.4.5 Discussion

Although the learners involved in the study claimed that they understood electricity after instruction, and that the post-test was not difficult, their overall performance did not bear evidence to this. The learners still performed poorly even after instruction, with no group reaching a mean score of 50%. The following section gives insight into their performance in the post-test through their responses to interviews done at the end of the study. These responses are dealt with under the following themes:

- Attitudinal change
- Attenuation model
- Language issues
- Link between school and home

Two learners were interviewed in each group. Learners 1 and 2 were from the C_1 group which was taught through the traditional lecture approach while Learners 4 and 5 and 8 and 9 respectively were selected from E and C_2 exposed to Vee-Diagramming.

(i) Attitudinal change

At the end of the study some of the learners were asked to express their views about the instructional methods used to introduce electricity to them. The purpose of this question was to determine if Vee-diagramming enhanced the learners' attitude towards electricity or science in general. The responses of the learners to the interview questions showed that there was a difference or change in their attitude toward electricity as a result of Vee-diagramming to which they were exposed. Those taught through the traditional lecture method did not see any difference in the way electricity was taught previously or during this study. The following excerpts reflect their viewpoints in this regard:

Excerpt 3

(Learners from C₁ group)

Learner 1 : I find it (*electricity*) easy. There is no difference to me in the way I was taught last year and this year. It is the same as last year

Learner 2 : I like it (*electricity*) Miss. No difference.

Excerpt 4

(Learners from C₂ group)

Learner 8 : I am getting to like it (*electricity*) more. I did not like it before.
(*When asked about what made him not to like it before*)...The shortage of things when it is time to do experiments. Now we connect things and we can see things happening. The teacher just teaches...talks and no experiments are done (*in the past*)

Learner 9 : At first I used not to understand...it is better now. We used not to do experiments the other year, we just wrote notes and the teacher explained. Now we do Vee diagrams and concept maps.



(ii) Attenuation model

Even after instruction the learners still thought that the bulbs consume energy and make the current less thus resulting in current not being the same at different points in a series circuit (e.g. see Arnold and Miller, 1987; Shipstone et al, 1988). Arnold and Miller (1987) summarise this problem well when they say that “the major stumbling block at this early stage in children’s progression towards a scientific perspective on electric circuits appears to be the tenacity with which the belief that current is consumed by electrical components (the sequence model) is held. This study has also confirmed this tenacity of viewpoints among the learners. When asked whether putting an ammeter at different positions in the same series circuit would result in the same or different readings, the learners had the following to say:

Excerpt 5

- Teacher : What effect would connecting an ammeter at different points in this series circuit have on the reading?
- Learner 1 (from C₁): It would be big here (*before the bulbs*) and less here (*after the bulbs*) and the same here (*just before it enters the negative terminal*). This is because there is more fire here; it gets less here and there and gets bigger again here.
- Learner 2 (Also from C₁): It will be bigger here...here next to the bulb (*before entering bulbs*), ...it will be bigger here than in between the bulbs.
- Teacher : What is the cause of that?
- Learner 2: At this point (*before the bulbs*) it still has more power...(Learner 1 intervenes and says “*there is still a lot of current*”)... As well as here (*after the bulbs*) so it is only less in between the bulbs. When it gets here, it leaves some of the current here.
- Learner 1: Some current is left in the bulb here and some goes through and some is left in the second bulb...

Even though the learners held to the attenuation model, they were not consistent. Some learners would claim that the bulb takes up some current thus making it less after the bulb, yet increases again before it enters the battery. Even the attenuation model they seemed to hold is mixed up.

These learners did not show much improvement in their understanding of series circuits. They still had the same attenuation model as before the instruction. Some of the learners could not even tell the difference between a series and a parallel circuit. One learner even thought that the more cells there are in a series circuit the less the current there would be because “the current (*umbane*) is quick if there is one cell...they (*cells*) do not share.” This learner seemed to be seeing cells as resistors and therefore the more there are in a circuit the more the resistance thus less current in the circuit.

Although the learners from the experimental group (E) did slightly better than those from the C₁ group, there was still evidence of the existence of the attenuation model as well as misconception about an ammeter in the former. For example, learners 4 and 5 (from group E) saw an ammeter as “using” current and therefore, resulting in current not being the same at various points in the same series circuit. The bulbs were seen as “consumers” of energy and thus making the current less.

Learner 4: *(In explaining why the current will be less at the second bulb says):* This bulb will get the energy first before it gets to the other bulb.

One learner from the E group had a misconception of seeing the cells as resistors (that would slow down flow of current) in a circuit. To him, “the more you put in a circuit the less current you would have.”

Learner 5: “ If there are three cells, they must still pass on the energy to one another and that slows it down unlike if it is just one cell carrying the energy into circuit.”



Misconceptions in any subject inhibit a person’s understanding of the subject, especially when the person intends studying the subject further. The fact that these learners have the above mentioned misconceptions will make it difficult for them to understand other concepts in electricity as they will be building their knowledge on a faulty foundation. Although the concepts concerned in this study are basic to the understanding of electricity the learners are still encountering some difficulties. For instance Learner 5 will struggle with understanding voltage for construing the role of a battery in a circuit as that of offering resistance.

Although there was a strong presence of the attenuation (consumer) model amongst most of the learners, there seemed to be no evidence for the existence of other models e.g. clashing model etc. mentioned in the extant literature (e.g. Borges et.al., 1999; Fler, 1994; Fredette & Lochhead, 1980; Osborne, 1981; Shipstone, 1984).

(iii) Language issues

Earlier in this chapter, the issue of language proficiency or lack thereof was highlighted. The main point made was that lack of proficiency in a language of instruction inhibits understanding as well as becomes a major obstacle in the articulation of views or responses to questions by learners. Whilst the focus of the earlier section was on the English language in general, this sub-section deals with the language of science. It is common knowledge that scientific language is more “abstract than everyday language, it is more precise in its definitions and it even takes ordinary words and gives them specific counter-intuitive scientific meaning” (Puhl, 2000). This precision and transforming ordinary words into the scientific language tends to create conceptual difficulty for learners. Hence, familiar words like heat, energy, light, power or even electricity assume a different status or meaning in a scientific context. Sutton (1992) mentions the “cell” in a biology context and a “prison cell” as well as a “monk’s cell”. Unless the learner knows the context in which the term is used he/she may be so confused that meaning may be lost. Puhl also makes reference to Halliday and Martin’s “nominalisation” as adding further complication to the language of science. “Nominalisation is defined as the process by which a process is changed from being seen as a process into being seen as a thing e.g. refraction” (Puhl, 2000:126).

Sanders and Mogodi (2000) mention the four types of terms used in the scientific language that have proved to be problematic i.e.

- logical connectives e.g. consequently, however, etc.
- technical terms e.g. current
- non-scientific terms (everyday words from the language of instruction e.g. simultaneously)
- paradoxical jargon terms (these words have more than one meaning, often a scientific one and a different everyday one) e.g. conductor in music, or taxi as opposed to a conductor in physics.

It is common that teachers concern themselves with the scientific jargon more than the other less scientific terms. The thinking is that in a science lesson we should be teaching science for forgetting that the non-scientific jargon used to explain science can also

hinder or promote understanding. If a learner cannot understand the meanings of words being used to explain science to them, what chance do they have in understanding the concepts? In a statement, “the current in a series circuit is the same throughout the circuit as there is no branching of the current.” If a learner does not understand the way ‘as’ is used in the statement, he or she will not appreciate the fact that the reason for the current being the same is that there is no branching.

Certainly, it became apparent during this study that language was a major problem among the learners. The learners had difficulty in understanding the science that was communicated to them in English, and they in turn, had difficulty in expressing themselves in English. Most of the time I had to allow them to express themselves in their mother tongue, Xhosa, so that I could get a better sense of what they were trying to say. Some confused terms like increase and decrease. They would state that adding cells in a circuit results in an increase in current. When they were asked to translate this into mother tongue, it was discovered that they meant the opposite. Allowing learners to express themselves in their mother tongue therefore, proved useful in digging misconceptions which otherwise would not have been brought to surface. Rollnick and Rutherford (1996) also found this method of code switching useful in exploring existing ideas. They also found that in their study, learners wrote correct answers yet during discussions misconceptions were revealed in the vernacular language.

Nhlapo (cited by Sanders and Mogodi) states that although students from all walks of life experience terminology problems, students learning science through a medium of instruction which is not their mother-tongue are especially disadvantaged. This proved to be the case even during this study. Learners persisted in using “incorrect” terms that are acceptable in the mother-tongue as they resulted in misconceptions when translated to English. For example, in C₁, a learner referred to electricity as fire, “umbane”-which could be interpreted as “lightning”. Some used the term “power” for electricity. Arnold and Miller (1988) refer to this “usage of the term “electricity” as an umbrella term by most children, incorporating the separate ideas of current, power and energy” as the reason why learners are not able to conserve current. Learners are of the view that current

is consumed by electrical components and decreases further around the circuit, which they refer to as the sequence model.

In conclusion, it is important for teachers to be aware of the major role played by the language of instruction as well as the language of science in the communication and understanding of scientific concepts. If teachers are aware of this, they will always make sure that they “level the playing field” during communication. This is done ensuring that learners are fully conscious of the context, the connecting terms and ordinary terms. Otherwise, the scientific meaning will be lost. Teachers must not separate science teaching from English teaching especially to second language users. Teachers must also make room for mother tongue use in a science lesson so as to expose any underlying misconceptions their learners might be holding.

(iv) Link between school and home

Costa (1995) states that learners who “plan a future in a science-related career have one major thing in common: their worlds of family and friends are congruent with the worlds of schooling and science.” She goes on to say that those learners who “do not experience such congruence ... do not have positive experiences in science classrooms and become academically and personally alienated from science” (p.330). For learners to manage crossing between the two worlds of the home and the school, it is therefore, imperative that the two worlds are congruent (Aikenhead & Jegede, 1999). The following excerpt reflects the learners’ opinions about the importance of this congruence:

Excerpt 6

- Teacher : Are things that you learn at school related to what you do at home?
Is the knowledge that you bring from home helpful or not at school? If yes, in what way?
- Learner 1 : I do get a chance to connect things up at home....I find that they
(the school and the home) are similar or close

- Learner 2 : We have electricity at home and we connect things up. We know that when wires touch, there is an explosion. You know what to do for things to light up.
- Learner 4 : Learners (*who do not practice connecting things up at home*) will find it (*electricity*) difficult because they will not get some things at school. You are not told everything at school, so we come with some knowledge from home.
- Learner 5 : Yes, it (*knowledge from home*) makes my life easy when I get to school. When the teacher talks about connecting this and that, I already have an idea.

The critical issues raised in the above excerpt are that learners find it easier to move between the world of home to that of school science if there are some similarities between the two worlds. Unfortunately because of social stereotyping, a girl is not normally given an opportunity to connect electrical items, the traditional home still sees this as a boy's role. This somehow puts the girl child at a disadvantage as she will not be familiar with electric appliances and thus develop phobia to anything to do with electricity. The constant fidgeting with electrical toys and being asked to fix electrical appliances when they break at home puts boys ahead of girls in the class in as far as the experience in electricity is concerned (although parents need to be vigilant about safety issues). This makes the boys better disposed towards electricity. It was noted during classroom observations that when learners were given a task of connecting up circuits, boys jumped at the opportunity first while girls shied away from the activity. It is important for teachers to be aware of these disparities in the home upbringing that impact on later schooling and encourage the girls to also be actively involved in connecting circuits and not become secretaries for boys during an experiment.

In as much as the boys seem to be at an advantage due to the prior knowledge that they might have gained from home, teachers need to be wary of the fact that the information that boys bring to school might contain misconceptions which they have held on to for

some time. These misconceptions as Driver and Erickson (1993) have said, could be difficult to eradicate as the learners might have held on to them for a long time.

4.5 Comparison of pre and post-test

Fig 5 below represents the process skills demonstrated by the learners at the pre- and post-test stages. Each column represents the process skills mobilised by the learners to perform cognitive tasks on the MCOET at pre- and post-test stages. An examination of the average percentages achieved by each group shows at the pre- and post-test shows considerable improvement in the latter compared to the former. Group E shows an improvement in performance in the recall category of process skills from 31% to 63% while C_1 improved from a pre-test score of 27% to 44%. The improvement in the performance of C_1 can be attributed to the lecture method. Although C_2 did not write the pre test, their post-test score (61%) in the recall category is close to that of E which was also taught through Vee-diagramming. This performance can thus be attributed to Vee diagramming and not the effect of pre test.



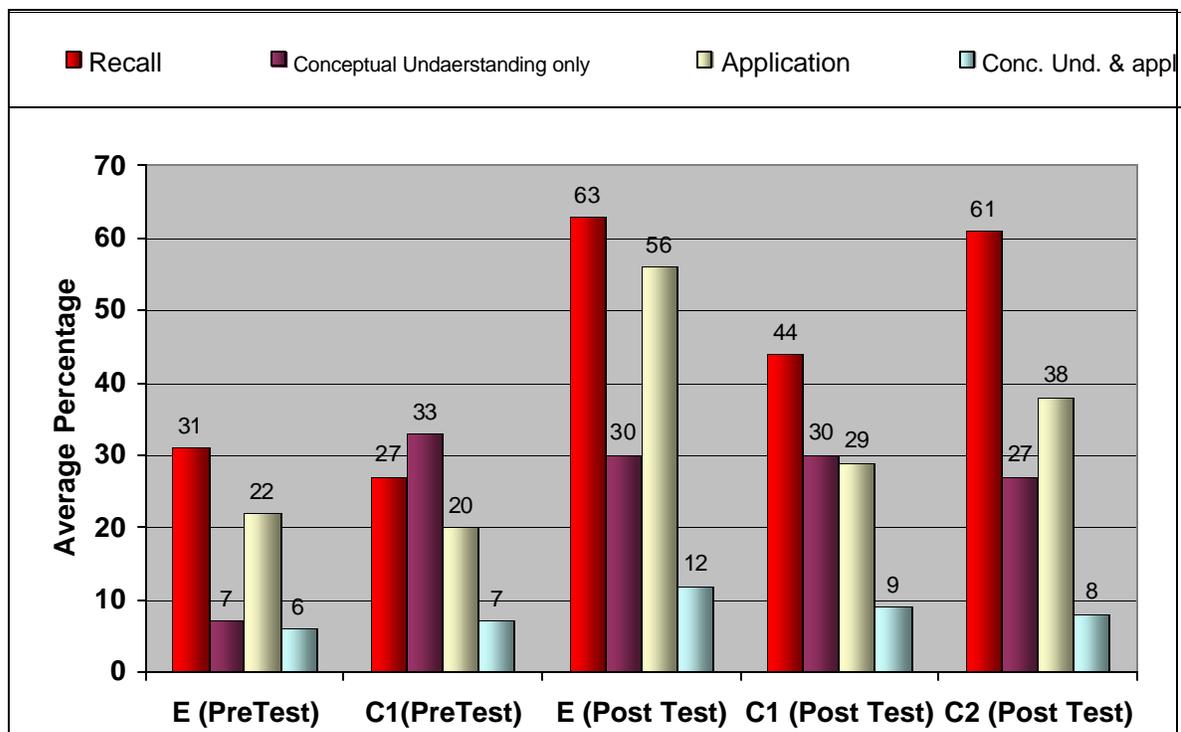


Figure 5 : Learners' performance on the MCOET at the pre- and post-test stage.

A close examination of the “conceptual understanding only” column shows that E has improved performance while C₁'s performance declined from 33% to 30%. The reason for this decline in performance is not clear at this exploratory stage (Fig 5 and 6).

In the “application only” category, E group has the highest score at post test and shows considerable improvement from 22% to 56% compared to C₁ whose percentage rose from only 20% to 29%. The performance of C₂ on the “application only” category is between E and C₁ i.e. 38%.

The process skill category with the smallest improvement encountered was the “conceptual understanding and application” category whereby the improvement was less than 10% in both E and C₁.

Fig 7 perhaps provides a clearer picture of the conceptual change between the pre-test and post-test.

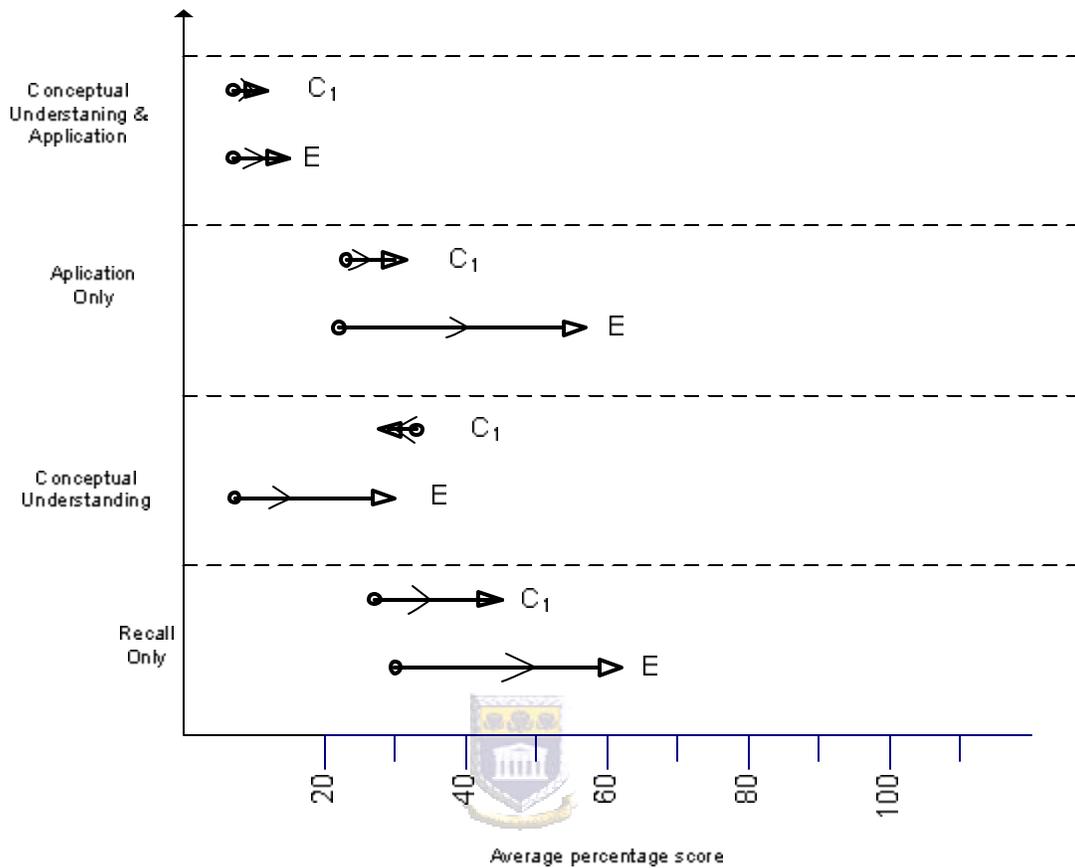


Figure 6 : Graph showing the change in performance on the MCOET by groups E and C₁ at the pre- and post-test

Key : o = pre-test average score

Δ = post-test average score

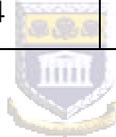
Fig 8 provides another visual representation of the changes in the learners' mastery of process skills and consequently, understanding of electrical concepts subsections of the test as a result of the instructional intervention. C₁ group in some instances show evidence of confusion that could be attributed to instruction since learners knew more before instruction than after instruction e.g. in the " application " category where learners' performance declined after instruction.

Table 15 below explores the shift between pre test and post test of groups E and C₁ to see if the shift is significant or not.

Table 15 : Performance on the MCOET at the pre- and post-test stages.

Group	N	Mean%	Mean	SD	t test
E Pre test	15	20.3	5.9	2.05	$t_{\text{obs}} (10.11) > t_{\text{crit}} (1.76)^*$
Post test	15	42	12.5	2.92	
C ₁ Pre test	15	20.3	5.9	2.6	$t_{\text{obs}} (2.36) > t_{\text{crit}} (1.76)^*$
Post test	15	30	8.9	5	
E boys pre-test	10	19.9	5.7	2.5	$t_{\text{obs}} (10.81) > t_{\text{crit}} (1.83)^*$
Boys post-test	10	47	13.6	2.76	
Girls pre-test	5	22	6.4	0.58	$t_{\text{obs}} (3.46) > t_{\text{crit}} (1.83)^*$
Girls post-test	5	43	12.4	3.91	
C ₁ boys pre-test	6	19	5.5	1.87	$t_{\text{obs}} (2.42) > t_{\text{crit}} (2.01)^*$
Boys post-test	6	36	10.5	6.75	
Girls pre-test	9	21.4	6.2	2.9	$t_{\text{obs}} (1.28) < t_{\text{crit}} (1.86)$
Girls post-test	9	26	7.4	3.32	

* Significant at $p = 0.05$



An examination of Table 15 shows that with the exception of the pre- and post-test means of the girls in C₁, all the pair-wise comparisons are significant at $p = 0.05$ level. The most noticeable shifts are found in the E group in terms of the overall contrasts. The t-value for the pre- post test contrast is 10.11 at $p = 0.05$ against a critical t-value of 1.76. Similarly the t-value for the pre- post-test contrast for the boys is 10.81. The t-value with respect to the pre- post-test for the girls, though less than that for the boys, is nevertheless significant ($t = 3.46 > t_{\text{crit}} = 1.83$ at $p = 0.05$). On the other hand, the t-values for the pre- post-test in C₁ are 2.36, 2.42 and 1.28 for the whole group, boys and girls respectively. This sharp contrast between the shifts noticeable in E compared to C₁ may not be unrelated to the differential effect of the treatments they received.

The findings of the study have again confirmed the positive effects of Vee-diagramming that have been reported in a plethora of studies e.g. Wandersee (1990), Novak et al

(1983), to name but a few. As has been shown in earlier studies, Vee-diagramming along with concept mapping has been found to:

- (1) assist learners organize and relate science concepts and ideas in a meaningful way;
- (2) facilitate learners' understanding of the processes by which knowledge is made in scientific investigations;
- (3) helps learners to learn how knowledge is constructed and re-constructed and
- (4) to allow learners consider their own conceptions of various natural phenomena (Ebenezea & Connor, 1998).

4.6 Opinions on Vee diagramming

Since the learners were introduced to Vee diagramming for the first time, I was interested to know their opinions about this method of instruction. During the interviews, the learners were asked to express their views about Vee diagramming to which they had been exposed. The excerpt below reflects their view on Vee-diagramming:



Excerpt 7

- Teacher : What are your opinions about Vee-diagramming as a learning tool?
- Learner 4 : It helps us in understanding things better.
- Learner 5 : When I get home I practise on my own and I find it easier...concept map and Vee mapping. It helps in the understanding. Even someone who is slow in catching things should find it easy to understand because everything (*related concepts*) that was taught is now in one place.
- Teacher : If you were to suggest the way in which you were to be taught, what would you suggest?
- Learner 5 : Experiments and using Vee mapping and concept mapping. This will be of great help to students. Doing experiments alone and the teacher just writes on the board, it will be difficult to understand.
- Teacher: When revising, which one is easier, going through notes or using concept maps?
- Learner 4 : Concept map

- Learner 5 : I agree.
- Teacher : Don't you think using Vee mapping was a waste of time? We could have just done things the usual way and managed to cover a lot much quicker?
- Learner 5 : It was not a waste of time.
- Teacher : Looking back at how I taught you, do you think it has helped to change the way you feel about science now? You said you like electricity now, is it because of how you were taught electricity this year or what...what changed your attitude?
- Learner 5 : What makes me to like it more is that now there is concept mapping and Vee mapping that helps me to understand things better and quicker. When notes are written, they are too many, the teacher explains the notes until your mind gets tired...and you even forget what was said before.
- Teacher : Are you ever going to use concept mapping and Vee-diagramming again in your life or you feel it is the end of it now, you will never use it again?
- Learner 4 : I will use them again; they help me understand things better.
- Teacher : Have you tried using them in other subjects?
- Learner 4 : Not yet.
- Learner 5 : I haven't but I will try it.
- Learner 6 : I find concept mapping useful when revising... let us say a paragraph has ten lines, but the Vee-diagramming is like a summary of everything that was done.
- Learner 8 : The concept map summarises and also shows how terms or concepts are related.

The above dialogue shows that the learners find the traditional way of teaching and learning tedious and less beneficial in as far as enhancing conceptual understanding is concerned. The learners seem to be tired of writing long notes and which at the end are meaningless. The learners seem to appreciate that if knowledge in general is well organised, it is easier to make sense of it. Once this is possible, then recall at a later stage will be possible. Unlike notes which are stored haphazardly in the mind and later become difficult to recall, the sequential and hierarchically organized knowledge, in form of concept maps and Vee-diagrams, are much easier to recall and apply in the performance

of specific tasks. All three learners in the above excerpt have alluded to the fact that Vee-diagrams help them to see how concepts in a topic are related. This indicates that learners are not interested in learning small chunks of information that are disjointed, but want to see how concepts are related in order to make sense of the full picture. In the light of low proficiency in English in second language users, the Vee-diagrams seem to be beneficial in that they reduce long and winding sentences into manageable and meaningful forms.

From the foregoing, it is safe to say that a great number of learners involved in this study seemed to construe Vee-diagramming as a viable alternative to traditional instruction. As the learners construct their own Vee-diagrams, they do not only get an opportunity to learn how to organise knowledge meaningfully but they also get to learn how knowledge is deconstructed, constructed, and re-constructed.

Although the learners attested to seeing value in Vee-diagramming, it was disappointing to learn that during the interview that none of them have tried using it in other topics besides electricity. This perhaps suggests that they are still not very confident with it to be able to apply it in different contexts.



4.7 Summary of findings

The major findings of the study can be summarised as follows:

- Grade 10 learners at Hope High School have a poor understanding of electricity – with the E and C₁ groups at the pre-test stage scoring a mean percentage of 20.5% each.
- As has been pointed out in a plethora of studies the learners do hold misconceptions about some electric concepts. These misconceptions can be categorized into three types of misconceptions such as the sharing model, attenuation model and resistance (e.g. Shipstone, 1984; Osborne, 1981; Fredette & Lockhead, 1980; Shipstone et al, 1988; Metioui et al, 1996; Millar & King, 1993; Solomon, 2001; Habte, 2003; Hendricks, 2001).

- As in many other studies, there is no significant difference between the boys and the girls relative to the understanding of selected electrical concepts (e.g. Habte, 2003; Ogunniyi & Fakudze, 2003; Ogunniyi & Taale, 2004).
- Although the older learners held relatively poorer conceptions of electrical concepts explored in this study, the overall differences were not significant on account of age.
- As in other studies, the learners exposed to Vee-diagramming performed significantly better than those taught using the traditional method, although they all showed the tendency to hold on tenaciously to pre conceived ideas (e.g. see Novak & Gowin, 1984).
- Although the learners found concept mapping and Vee diagramming to be challenging especially at the initial stages, nevertheless they seemed to find the instructional approach informative, useful and facilitative to their conceptual understanding of the selected electrical concepts in question.
- English is still a major challenge at the school and it hinders the learning process.



4.8 Conclusion

From the findings of this study one can conclude that learners involved in this study, like other learners elsewhere have common misconceptions about electric current, and that these misconceptions are difficult to remove as they still persisted even after instruction (Clough, Driver & Wood-Robinson, 1987; Fler, 1994, Posner et al, 1982). One main contribution of the study has been that although the learners still held on to some of their misconceptions, those taught using Vee-diagramming did perform significantly better than those taught using the traditional approach. The areas where there was marked improvement in the results, has been in questions that required recall and application of knowledge. It has also been evident from the interviews that the learners enjoyed the way the topic was taught. This approach seems to have resulted in the change of the learners' attitude towards the study of electricity and science in general. Another point that has come up strongly has been the role played by experiments as well as knowledge from home in the teaching and learning of electricity.

One can therefore safely say that Vee-diagramming has enhanced process skills in the learners, as well as their understanding of electricity. Despite the positive trends, it is noted that the study was less successful in shifting the pass mark of learners to a more acceptable average of above 50%. The main findings of the study as well as implications and limitations are highlighted in the next chapter.



CHAPTER 5

CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

5.1 Introduction

Various studies have sought to look at ways in which learners' understanding of scientific concepts e.g. electrical concepts could be enhanced. Examples of such studies are by Braund (1999) who looked at the use of "electric drama", Lee and Law (2001) who set up "explorations in promoting conceptual change in electrical concepts via ontological category shift", Anderson et al (2000) who looked at the impact of Science Museums in the development of knowledge about electricity. Some of these strategies succeeded in certain areas and failed in others for example, in Braund's (1999) study which involved the use of drama, some learners felt that the drama did not increase their understanding of electricity because the drama was too simplistic. Others felt that some electric ideas were rather too abstract to portray clearly by the drama. The success obtained by Anderson et al (2000) was that the intervention increased the learners' understanding of electricity but certain alternative conceptions persisted.



This study specifically sought to contribute to the existing pool of knowledge using Vee diagramming as a means of intervention especially in a South African township school. In doing this, the study focused on the following:

- The conceptions of selected electrical concepts that grade 10-township learners hold.
- Learners' performance on the selected electrical concepts in terms of their age or gender.
- The effect of Vee-diagramming on the learners' performance on selected electrical concepts.

5.2 Findings

The major findings of the study can be summarised as follows:

- Grade 10 learners at Hope High School have a poor understanding of electricity – with the E and C1 groups at the pre-test stage scoring a mean percentage of 20.5% each.
- Grade 10 learners of Hope High School do hold misconceptions about some electric concepts. These misconceptions fall under certain conceptual categories that have been documented in the extant literature (e.g. Fredette & Lockhead, 1980; Habte, 2003; Hendricks, 2001; Metioui et al, 1996; Millar & King, 1993; Osborne, 1981; Shipstone, 1984; Shipstone et al, 1988; Solomon, 2001).
- As in many other studies, there is no significant difference in performance of boys as compared to that of girls in their conceptions of certain electrical concepts (e.g. Ogunniyi & Taale, 2004; Ogunniyi & Fakudze, 2003, Habte, 2003, etc).
- Although the older learners held relatively poorer conceptions of electrical concepts explored in this study, the overall differences were not significant on account of age.
- Learners taught using Vee-diagramming performed significantly better than those taught using traditional method, although they all showed the tendency to hold on tenaciously to certain alternative conceptions.
- Learners at Hope High school found concept mapping and Vee diagramming to be challenging, especially at the initial stages, nevertheless they seemed to find the instructional approach informative, useful and facilitative to their conceptual understanding of the selected electrical concepts in question.
- Learners taught using Vee-diagramming saw this method as a viable alternative to traditional instruction.
- English is still a major challenge at the school and it hinders the learning process.
- Similar to the findings of Rollnick and Rutherford (1996), sometimes the learners gave a correct answer in the language of instruction i.e. English and only to

discover during further probing in the mother tongue that they still had misconceptions.

The above findings show that the learners of Hope High School involved in this study, like other learners else where, find electrical concepts very challenging. This challenge is brought about by amongst other things, the mental models that learners bring to school which are in direct contrast to school science, and therefore, hinder the acquisition of school science. To second language users, the challenge is even more compounded especially if they are less efficient in the language of instruction. Because these learners struggle to express themselves, the teacher is not able to pick up the misconceptions they hold unless they express themselves in the mother tongue. Worst situations have been reported whereby learners give the correct answer in the language of instruction and when probed further in mother tongue, more underlying misconceptions are revealed (Rollnick and Rutherford, 1996). This can mislead the teacher to thinking that the learners understood the conceptions well when they in fact didn't.



As the other studies have shown, the mental models that result in these misconceptions are resistant to change. This is perhaps due to the fact that the learners have held onto these for long periods and they have found them useful, and as a result drew upon them in response to various tasks. Ogunniyi and Mikalsen (2004) allude to this when they state that the learners have come across a range of experiences with phenomena involving scientific concepts and hence have developed their own robust interpretations or conceptions to account for them (p. 162). Even though Posner et al (1982) have suggested that learners should be made to be dissatisfied with an existing theory. However, is it easy for learners to abandon intuitive and commonsensical ideas and adopt unfamiliar and counterintuitive ideas? Although learners can be made aware of the invalidity of their ideas, they are not always eager to change their ideas for scientific ideas which are largely abstract, unnatural, counter-intuitive and uncommonsensical (e.g. see Cobern, 1994; Aikenhead & Jegede, 1999; Gunstone & White, 2000). Clough, Driver and Robinson allude to this and state that the learners' ideas are "resistant to change in that they do not appear to be significantly altered by science teaching" (1987:256). The anti-

intuitive and technical language of science, its abstract nature; the use of common words in a rather peculiar way etc. e.g. power, energy, heat, etc. all contribute towards this resistance. Electrical concepts are notoriously abstract e.g. current, voltage, resistance, short circuiting, positive and negative terminals, parallel circuit, circuits in series etc, all these are challenging to learners whose lives are embedded in concrete things and events. Gunstone & White (2000) suggest that instead of teachers trying to make learners abandon their intuitive and commonsensical ideas and replace them with scientific ideas, teacher should try and seek for co-existence of these ideas.

Although the learners improved significantly in performance after instruction using Vee-diagramming, they still held on to their misconceptions hence the mean percentage score of less than 50% at post- test stage for the experimental group. As indicated earlier, Ogunniyi and Taale (2004) in a study in which they sought to see the effects of a remedial instruction on grade seven learners' conception of electricity also found that the learners' alternative conceptions remained even after instruction. Habte (2003), in a study conducted on first year technical students' in Eritrea also found that a computer based programme did not manage to completely remove alternative conceptions held by students at pre-test stage. Various other studies found similar results (e.g. Solomon, 2001; Hendricks, 2001; Ogunniyi and Fakudze, 2003; Shipstone, 1984, 1988; Shipstone et al, 1988).

As Jenkins (2001) has argued, commonsense language used by learners or even adults often falls short of what is required in school science. The problem is made even more complex when it is realized that individuals (learners inclusive) have a variety of models with which they think about, or interpret natural events or phenomena. According to Jenkins (2001), the simplistic way in which teachers are urged to bring about conceptual change in their learners ignores the fact that learners live in a world where the technical science language plays only a small role compared to the general common sense knowledge and language they use at home. As alluded to on page 99 and elsewhere, learners had a problem with the language of instruction as well as the language of science and that created a "gap" in knowledge. This "gap" between common sense language and

the language of science may to a certain extent have contributed to the low performance of the learners even after the intervention.

Posner et al (1982:223) state that, “teaching science involves providing a rational basis for conceptual change”. They further assert that conceptual change can be potentially threatening, particularly when the individual is firmly committed to prior assumptions.” They provide an explanation (frequently cited in the literature) of the tenacity in which alternative conceptions are held by learners by suggesting that:

- Learners would not abandon the alternative conceptions they hold and accept new ones unless they were dissatisfied with the former.
- Learners wouldn't accept new conceptions unless such conceptions are intelligible, plausible and fruitful.

Despite the suggestion required for conceptual change indicated above, getting learners to become dissatisfied with what they have always held and found to be useful in their daily lives poses a great challenge for them. The challenge seems to be in bringing about dissatisfaction with existing ideas they hold in favour of scientific ideas introduced to them in the artificial environment of a science classroom. Hence, Gunstone and White (2000) have argued that:

The issue now appears to be not one of abandonment and replacement, but one of addition, so that the earlier belief and the scientific belief co-exist. The learner's task is to learn the scientific belief, and to become clear about when it is appropriate to apply one belief or the other (p. 298).

From the foregoing, it seems obvious that although Vee-diagramming promises to promote conceptual change, it has only been successful with some learners but certainly not the majority. Most seemed firmly committed to their prior conceptions and hence their poor performance even after instruction. Besides, the latter did not seem to be dissatisfied with their existing concepts or find the current concepts “intelligible, plausible or fruitful.”

5.3 Limitations

5.3.1 Area or Location

Townships are a difficult area to work in and are faced with challenges that do not only end at the gates of the school but affect what happens within the school premises. Township schools face problems of overcrowding, late coming and demoralized learners amongst others. Lateness to classes is not uncommon among learners; it is a common phenomenon among teachers as well. The learning environment at Hope High School where the study was conducted was anything but conducive. It was for the same reason that the number of learners who participated in the pre-test was different from the number that did the post-test, and hence the reduction to 15 learners each per group.

Poverty is one major factor contributing to the problems and often leads to drug trafficking in some instances as a way of survival. Due to their poor socioeconomic background, some learners come to school on empty stomachs. Also due to the area that these children go home to after school, some have difficulty in doing their homework. The noise level and the crime rate are of such magnitude that learners have little or no respite to concentrate on their studies. These are some of the multifarious problems faced by learners at Hope High School and which no doubt are likely to impact on their performance in school science or any subject for that matter. However, critical as these socio-economic problems are to this study, they are not the focus of the study. To do a detailed analysis of these factors would constitute another study.

5.3.2 Time of the year

This study was conducted in the last term of the year according to the plan of the teacher at Hope High School. This was not such a good time in township schools. This was because as soon as the matriculation examination started, the other classes were affected as well through the following ways:

- Bell times changed, and sometimes the person in charge would forget ringing the bell and time would be lost in other periods. Learners and teachers took long to adjust to new programme
- There was a bit of chaos in the school in that learners were unable to follow a rotation time-table they followed before the matriculation examination began.
- The last period of the day sometimes was forfeited as very few students were in the premises at that time; they normally sneaked out of the school with the matriculants who had finished certain examination papers and in such a large school, it was difficult to tell which learners were leaving school at a given period.
- Due to change in the time-table, the school had six periods instead of seven. This had an impact on teaching if one had the last period for the day.
- The situation was further compounded by the poor attendance of certain teachers involved in the examination moderation exercise, etc.



5.3.3 School culture

Although the school tried its best in as far as discipline was concerned, the problem of poor culture of learning among the learners still persisted and had an impact on the teaching and learning process, including this study. In such a setting, it was a challenge to motivate learners either to develop a systematic study habit e.g. practicing Vee diagramming and the like outside the lesson period. As in the previous section, a study of the school culture, relevant as it is to the study, could constitute another study. It is therefore, considered as a topic beyond the scope of the present study.

5.3.4 Time allocation

The time that was allocated for doing electricity in grade 10 at the school was four weeks. This presented challenges for me and the learners especially because a new teaching and learning method was being introduced to learners to a congeries of aforementioned problems. Even from the former model C school, the time would probably be too short to

attain much success. The learners first had to be introduced to this methodology and that took time because they were not familiar with it. Since Vee-diagramming entails the concept map in it, it meant that before learners could learn how to do the full Vee-diagram they first had to learn how to do the concept map. As Wandersee (1990) has pointed out, concept maps may seem easy and uncomplicated, learners find them quite challenging at the initial stages. The same was encountered in the study. Novak et al (1983) in their study with seventh and eighth graders also found that an effective use the Vee heuristic takes time for students to acquire. Time was therefore, one major limitation for the study, considering the fact the study could not be extended beyond the time that was set by the syllabus to cover the topic.

5.5 Implications of the findings

The findings of this study have practical implications for practising science educators, especially township educators. Based on the findings, it is clear that the traditional methods of teaching science do not always lead to a desired outcome in as far learners' understanding of electrical concepts is concerned. The major shortcoming of the traditional method of teaching is that it does not give the educator adequate opportunity to investigate the conceptions that these learners bring to class. Through concept mapping, along with Vee-diagramming, I was able to at least get a preview of the learners' conceptions. As the misconceptions surfaced, concerted effort was made to plan my teaching such that these misconceptions were ameliorated as much as possible. But as I have pointed out in the previous section, time limitation proved to be a serious constraint on how far I could go. Based on my experience in this study, it seems to me that in order for learners to change their attitude towards science, teachers need to explore their teaching strategies as has been attempted here. This study has shown that the traditional method of teaching does not go far enough in motivating learners to develop a positive attitude towards science. Learners preferred Vee-diagramming to writing long notes and they found that Vee-diagramming facilitated revision as all the related information were well encapsulated within the Vee-diagram. As has been shown in a number of studies, the advantages of this instructional approach, particularly for second

language learners, struggling with English is enormous (e.g. see Adams, 2002; Dinie, 2000; Fakudze, 2002; Ogunniyi & Taale, 2004).

The fact that there was no significant difference in the performance of boys compared to girls implies that the teachers need to be aware of the myth that boys normally perform better than girls in Physical Science. This is not to say that science educators should ignore the reality of the male dominated science classrooms. The important point here is that educators should avoid gender biases in their teaching. Another myth that teachers should be aware of is that older learners are necessarily better disposed to learning science than younger ones. If anything at all, the younger learners for one reason or the other have generally performed better (contrary to the stage theory) than their older counterparts (e.g. see Ogunniyi, 1999; Ogunniyi & Taale, 2004; Ogunniyi & Mikalsen, 2004). Space limitation would not permit delving into issues surrounding the varied age groups in the same class. However, the most obvious in this regard, is the socio-economic history that has led to the establishment of townships by the then apartheid government and the concomitant problems which the new democratic dispensation has not been able to remove completely. But again, this is an issue warranting a closer consideration in future studies.

5.5 Conclusion

This study has been daring enough to try out within four weeks, an instructional tool that learners are unfamiliar in an environment that was full of challenges far beyond the scope of the present study. In hindsight, perhaps using a simpler concept for implementing vee-diagramming might have provided more desirable results rather than using a difficult concept with a difficult method all at the same time. As it turned out, the challenge was to implement Vee-diagramming in the worst learning environment. The thought that I had as a researcher was that if Vee-diagramming could produce appreciable results in a township school, then it probably could succeed in any other environment. This of course

needs to be investigated. Some researchers had tried this approach in situations that were much more conducive to learning and still came up with mixed results.

The conclusion drawn from this case study is that Vee-diagramming has succeeded to some degree in a township school. Perhaps, if the conditions were not as strenuous as they were at the school, the results would have been even better than what they were. As Novak (1990) has argued, “concept maps, or any other learning tool is no magic bullet, no quick fix” for classrooms where rote learning predominates” (p. 947). I would like to conclude by saying that this study has also shown that though Vee-diagramming is not a “quick fix solution” to problems encountered by learners in electricity, it does have a potential in enhancing learners’ understanding even in conditions such as those found at Hope High School, and perhaps township schools in similar settings.

Villani (1992) makes a distinction between two types of conceptual change i.e. conceptual change “latu sensu” (c.c.l.s) and conceptual change “strictu sensu” (c.c.s.s.).

According to him:



In c.c.l.s there is a co-presence of new and old knowledge and in c.c.s.s. the new academic knowledge as well as its ways of reasoning and intellectual values implicit in its scientific use are accepted by the learner who succeeded in integrating them in a coherent and efficient conceptual system (p. 233).

In as much as the c.c.s.s. seems to be the ultimate in conceptual change, Villani has warned us that a study conducted in Brazilian schools showed that c.c.s.s. is viable only at the university level. He quotes Grimellini et al, (1989,1990) who noted that for primary and secondary school levels, c.c.l.s. seems to be an adequate explicit objective. Perhaps one needs to be satisfied with the outcome that Vee-diagramming used in this study does have some merit that could be capitalized upon in a much longer study.

5.6 Recommendations

For any intervention, no matter how good, to be fully effective in a township school with similar conditions as Hope High School, the mobilization of skilled human resources and good instructional strategies is inevitable. Due to the complexity of townships, one can easily fall into a trap of saying nothing works optimally in these schools. At the same time we cannot fold our arms and continue with the status quo whilst waiting for these complex issues to be resolved.

Whilst the government and other interested stakeholders have been making concerted efforts to address some of the complex socio-economic issues like improved housing, availability of drinking water, roads, schools and the like, the teaching/learning environment cannot be assumed to change automatically. It takes a lot of courage to start somewhere, albeit small to begin to address these challenges. An important lesson I have learnt in this study is that a teacher must be creative, patient and avoid unreasonable expectations. During my visit to Hope High School after the matriculation results were released the following year the principal informed me that only 36% of their learners managed to pass the matriculation examination. This in a way made me realise even more how ambitious and perhaps unrealistic my expectations were when I began with my study.

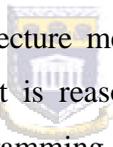
Another point that became even clearer in my mind was that there is still a lot that needs to be done in this school and schools with similar characteristics to achieve what the former South African State President Nelson Mandela once said:

Education is the greatest engine of personal development. It is through education that the daughter of a peasant can become a doctor, that the son of a mine worker can become the head of the mine, that a child of farm workers can become the president of a great nation. It is what we make out of what we have, not of what we are given that separates one from another (Nelson Mandela, Autobiography)

Perhaps for us to achieve the above, the curriculum planners should plan in such a way that the curriculum allows for meaningful learning to occur by making it more relevant, useful and meaningful to the learners' lives. This will enable learners to relate the new

knowledge from school to what they already know and not find serious boundaries between school and home that are impossible to cross.

In order for teachers to be able to facilitate meaningful learning, they need to undergo good training especially in instructional tools like Vee-diagramming which enhance meaningful learning. I would therefore recommend as Wandersee (1990) did, that Vee-diagramming be part of every graduate program in science and science education” (p. 930). This will help ensure that they are familiar with this instructional tool.

Although the study has shown a significant improvement in the learners’ performance in electricity as a result of Vee-diagramming, it is still worthy to be aware that despite the effort, no group scored above 50%. However, it will be unrealistic to make a direct comparison to what might have been achieved in a well resourced Model C school. The significant shift in the understanding of electrical concepts displayed by the E group cannot easily be discountenanced. This is even more so when it is realized that their counterpart C1 group exposed to the  lecture method did not perform as the E group. Based on the findings of this study, it is reasonable to suggest that further in-depth research into effectiveness of Vee diagramming in township schools be carried out on a much larger scale and over a longer duration.

BIBLIOGRAPHY

- Adams, S. (1990). A study of misconceptions in the understanding of simple electric circuits in a sample of South African and American school pupils. M. Ed Dissertation, University of Western Cape.
- Adams, S. (2003). Worldview presuppositions and conceptions of force held by junior secondary school science students. Doctor of Philosophy Dissertation, University of Western Cape..
- Aikenhead, G.S. (1996). Science Education: border crossing into the subculture of science. *Studies in Science Education*, 27:1-52.
- Aikenhead, G. S. and Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching*, Vol. 36, No. 3, pp. 269 – 287.
- Akatugba, A. H. and Wallace, J. (1999). Socio-cultural influences on Physics students' use of proportional reasoning in a non-Western country. *Journal of Research in Science Teaching*, Vol. 36, No.3, pp. 305-320.
- Anderson, D.; Lucas, K.B.; Ginns, I.S. and Dierking, L.D. (2000). Development of knowledge about electricity and magnetism during a visit to a science museum and related post-visit activities. *Science Education*, 84, 658-679.
- Andre, T. and Ding, P. (1991). Student misconceptions, declarative knowledge, stimulus conditions and problem solving in basic electricity. *Contemporary Educational Psychology*, 16, 303-313.
- Arnold, M. and Millar, R. (1987). Being constructive: An alternative approach to the teaching of introductory ideas in electricity. *International Journal of Science Education*, Vol. 9, No. 5, pp. 553-563.
- Arnold , M. and Millar, R. (1988). Teaching about electric circuits: a constructivist approach. *School Science Review*, 70 (251).
- Arsham, H. (2004). Questionnaire design and survey sampling. <http://ubmail.ubalt.edu/harsham/sta-data/opre330Surveys.htm>, pp.1-20.
- Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*. New York: Grune & Stratton
- Ausubel, D. P. (1968). *Educational Psychology: A cognitive view*. New York: Holt, Rinehart & Winston.

- Ausubel, D. P., Novak, J. D. & Hanesian, H. (1978). *Educational Psychology: A cognitive view*, 2nd Edition. New York: Holt, Rinehart & Winston.
- Bacon, A.E. (2001). *Qualitative research methods for the social sciences*. 4th Edition.
- Badat, S. (1992). Democratising education policy research for transformation. In E. Unterhalter, H. Wolpe and T. Botha (eds), *Education in a future South Africa: Policy Issues for Transformation*, pp. 73-94. London: Heinemann.
- Badat, S. (1991). Reformist strategies in black education since 1976. In E. Unterhalter et al (eds) *Apartheid education and popular struggles*, pp. 77-94. Braamfontein: Ravan Press.
- Balnaves, M. and Caputi, P. (2001). *Introduction to quantitative research methods – An investigative approach*. Sage Publications. London: Thousand Oaks – New Delhi.
- Beeth, M. E. (1998). Facilitating conceptual change learning : The need for teachers to support metacognition. *Journal of Science Teacher Education*, Vol. 9, No. 1, pp. 49-61.
- Black, D. and Solomon, J. (1987). Can pupils use taught analogies for electric current? *School Science Review*, 69(247), 249-254.
- Borges, A.T.; Tecnico, C.; Horizonte, B. and Gilbert, J.K. (1999). Mental models of electricity. *International Journal of Science Research*, Vol. 21, No. 1, pp. 93-114.
- Bradley, J. D. and Stanton, M. (1986). Research into alternative conceptions and their remediation. *South African Journal of Science*, Vol. 82, 539-540.
- Braund, M. (1999). Electric drama to improve understanding in science. *School Science Review*, 81(294).
- Bruner, J. (1966). *The culture of education*. Cambridge, MA: Harvard University Press.
- Burges, R. G. (1985). *Strategies of educational research*. London: The Falmer Press.
- Cannel, C. & Kahn, R. (1975). *The dynamics of interviewing*. New York: Wiley.
- Chapman, B. (1991). The overselling of science education in the eighties. *School Science Review*, Vol, 72, 260.
- Chisholm, L. (1997). The restructuring of South African Education and Training in comparative context. In Kallaway, P. et. al. (eds) *Education After Apartheid : South African Education in Transition*. Cape Town: UCT Press. (pp. 50-67).

- Christie, P. (1999). OBE and Unfolding Policy Trajectories: Lessons to be learned. In Jansen, J. and Christie, P. (eds) *Changing Curriculum : studies on Outcomes based Education in South Africa*. Cape Town: Juta. (pp. 279-292}.
- Clackson, S. G. and Knight, D. (1992). An appraisal of practical work in science education. *School Science Review*, 74 (266).
- Clark, J. (1998). Stepping out with STAP into the classroom. Proceedings of the 6th annual Southern African Association of Research in Science Education Conference, University of South Africa.
- Clark, J. (2000). Challenges to practice, constraints on change: a narrative case study of a township science teachers at work. Thesis for Doctor of Education degree. UNIVERSITY OF WESTERN CAPE.
- Clough, E.E.; Driver, R. and Wood-Robinson C. (1987). How do children's scientific ideas change over time? *School Science Review*, pp. 255-267.
- Cobern, W.W. (1993). Public understanding of science as seen by the scientific community.
- Cobern, W.W. (1994). Worldview theory and conceptual change in science education. Paper presented at annual meeting of National Association for Research in Science Teaching, Anaheim, California. (pp. 1-18)
- Cohen, R., Eylon, B. and Ganiel, U. (1983). Potential difference and current in simple electric circuits : A study of students' concepts. *American Journal of Physics*, Vol. 51, No. 5, pp. 407-413.
- Confucius (2004). Own your education. Learn.nscu.edu/learn/saying.html.
- Costa, B. V. (1995). When science is "another world" : Relationships between worlds of family, friends, school and science. *Science Education*, Vol 79, No, 3, pp. 313 – 333.
- Davies, N. (2000). Can matric results in Physical Science at low-performance schools be sharply improved? Directions in the work of the Secondary Schools Partnership Project. Proceedings : Science and Technology Education Conference 2000, Cape Town. (pp. 21-24).
- Department of Education (1999). Report on the 1999 Senior Certificate Examination. <http://education.pwv.gov.za/Policies%20and%20Reports/1999-Reports.html>. (pp. 1-8).

- Dinie, S. (2000). Investigating the effectiveness of concept mapping in improving science language writing for English second language grade 12 learners at Lagunya Finishing School in Langa. M. Ed Thesis, University of Western Cape.
- Discovery Centre (2001). Report for the period 2000/2001.
- Driver, R. (1989). Changing conceptions: Children's conceptions and school science. In Adey, P., Bliss, J., Head, J. and Shayer, M. (eds) Adolescent development and school science, pp. 79-81. Philadelphia: The Falmer Press.
- Driver, R. Guesne, E. and Tiberghien, A. (1985). Children's ideas in science. Open University Press.
- Driver, R. and Erickson, G. (1983). Theories in action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. *Studies in Science Education*, 10, 37-60.
- Driver, R., Squires, A., Rushworth, P. and Wood-Robinson, V. (1994). Making sense of secondary science: Research into children's ideas. Leeds City Council Department of Education and the University of Leeds.
- Ebenezer, J. V. and Connor, S. (1998). Learning to teach science: A model for the 21st century. New Jersey: Prentice Hall.
- Fataar, A. (1997). Access to schooling in South Africa: Linking concepts to context. In Kallaway, P., Kriss, G., Fataar, A. and Donne, G. (eds) Education After Apartheid : South African Education in Transition. Cape Town: UCT Press.
- Fataar, A. (2000). Education Policy in South Africa in Socio-historical context : continuities and discontinuities. Mimeograph, Faculty of Education, University of the Western Cape).
- Fleer, M. (1994). Determining children's understanding of electricity. *Journal of Educational research*, Vol. 87, No. 4.
- Fleer, M. (1999). Children's alternative views: alternative to what? *International Journal of Science Education*, Vol. No. 2, pp. 119 – 135.
- Foster, P. (1993). Principles of social and educational research. The Open University Press.
- Fredette, N. and Lochhead, J. (1980). Students' conceptions of simple circuits. *The Physics Teacher*, 18: 194 – 198.
- Freyberg, P. and Osborne, R. (1985). Assumptions about teaching and learning. In Osborne, R. and Freyberg, P. (Eds) Learning in science. Heinemann.

- Gee, B. and Clackson, S. G. (1992). The origin of practical work in the English school Science curriculum. *School Science Review*, 73 (265).
- George, J. (1999) World view analysis of knowledge in a rural village: Implications for science education. In Cobern, W.W. (Ed.). *Science Education*, 83:77-95.
- Ginsburg, H. P. & Opper, S. (1988). Piaget's theory of intellectual development. 3^d edition. N. J. Prentice Hall.
- Good, R. and Shymansky, J. (2001). Nature of Science Literacy in Benchmarks and standards: Post Modern/Realist? In Bevilacqua, F., Giametto, E. and Matthews, M. R. (Eds) *Science Education and Culture: the Contribution of History and Philosophy of Science*, pp. 53 – 66. Netherlands: Kluwer Academic Publishers.
- Gray, B. (1999). Involving teachers in curriculum and material development – Insights from the Science Through Applications Project. Proceedings, 7th SAARMSE Conference, Harare, pp. 166-173.
- Guba, E. G. and Lincoln, Y. S. (1981). *Effective evaluation : Improving the usefulness of evaluation results through responsive naturalistic approaches*. San Francisco: Jossey-Bass.
- Gunstone, R. and White, R. (2000). Goals, methods and achievements of research in science education. In R. Millar, J. Leach and J. Osborne (eds) *Improving science education : The contribution of research.*, pp. 293-307. Buckingham: Open University Press.
- Guthrie, R. (2003). Contiguity theory. <http://tip.psychology.org/guthrie.html>. pp. 1-5.
- Habte, Y. (2003). The effect of a computer-based instruction (CBI) on Eritrean first-year Technical student's conceptions of electricity. M. Ed Thesis, University of the Western Cape.
- Habtemariam, T. (2003). Grade 10 Eritrean secondary schools students' understanding of chemical reactions. (Med Dissertation).
- Heinze-Fry, J. A and Novak, J.D. (1989). Concept mapping brings long-term movement towards meaningful learning. Wollman, W.T. (Section ed). *Science Education*, 73: 461 – 472.
- Heller, P. M. and Finley, F. N. (1992). Variable uses of alternative conceptions : A case study in current electricity. *Journal of Research in Science Teaching*, Vol. 29, No. 3, pp. 259 – 279.

- Helm, H. (1980). Misconceptions in Physics amongst South African students. *Physics Education*. Vol. 15. Printed in Great Britain, pp. 92 – 96.
- Hendricks, A. J. (2001). The effect of a computer simulation programme on promoting conceptual understanding of electricity amongst first year Peninsula Technikon science students. M. Phil. Thesis, University of the Western Cape.
- Hodson, D. (1992). Redefining and reorienting practical work in school science. *School Science Review*, March, Vol. 73, p.264.
- Hodson, D. and Hodson, J. (1998). From constructivism to social constructivism: a Vygotskian perspective on teaching and learning science. *School Science Review*, 79 (289).
- Hofmeyer, J. and Buckland, P. (1992). Education systems change in South Africa. In R. and A. Mc Gregor (eds) *Mc Gregor's education alternatives*. Cape Town: Juta.
- Jackendoff, R. (1994). *Patterns in the mind : Language and human nature*. Basic Books.
- Jegede, O. (1995). Collateral learning and the eco-cultural paradigm in science and mathematics education. *Proceedings of 3^d Southern African Association for Research in Mathematics and Science Education (SAARMSE) Meeting*, University of Cape Town: Cape Town. *Studies in Science Education*, 25: 97 – 137.
- Jenkins, E. W. (1997). Scientific and technological literacy for citizenship : What can we learn from research and other evidence? In Sjoberg, S. and Kallerud, E. (Eds) *Science, Technology and citizenship: The public understanding of Science and Technology in Science Education and Research Policy*. NIFU. Rapport 7/97.
- Jenkins, E. W. (2001). Constructivism in school science education: Powerful model or the most dangerous intellectual tendency. In Bevilacqua, F., Gianetto, E. & Mathews, M. R (Eds) *Science Education and Culture: the Contribution of History and Philosophy of Science*. Netherlands: Kluwer Academic Publishers, pp. 153 – 164.
- Kallaway, P., Kruss, G., Donn, G. and Fataar, A. (1997). *Education after apartheid*. Cape Town: UCT Press.
- Kitchener, R. F. (1986). *Piaget's theory of knowledge: Genetic epistemology and Scientific Reason*. London: Yale University Press.
- Leach, J. and Scott, P. (2000). Children's thinking, learning, teaching and constructivism. In Monk, M. and Osborne, O. (eds). *Good practice in Science Teaching; what research has to say*. Open University Press, pp. 41 – 56.

- Lee and Frass, S. H. (1996). Literacy skills in Science learning among linguistically diverse students. *Science Education*, Vol. 80, No. 6, pp. 651 – 671.
- Lee, Y. and Law, N. (2001). Explorations in promoting conceptual change in electrical concepts via ontological category shift. *International Journal of Science Education*, Vol. 23, No. 2, pp. 111 – 149.
- Levy, N. (1991). Matching education with employment: targeting the black labour force. In E. Unterhalter et al (eds) *Apartheid education and popular struggles*, pp. 19 – 34. Braamfontein: Ravan Press.
- Lewin, K. M. (1992). Science education in developing countries: Issues and perspectives for planning. I.I.E.P. Unesco.
- Liegeois, L.; Mullet, M. and Mullet, E. (2002). High school students' understanding of resistance in simple circuits. *International Journal of Science Education*, Vol. 24, No. 6, pp. 551-564.
- Linder, C. J. (1993). A challenge to conceptual change. *Science Education*, Vol. 77, No. 3, pp. 293-300.
- Lock, R. (1991). Open – ended, problem solving investigations - getting started. *School Science Review*, Vol. 72, p. 261.
- Mandela, R. N. (2005). Autobiography. http://wikiquote.org/wiki/Nelson_Mandela, p. 1.
- McRobbie, C. and Tobin, K. (1997). A social constructivist perspective on teaching environments. *International Journal of Science Education*, Vol. 19, No. 2, pp. 193 – 208.
- Measor, L. (1985). *Interviewing: A strategy in qualitative research*
- Merriam, B. S. (1978). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass Publishers..
- Metioui, A. Brassard, C., Levasseur, F. and Lavvoie, M. (1996). The persistence of students' unfounded beliefs about electrical circuits: the case of Ohm's Law. *International Journal of Science Education*, 18, 193 – 212.
- Millar, R. (1985). Training the mind: Continuity and change in the rhetoric of school science. *Journal of Curriculum Studies*, Vol. 17, No. 4, pp. 369-382.
- Millar, R. and Beh, K. L. (1993). Students' understanding of voltage in simple parallel electric circuits. *International Journal of Science Education*, Vol. 15, No. 4, pp. 351 – 361.

- Millar, R. and Driver, R. (1987) Beyond processes. *Studies in Science Education*, 14, pp. 33-62.
- Millar, R. and King, T. (1993). Students' understanding of voltage in simple series electric circuits. *International Journal of Science Education*, Vol. 15, No. 3, pp. 339-349.
- Mphahlele, M. (2000). Towards a single science and Technology educators' association : Reflections, challenges and future directions. *Proceedings: Science and Technology Education Conference 2000, Cape Town*, pp. 82 – 85.
- Muwanga-Zake, J. W. F. (2000). Is Science education in South Africa in crisis? The Eastern Cape experience. *JOSAARMSTE* 4(1):1-11.
- National Examinations – South African (2002)
- Novak, J.D. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching*, Vol. 27, No. 10, pp. 937-949.
- Novak, J. D. and Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press.
- Novak, J. D., Gowin, D.B. and Johanssen, T. G. (1983). The use of concept mapping and knowledge Vee Mapping with Junior High School science students. *Science Education*, Vol. 67, No. 5, pp. 625-645.
- Novodorsky, I. (1997). Constructing a deeper understanding. *The Physics Teacher*, 35:242 – 245.
- Nyagura, L. M. (1995). Educating Science teachers for lifelong learning: Trends, problems and projects in Southern Africa. *Conference Proceedings of a Regional Conference in Namibia*.
- Nye, R. (1996). *Three Psychologies: Perspectives from Freud, Skinner and Rogers*. USA: Brooks/Cole Publishing Company.
- O'Loughlin, M. (1992). Rethinking science education : Beyond Piagetian constructivism toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching*, Vol. 29, No. 8, pp. 791 – 820.
- Ogunniyi, M. B. (1984). *Educational measurement and evaluation*. Nigeria: Longman.
- Ogunniyi, M. B. (1986). *Teaching science in Africa*. Salem Media. Ibadan: Nigeria LTD.
- Ogunniyi, M. B. (1988). Adapting Western Science to Traditional African culture. *International Journal of Science Education*, 10(1):1-9.

- Ogunniyi, M. B. (1992). Understanding social science research. Ibadan : University Press.
- Ogunniyi, M. B (1998). Towards the formulation of science and technology policy in Mozambique: The Why, What and How.
- Ogunniyi, M.B. (1999). Assessment of grades 7 – 9 pupils’ knowledge and interest in science and technology. STL Project, University of the Western Cape: Cape Town.
- Ogunniyi, M. B. (1999). Understanding of science concepts among grade 7 – 9 pupils in the Western Cape. Proceedings of the 7th Southern African Association for Research in Mathematics and Science Education (SAARMSE) Conference, Harare: pp. 121-131, 337 – 342.
- Ogunniyi, M. B. (2002). Effects of exemplary instructional programme in science on learners’ understanding of force, acids and bases. STLP: Cape Town.
- Ogunniyi, M. B. (2004). The contiguity learning hypothesis: A cultural dialectic of border crossing? Paper presented at a seminar at University of the Western Cape.
- Ogunniyi, M.B. and Fakudze, C. (2003)  Grade nine South African students’ perceptions of force, energy and power.
- Ogunniyi, M. B. and Mikalsen, O. (2004). Ideas and process skills used by South African and Norwegian students to perform cognitive tasks on acids, bases and magnetism. African Journal of Research in SMT Education, Vol. 8 (2): 151-164.
- Ogunniyi, M. B. and Taale, K.D. (2004). Relative effects of a remedial instruction on grade seven learners’ conceptions of heat, magnetism and electricity. African Journal of Research in Mathematics, Science and Technology Education, Vol. 8(1): 77-87.
- Ogunniyi, M.B. and Yandila, C.D. (1994). Alternative conceptions of natural phenomena held by Batswana and Nigerian Secondary School Teachers. South African Journal of Mathematics and Science Education, 1(1):77-86.
- Orion, N., Hofstein, A., Tamir, A. and Giddings, G. (1997). Development and validation of an instrument for assessing the learning environment of outdoor science activities. Science Education, Vol. 81, pp. 161 – 171.

- Osborne, J. (1985). Building on children's intuitive ideas. In R. Osborne and P. Freyberg (eds) Learning in science – The implications of children's science. Heinemann, pp. 41 – 50
- Osborne, J. F. (1996). Beyond constructivism. Science Education, Vol. 80, No. 1, pp. 52 – 82.
- Osborne, R. J. (1981). Children's ideas about electric current. New Zealand Science Teacher: Vol. 29, pp.12-19.
- Osborne, R. J. (1983). Modifying children's ideas about electric current. Research in Science and Technological Education, Vol.1 (1):73-82.
- Osborne, R. J.(1983). Towards modifying children's ideas about electric current. Research in science and technology Education,1 (1), pp. 73-82.
- Osborne, J., Driver, R. and Simon, S. (1998). Attitudes to Science: Issues and concerns. School Science Review, March, Vol. 79, p. 288.
- Osborne, R. and Freyberg, P. (1985). Learning in science: The implications of children's science. Heinemann.
- Osborne, R.J. and Wittrock, M. C. (1985). The generative learning model. Studies in Science Education, Vol. 12: 59 – 87.
- Palmer, D. (1997). Linking theory and practice: a strategy for presenting primary science activities. School Science Review, Vol. 79, p. 286.
- Pardhan, H. and Bano, Y.(2001). Science teachers' alternate conceptions about direct currents. International Journal of Science Education, Vol. 23, No. 3, pp. 301-318.
- Patton, M. O. (1990). Qualitative evaluation and research methods (2nd edition). London: Sage Publications.
- Phelan, P., Davidson, A. L. and Cao, H. T. (1991). Students' multiple worlds : negotiating the boundaries of family, peer and school cultures. Anthropology and Education Quarterly, Vol. 22, 224 – 249.
- Phillips, D. C. (1995). The good, the bad and the ugly : The many faces of constructivism. Educational Researcher, Vol. 24, No. 7, pp. 5 -12.
- Piaget, J. (1970). Piaget's theory. In P. H. Mussen (ed). Carmichael's manual of child psychology. New York: Wiley.

- Posner, G. J. , Stirke, K. A., Hewson , P. W. and Gertzog, W. A. (1982). Accommodation of a scientific conception: Towards a theory of conceptual change. *Science Education*, Vol. 66, No. 2, pp. 211-227.
- Proper, H., Wideen, M. F. and Ivany, G. (1988). World view projected by science teachers : A study of claSsroom dialogue. *Science Education*, Vol. 72, No. 5, pp. 547 – 560.
- Psillos, D., Koumaras, P. and Tiberghiem, A. (1988). Voltage presented as a primary concept in an introductory teaching sequence on d.c. circuits. *International Journal of Science Education*, Vol. 10, No. 1, 29-43.
- Puhl, C. A. (2000). Teaching the language of science – A workshop. *Proceedings: STEC 2000*, Cape Town.
- Ramsden, J. M.(1992). If it's enjoyable, is it science? *School Science Review*, Vol. 73, p. 264.
- Riley, M. S., Bee, N. V. and Makwa, J. J.(1981). Representations in early learning: the acquisition of problem-solving strategies in basic electricity/electronics. *Proceedings of International Workshop on Problems concerning students' representations of Physics and Chemistry Knowledge*, Ludwigsburg (Ludwigsburg, West Germany: Padagogische Hochschule): 107-173.
- Rogan, J. M. (2001). Comments on the National Curriculum Statements- Natural Science – On behalf of the Centre for Science, mathematics and Technology education.
- Rollnick, M. and Rutherford, M. (1996). The use of mother tongue and English in the learning and expression of science concepts: a claSsroom based study. *International Journal of Science Education*, Vol. 18 (1), 91 – 103.
- Roth, W. and Roychoudhury, A. (1992). The social construction of scientific concepts or the concept map as conscription device and tool for social thinking in high school science. In Mollman, W.T. (section ed). *Science Education*, 76 (5): 531 – 557.
- Rozenchwajg, P. (1992). Analysis of problem solving strategies on electricity problems in 12 to 13 year olds. *European Journal of Psychology of Education*, Vol. VII, No. 1, pp. 5 – 22.
- Salkind, N. J. (2000). *Statistics for people who (think they) hate statistics*. Carlifonia: Sage Publications.
- Sanders, M. and Mogodi, M. (2000). Grade 10 learners' problems with words used in science lessons. *Proceedings: STEC 2000*, Cape Town. (pp. 163 – 171).

- Schollum, B. and Osborne, R. (1985). Relating the new to the familiar. In R. Osborne and P. Freyberg (eds). Learning in science : The implications of children's science. Heinemann, pp. 51 – 65.
- Setati, M. (1997). Teaching and learning mathematics in a second language. 5th SAARMSE conference, Witwatersrand.
- Shallcross, T., Spink, E, Stephenson, P. and Warwick, P. (2002). How primary trainee teachers perceive the development of their own scientific knowledge: links between confidence, content and competence? International Journal of Science Education, Vol. 24, No. 12, pp 1293 – 1312
- Shayer, M. and Adey, P. (1982). Towards a science of science teaching. London, Heinemann.
- Shayer, M. (1981). Towards a science of science teaching: Cognitive development and curriculum demand. London: Heinemann.
- Shepardson, D. P. and Moje, E. B. (1999). The role of anomalous data in restructuring fourth graders' frameworks for understanding electric circuits. International Journal of Science Education, Vol. 21, No. 1, pp. 77 – 94.
- Shipstone, D. (1984). A study of children's understanding of electricity in simple D.C. circuits. European Journal of Science Education, Vol. 6, No. 2, pp. 185-198.
- Shipstone, D. (1985). Electricity in simple circuits. In R. Driver, E. Guesne and A. Tiberghien (eds) Children's ideas in science. Open University Press.
- Shipstone, D. (1988). Pupils' understanding of simple electrical circuits. Physics Education, Vol. 23, pp. 92-96.
- Shipstone, D. and Cheng, P.C-H. (2001). Electric circuits : a new approach-part-1. School Science Review, 83 (303),55-63.
- Shipstone, D. M., von Rhoneck, C., Jung, W., Karrqvist, C., Dupin, J.J., Johsua, S. and Licht, P. (1988). A study of students' understanding of electricity in five European countries. International Journal of Science Education, Vol. 10, No. 3, 303 - 316.
- Smit, J. J. A. (1993). Shocking facts about electricity teaching. SAARMSTE Proceedings : First annual meeting.
- Smith, E. (1994). Mathematics, computers, and people: Individual and social perspectives. In P. Ernest (ed) Constructing mathematical knowledge: Epistemology and mathematical education. Vol. 4 (pp. 73 – 91). London: Falmer Press.

- Smith, E. (1995). Where is the mind? Knowing and knowledge in Cobb's constructivist and socio-cultural perspectives. *Education Researcher*, 24(6):23 – 24.
- Smith, H. W. (1975). *Strategies of social research*. Prentice – Hall Inc. New Jersey: Engelwood Cliffs.
- Smith, M. R. (1994). Scientific knowledge and cultural knowledge in the classroom. In K. P. Buda (ed) *First nations education*, (pp. 38 – 54). Brandon , M. B. : Brandon University Northern Teacher Education (BUNTEP), faculty of Education, Brandon University.
- Solomon, Z. (2001). An analysis of Eritrean grade 10 students' understanding of simple circuits, M. Phil. Mini-thesis, University of the Western Cape.
- Sono, T. (1999). *African teachers' struggle for educational justice in South Africa 1906 – 1996*. Pretoria: J. L. van Schaik.
- Statistics South Africa : *Education in South Africa (1996)*. Selected findings from Census 96.
- Stanton, M. (1989). Students' rule governed notions in series and parallel circuits, Institute for Mathematics and Science Teaching (IMSTUS), University of Stellenbosch, Newsletter 18:5-6.
- Sutton, C. (1992). *Words, science and learning*. Buckingham: Open Press University.
- Swainson, N. (1991). Corporate intervention in education and training, 1960-89. In E. Unterhalter et al (eds) *Apartheid education and popular struggles*, pp. 96-115. Braamfontein: Ravan Press.
- Tasker, R. & Osborne, R. (1985). Science teaching and science learning. In Osborne, R. and Freyberg, P. (eds). *Learning in science: The implications of children's science*. Auckland: Heinemann, pp. 15-27.
- Taylor, A. (1997). Learning science through creative activities. *School Science Review*, Vol. 79, p. 286.
- Taylor, P. C. (1997). *Constructivism : value added*. Curtin University of Technology, Perth, Australia, 1-22.
- Thorley, R. N. and Woods, R. K. (1997). Case studies of student's learning as action research on conceptual change teaching. *International Journal of Science Education*, Vol. 19, No. 2, pp. 229-245.

- TIMSS (1996). Science achievement in the middle school years. TIMSS International Study Centre, Boston College, MA, USA.
- Tobin, K. (1996). Cultural perspectives on the teaching and learning of science. Proceedings of the STS Joint Symposium, Tokyo, Japan, 76 – 99.
- Trochim, W and Land (1982). Designing designs for researcher. *The Researcher*, 1,1:1-6.
- Tsai, C-C (2003). Using a conflict map as an instructional tool to change students' alternative conceptions in simple series electric circuits. *International Journal of Science Education*, Vol. 25, No. 3, pp. 307 – 327.
- Tyobeka, E. (2000). Opening address : Science and Technology Education Conference (STEC), September 2000, Cape Town Conference Proceedings, pp. 1-3.
- Unterhalter, E. (1991). Changing Strategies of Reformism in Bantu education:1953-1989. In E. Unterhalter et al. (ed). *Apartheid Education and Popular Struggles*, Johannesburg : Ravan Press, pp. 62-64.
- Unterhalter, E., Wolpe, H., Botha, T., Badat, S., Dlamini, T. and Khotseng, B. (1991). *Apartheid education and popular struggles*. Johannesburg: Ravan Press.
- Urevbu, A. (1985). Methodology of science teaching. Benin: Juland Educational Publishers.
- Villani, A. (1992). Conceptual change in Science and Science Education. In Aikenhead, G. S. (section ed). *Science Education*, 76 (2): 223-237.
- Vygotsky, L. (1962). *Mind in society : the development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Vygotsky, L. (1978). *Thought and language*. Cambridge: MIT Press.
- Waldrup, B. G. and Taylor, P. C. (1999). Permeability of students' worldviews to their school views in a non-Western Developing country. *Journal of Research in Science Teaching* , Vol. 36, No. 3, pp. 289 – 303.
- Wandersee, J. H. (1990). Concept Mapping and the Cartography of Cognition. *Journal of Research in Science Teaching*, Vol. 27, No. 10, pp. 923-936.
- Watts, M., Jofili, Z. and Bezera, R. (1997). A case for critical constructivism and critical thinking in science education. *Research in science Education*, Vol. 27, No. 2, pp. 302 – 322.
- Webb, P. (1992). Primary science teachers' understandings of electric current. *International Journal of Science Education*, Vol. 14, No. 4, pp. 423-429.

- Wesi, P. R. (1997). Conceptualization of core concepts in electricity by Physical Science Teachers. *Journal of Research in Science Teaching*, 12(3): 255-267.
- White Paper on Education and Training (Notice 196 of 1995). Cape Town. 15 March WPJ/1995.
- White Paper on Science and Technology: Preparing for the 21st century (1996). Department of Arts, Culture, Science and Technology, pp. 1-96.
- Wittrock, M. C. (1974). Learning as a generative process. *Educational Psychology*, 11:87-95.
- Wolpe, H. & Unterhalter, E. (1991). Reporting, reform and transformation: approaches to the analysis of education in South Africa. In E. Untehalter et al (eds) *Apartheid education and popular struggles*, pp. 1-18. Braamfontein : Ravan Press..
- Woolnough, B. E. (1997). Motivating students or teaching pure science? *School Science Review*, Vol. 78 (285).
- World Book (2001). World Book Inc., 233N. Michigan, Chicago.
- Worldbook (2002). World Book Inc.,  233N. Michigan, Chicago.
- Yore, L. D. (2001). What is meant by constructivist science teaching and will the science education community stay the course for meaningful reform? *Electronic Journal of Science Education*, Vol. 5, No. 4.

APPENDIX A

PERMISSION LETTER TO SCHOOLS

23 Brink Crescent
Mandalay
7785
12 March 2002

The Principal
Hope High School
Langa
7505

Dear Madam

Re: LETTER SEEKING PERMISSION TO DO RESEARCH



My name is Khalipha Ramahlape, a science educator at Fezeka High School in Gugulethu. I am also pursuing further studies in the field. Currently I am studying for an M. Ed at UNIVERSITY OF WESTERN CAPE. As part of my studies, I am required to do research and submit a mini-thesis. This letter therefore serves to ask for your permission to do my research at your school.

My research involves finding out if an instructional tool known as “Vee-diagramming”, designed by Gowin in 1977, is effective or not in enhancing township learners’ understanding of some electrical concepts. I would like to use grade 8 learners for the study.

The completion of this study will not only be beneficial to me, but to the teaching fraternity as well, in that I will have added to the pool of knowledge about what instructional tool works or not in townships.

I hope that your management and School Governing Body will see value in this research and grant me the permission.

Yours in education
Khalipha Ramahlape (Mrs)

APPENDIX B

QUESTIONNAIRE

Please make a circle around what is applicable to you.

Personal information

Male

Female

Age

13

14

15

16

Above 16

Home language

Xhosa

Sotho



Tswana

Other

Questions

1. Where do you live?

Nyanga/Guguletu

Khayelitsha

Cross Roads

New Cross

Montana

Mandalay

M'Plain

Delft

Paarl

Stellenbosh

Langa

Philippi

2. Who do you live with at home?

Both parents single parent grand parents

Aunts and uncles

3. How many people stay with you at home?

Less than 4 5 6 7 8

Above 8

4. How big is the house that you live in?



Single room two roomed three-roomed

Four roomed more than four rooms

5. How do you get from home to school everyday?

Walk bus train taxi private car

6. Are any of your parents employed? Yes No

7. Do you have space to study or do homework at home? Yes No

8. Are you given time to study or do homework at home? Yes No

9. Does anyone at home help you with your school work? Yes No

10. Choose the highest educational background that your parents or the people you live with have.

Primary school High school College University
Technikon

11. Do you like science? Yes No

(ANSWER EITHER OR 12 OR 13)

12. If “yes”, what do you like about it?

How it is taught  What is taught The teacher
It is easy

13. If “no”, what do you hate about it?

How it is taught What is taught The teacher

14. Do you like the way electricity was taught? Yes No

(ANSWER EITHER 15 OR 16)

15. If “yes”, what exactly did you like?

Doing experiments Teacher talking too much

Doing concept maps

16. If “no”, what did you hate?

Doing experiments

Teacher talking too much

Doing concept maps

GENERAL COMMENTS – any comments about science, how it is taught, is it given enough time, any suggestions to the teacher?



**APPENDIX C
MCOET**

Name of the Learner: _____

Please complete the following

Gender

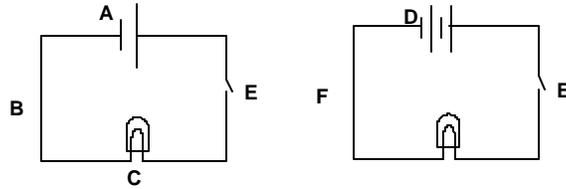
Female	<input type="checkbox"/>
Male	<input type="checkbox"/>

Age

Under 13 years	<input type="checkbox"/>
13 years	<input type="checkbox"/>
14 year	<input type="checkbox"/>
15 years	<input type="checkbox"/>
16 years	<input type="checkbox"/>
Above 16 years	<input type="checkbox"/>

My career choice is :

1. The two diagrams below are electrical circuit diagrams

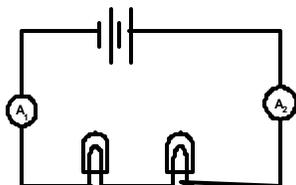


Identify each electrical symbol by placing the correct letter in the space next to each other.

- 1.1 a cell
- 1.2 a light bulb
- 1.3 an open switch
- 1.4 a closed switch
- 1.5 a battery
- 1.6 a connecting wire



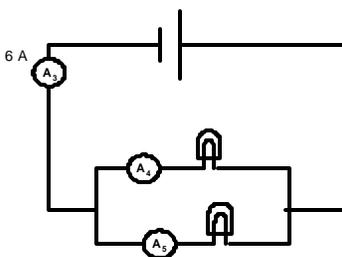
2. The following questions are based on the circuit below.



- 2.1. What type of instrument is A_1 _____
- 2.2. What does A_1 measure? _____
- 2.3. What are the units of current? _____
- 2.4. If the reading on A_1 is 6A. What would the reading be on A_2 _____
- 2.5. Another cell is added in series with the two cells in Circuit A. What happens to the reading on A_1 _____
- 2.6. How would this extra cell change the brightness of the bulbs? _____

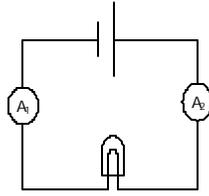


3. Look at the circuit below and answer the following questions.



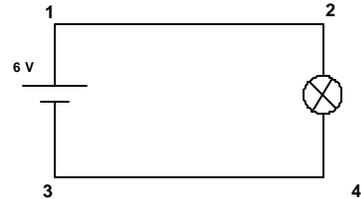
The current in A_5 is 4A and the current in A_3 is 6A. What would be the reading on A_4 ? _____

4. The reading on the ammeter in the circuit below is 5 A.

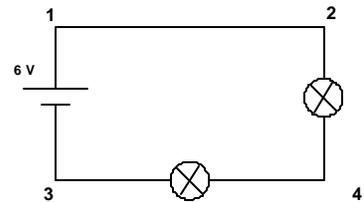


- 4.1 Charge is measure in units of _____
 4.2 What quantity of charge passes through the ammeter in 1 second. _____

5. Look at the following circuit.



- 5.1 Insert the values of the voltages across the points:
 1 and 2V, 2 and 3,V 3and 4
- 5.2 Now a second bulb of the same type is added between the points 3 and 4



Insert the values of the voltages across the points:
 1 and 2V, 2 and 3,V 3and 4

6. Resistors are used in most electronic circuits.

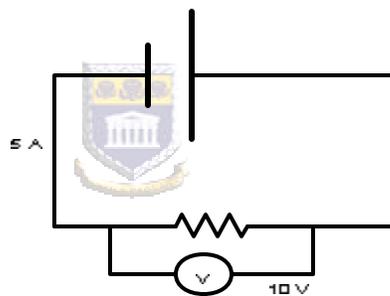
6.1 Name one purpose of the resistors in a circuit.

6.2 What are the 4 factors on which the resistance of a conductor depends?

7. The value of a resistance can be found by dividing the voltage across resistor by the current in the resistor

$$\text{Resistance} = \frac{\text{Voltage across resistor}}{\text{Current in Resistor}}$$

Look at the circuit below and answer the questions,



APPENDIX D

Lesson overview for introduction of the concept map

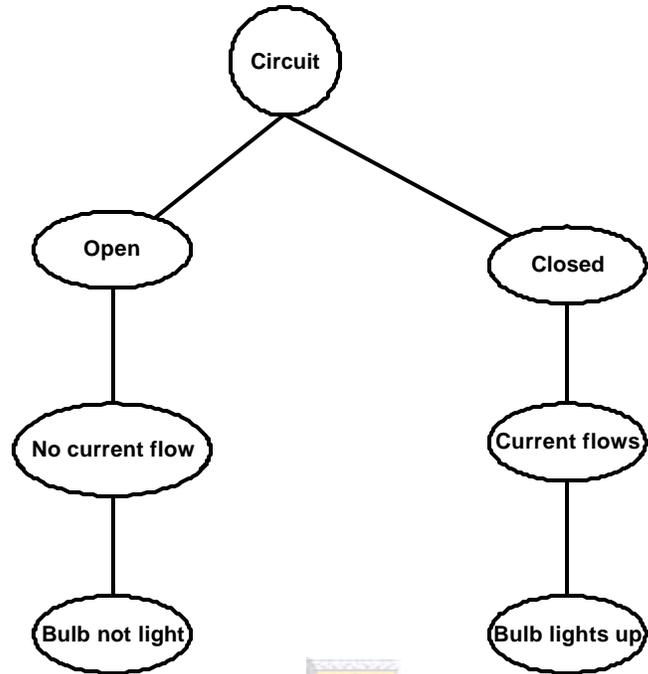
- Learners were given a meaningful paragraph e.g. :

In an electric circuit, the current will only flow if the circuit is closed, i.e. has no “gap”. Such circuits are said to be closed. Once there is a “gap”, the circuit is said to be open and the current will not flow. Once the current flows, the bulb will light up and if it does not light up, it means there is no current.

- They were given an opportunity to read the text and make sense of it.
- Key concepts necessary for understanding the text were selected as a class
- As a class they had to decide on the most inclusive concept, and it was placed at the top and the less inclusive followed
- Links between concepts were discussed and the concept map was built hierarchically.

APPENDIX E

CONCEPT MAP BY SOME OF THE LEARNERS



APPENDIX F

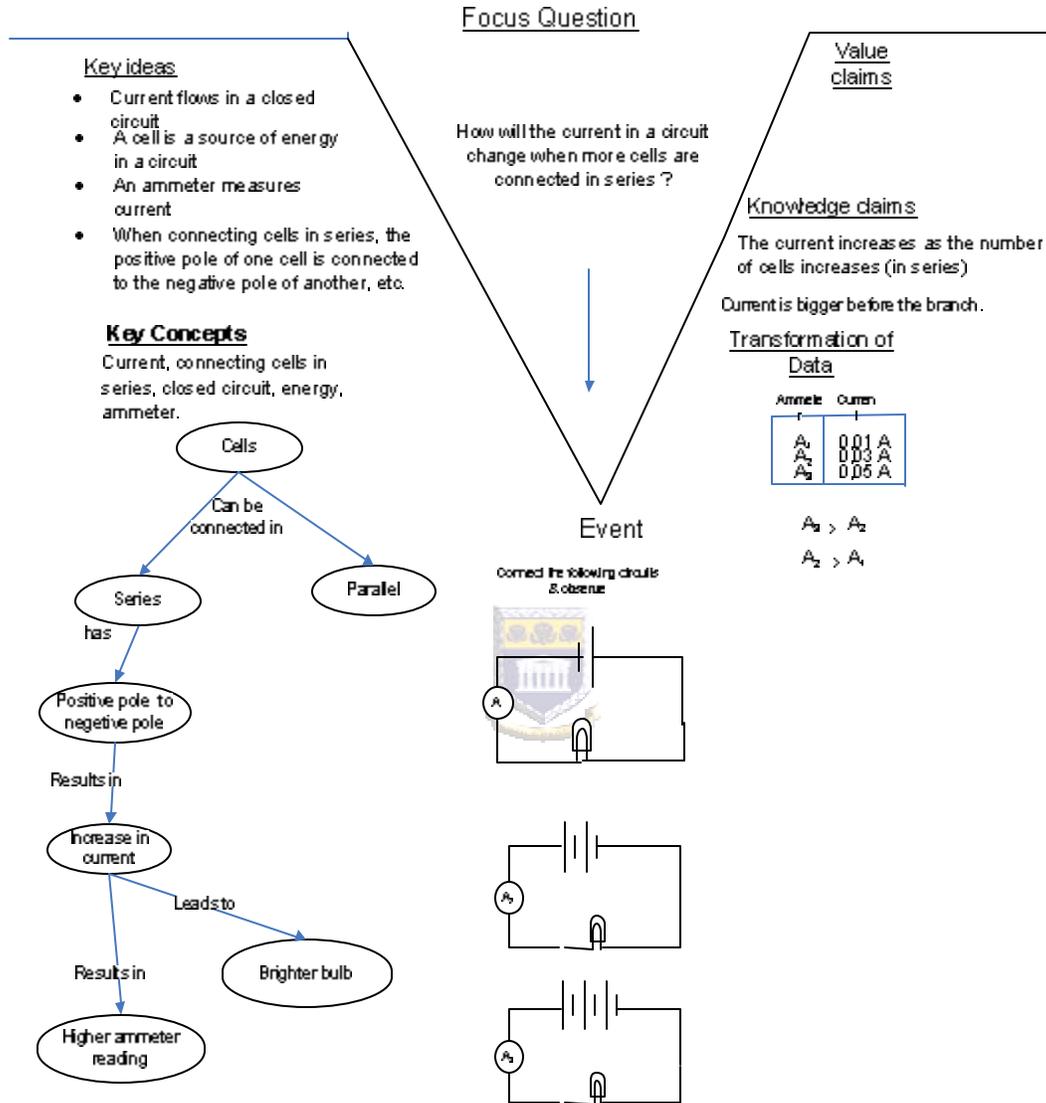
LESSON OVERVIEW ON VEE-DIAGRAMMING

- At this stage learners could draw concept maps already, they were introduced to idea of records and focus questions i.e. why record keeping is important, how records can be kept, what a focus question is, etc.
- Learners were then given a “focus question”.
- They were asked what other concepts they needed in order to answer the focus question.
- As this was discussed, various aspects were picked up from their discussions, i.e. what they were thinking. This then constituted the “My thinking” part of the Vee-diagram. From their thinking, key ideas or theories, principles and concepts were drawn.
- The actual investigation was then carried out.
- Observations were made and records taken
- Data was then transformed.
- Conclusions were drawn and knowledge claims and value claims were made.



APPENDIX G

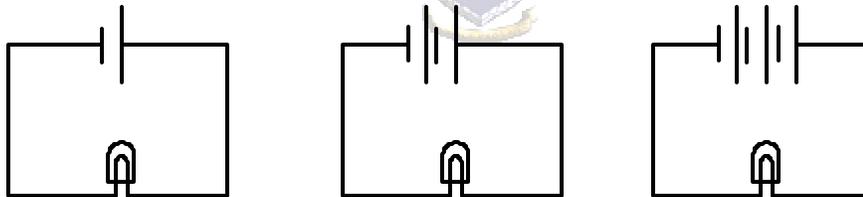
LEARNERS' VEE-DIAGRAM



APPENDIX H

INTERVIEW ITEMS

- a) How do you feel after the test?
- b) How was the test?
- c) How did you find the topic “electricity”? Has it been easy or difficult?
- d) Do you like the topic or not. If yes, what do you like? If no, what do you hate about it?
- e) When we do science at school, we do experiments. Did you find experiments helpful to your understanding or not?
- f) You did electricity last year as well. How did you feel about electricity last year as compared to this year?
- g) Were there any questions that you found challenging in the test?
- h) Let us look at some of the questions again:

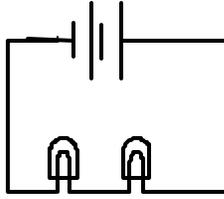


Which bulb will glow the brightest of the three?

Why?

- i) If we were to connect an ammeter in these circuits, which ammeter would give the highest reading? Why?

- j) If we were to connect an ammeter in circuit 2, next to the battery; after the first bulb; after the second bulb; next to the negative terminal – what would happen to the reading? Which one would be the highest?



- k) Are things that you learn at school related to what you do at home? Is the knowledge that you bring from home helpful or not? If yes, in what way?
- l) What can you say about the way you learned electricity this year as compared to last year? Has it been helpful or not? If so, in what way?
- m) Would you use Vee-diagramming in learning another subject?
- n) Have you tried using Vee-diagramming in another subject?

