

**THE EFFECT OF ACTIVITY-BASED INSTRUCTIONAL APPROACHES IN
AMELIORATING ALTERNATIVE CONCEPTIONS ABOUT ELECTRIC
CIRCUITS HELD BY STUDENTS FROM THE NATIONAL CURRICULUM
STATEMENT AND THE OLD SCHOOL CURRICULUM**

by

MMUSHETJI PETRUS RANKHUMISE

(U.D.E.S, H.E.D, B.Ed. Hons, M.Ed)

Submitted in fulfilment of the requirements for the degree

DOCTOR EDUCATIONIS: SCIENCE EDUCATION

in the

Department of Mathematics, Science and Technology Education

FACULTY OF EDUCATION

UNIVERSITY OF ZULULAND

Supervisor: Prof. SN Imenda

November 2012

DECLARATION

I hereby declare that the thesis submitted for the degree Doctor Educationis (D.Ed), at University Of Zululand, is my own original work and has not previously been submitted to any other institution of higher education.

Signature

Date

DEDICATION

This study is dedicated to my father, Titus Radetana Rankhumise, and my late mother, Paulina Ivy Rankhumise.

ACKNOWLEDGEMENTS

Anything you try to do cannot be reached or achieved without moral and spiritual support from others.

I therefore wish to express my sincere gratitude and appreciation to:

- My Heavenly Father for granting me the knowledge, wisdom and courage to pursue this study.
- Professor S.N.Imenda for his prompt and meticulous supervision as well as his tolerance and understanding.
- My wife, Nomathamsanqa, and my two beautiful daughters, Kutlwano and Kago, for support, motivation and courage
- My brothers and sister for support throughout the study.

ABSTRACT

Science students come to class with pre-instructional ideas that may influence the acquisition of science concepts. A basic assumption of the constructivist learning theory is that these pre-instructional ideas should be taken into account in constructing students' learning experiences in science classes. A number of conceptual change strategies have been studied in order to alter unscientific (also called alternative) conceptions towards the scientifically accepted conceptions. The challenging task of the science educator is to select appropriate teaching strategies and techniques that will enhance learning.

This study investigated students' alternative conceptions about electric circuits and the effect of activity-based instructional approaches in ameliorating these alternative conceptions. The approach took into account the prior beliefs of the students. A learning sequence was developed, presenting a variety of learning experiences in such a way and order that learners' alternative conceptions could progressively be changed into scientifically accepted ones. The sequence progressed from contextual to conceptual to formal activities. Co-operative learning, scientific enquiry, verbalisation and analogous reasoning techniques were used to guide learners in the acquisition of scientific concepts. The approach was based on the assertion that learners' scientific knowledge and understanding are socially constructed through talk, activity and interaction around meaningful problems and tools.

The research population consisted of hundred (100) first-year science students enrolled at a South African university both from the NCS and the OSC (Nated 550). The test that served as pre- and post-test probed into learners' alternative conceptions about electric circuits. A theoretical framework, based on activity-theory as it is applied in a constructivist view of learning, was developed. A pre-post-test comparison group design was followed. In particular, the pre-test helped to identify alternative conceptions held by the students in the research sample. This was then followed by activity-based interventions within the pedagogical aegis of OBE with a view to alleviate the identified alternatives conceptions. These interventions were followed by a post-test in order to ascertain the effectiveness of the interventions in alleviating the identified alternative conceptions. Both quantitative and qualitative data were collected. From the quantitative data, using McNemar and “t” test, the findings showed highly statistically significant gains between the pre- and post-test scores of both the OBE and OSC groups ($p < 0, 05$), thus indicating the effectiveness of the intervention. The qualitative data showed that most of the alternative conceptions appeared to have been alleviated, No statistically significant difference was found between the normalised gains of OBE and OSC groups.

Keywords: alternative conceptions, conceptual change, electric circuits, activity-based instructional approaches, teaching strategies, activity-theory

TABLE OF CONTENTS

TITLE PAGE.....	I
DECLARATION.....	II
DEDICATION.....	III
ACKNOWLEDGEMENTS	IV
ABSTARCT.....	V
LIST OF ACRONYMS.....	XX
INTRODUCTION	1
1.1 MOTIVATION FOR THE STUDY	1
1.2 STATEMENT OF THE PROBLEM.....	4
1.3. RATIONALE OF THE STUDY	7
1.4 OBE.....	9
<i>1.4.1Principles of OBE</i>	<i>9</i>
<i>1.4.2 The Key Principles of OBE :.....</i>	<i>10</i>
<i>1.4.3 OBE principles that lead to success:</i>	<i>11</i>
1.5 OBJECTIVES OF THE STUDY.....	12
1.6 RESEARCH QUESTIONS.....	13
1.7 HYPOTHESES	13
1.8 RESEARCH METHODS.....	14

1.8.1 Research Design	14
1.8.2 Research Instrument	14
1.8.3 Research Sample	15
1.9 LIMITATIONS OF THE STUDY	15
1.10 DEFINITION OF TERMS	16
1.10.1 Alternatives conceptions	16
1.10.2 Outcome-Based Education (OBE)	16
1.10.3 National Curriculum Statement (NCS)	17
1.10.4 Old school Curriculum (OSC)	17
1.10.5 Activity-Based Instructional Approaches	17
1.10.6 Learning	18
1.10.7 Model –Based Learning	19
1.11 ETHICAL CONSIDERATIONS	19
1.12 PLAN OF THE STUDY	20
REVIEW OF RELEVANT LITERATURE	22
2.1 INTRODUCTION	22
2.2 THE THEORETICAL PERSPECTIVE THAT FRAMES THE EMPIRICAL STUDY	23
2.2.1 THE NCS AS AN OBE CURRICULUM	23
2.2.2 CONCEPTUAL CHANGE THEORY	29
2.2.3 ACTIVITY THEORY (AT)	38

2.3 CURRICULUM CHANGES IN SOUTH AFRICA.....	42
2.3.1. OSC.....	45
2.3.2 NCS.....	50
2.3.3 OSC VERSUS NCS.....	60
2.4 GENERAL OVERVIEW OF ALTERNATIVE CONCEPTIONS.....	62
2.4.1 <i>Formulation of Alternative Conceptions.....</i>	<i>63</i>
2.4.2 <i>Synonyms for Alternative Conceptions.....</i>	<i>63</i>
2.4.3 <i>Origins of Alternative conceptions</i>	<i>64</i>
2.4.3.1 <i>Everyday experiences.....</i>	<i>64</i>
2.4.3.2 <i>Terminology.....</i>	<i>65</i>
2.4.3.3 <i>Teaching.....</i>	<i>66</i>
2.4.3.4 <i>Cultural beliefs and religion.....</i>	<i>66</i>
2.4.3.5 <i>Textbooks</i>	<i>67</i>
2.4.3.6 <i>Metaphoric use of terms.....</i>	<i>68</i>
2.5 HISTORICAL DEVELOPMENT OF CONCEPTS IN ELECTRICITY.....	68
2.5.1 CHARGE.....	70
2.5.2 ELECTRIC FORCE.....	72
2.5.3 ELECTRIC FIELD.....	72
2.5.4 ELECTRODYNAMICS.....	72
2.5.5 ELECTRIC CURRENT.....	74

2.5.6 CONVENTIONAL CURRENT.....	74
2.5.7 BATTERY.....	76
2.6. ALTERNATIVE CONCEPTIONS ABOUT ELECTRIC CIRCUITS	82
2.7 CONTEMPORARY TEACHING STRATEGIES.....	86
2.7.1 CONSTRUCTIVIST TEACHING APPROACHES.....	89
2.7.2 <i>ACTIVITY-BASED LEARNING (ABL) AND PROBLEM-BASED LEARNING (PBL)</i>	93
2.7.3 <i>VERBALISATION</i>	97
2.7.4 <i>ANALOGICAL REASONING</i>	98
2.7.5 <i>ENQUIRY AND INQUIRY TEACHING AND LEARNING</i>	100
2.7.6 <i>DISCUSSION BASED TEACHING</i>	104
2.7.7 <i>JUST-IN TIME TEACHING (JITT)</i>	105
2.7.8 <i>THE EPISTEMOLOGICAL APPROACH TO TEACHING ELECTRICITY..</i>	105
2.7.9 <i>THE MODELING APPROACH TO TEACHING ELECTRICITY</i>	107
2.7.10 <i>A MORE PRACTICAL APPROACH IN TEACHING ELECTRICITY</i>	113
2.7.11 <i>THE QUALITATIVE PROBLEM SOLVING APPROACH</i>	114
2.7.12 <i>USING MULTIPLE REPRESENTATIONS</i>	115
2.7.13 <i>CONCEPT MAPPING</i>	117
2.7.14 <i>CONTEXTUALISATION AS A DIDACTICAL APPROACH IN PHYSICS EDUCATION</i>	118

RESEARCH METHODOLOGY	122
3.1 INTRODUCTION.....	122
3.2 ACTION RESEARCH AS THE METHODOLOGY FOR THE STUDY TEACHING AND LEARNING OF SCIENCE	123
3.3 RESEARCH DESIGN	125
3.4 DATA COLLECTION.....	127
3.4.1 RESEARCH INSTRUMENT.....	127
3.4.2 Validity of the instrument.....	129
3.4.3 Reliability of the instrument.....	129
3.5 ACTIVITY-BASED INTERVENTION	130
3.6 PILOT STUDY	144
3.7. MAIN STUDY	145
3.8 AVERAGE NORMALISED GAIN.....	146
3.9 ETHICAL CONSIDERATIONS	148
3.10 SUMMARY	149
RESULTS AND DISCUSSION OF RESULTS	150
4.1 INTRODUCTION.....	150
4.2 BIOGRAPHICAL PROFILE OF THE RESPONDENTS	151
4.3PRE-TEST RESULTS AND IDENTIFICATION OF ALTERNATIVE CONCEPTIONS	152
4.3.1 PERFORMANCE OF NCS AND OSC GROUPS ON THE PRE-TEST	152

4.3.2 COMPARISON OF THE PERFORMANCE OF THE NCS AND OSC GROUPS ON THE PRE-TEST	154
4.4 ANALYSES OF PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	157
4.5 STATISTICAL COMPARISONS AND TESTING OF HYPOTHESES	190
4.5.1 THE EFFECT OF THE OBE- BASED INTERVENTION ON THE STUDENTS FROM THE NCS	191
4.5.1.1 <i>Normalised gain scores for the NCS group</i>	193
4.5.1.2 <i>The effect of the OBE- based intervention on the students from the OSC..</i>	195
4.5.2 COMPARISON OF PRE&POST-TEST RESULTS OF OSC STUDENTS	197
4.5.2.1 <i>Average normalised gain scores</i>	198
4.5.3 COMPARISON OF POST-TEST RESULTS OF NCS AND OSC STUDENTS	200
4.6 DISCUSSION OF FINDINGS	217
4.6.1 ALTERNATIVE CONCEPTIONS IDENTIFIED	217
4.6.2 CURRICULUM INTERVENTION BASED ON OBE PRINCIPLES WITH A VIEW TO REDRESS THE IDENTIFIED ALTERNATIVE CONCEPTIONS.....	219
4.6.2.1 <i>The effectiveness of the OBE-based intervention on NCS students</i>	219
4.6.2.2 <i>The effectiveness of the OBE-based intervention on OSC students</i>	219
4.6.2.3 <i>The effectiveness of the OBE-based intervention on NCS versus OSC students</i>	220
4.6.3 <i>Interpretation and discussion of the results of the gain scores</i>	222
4.7 CONCLUSION	222

CONCLUSIONS AND RECOMMENDATIONS	224
5.1 INTRODUCTION.....	224
5.2 SUMMARY OF STUDY	225
5.3 CONCLUSION	231
5.4 RECOMMENDATIONS	233
REFERENCES.....	234
APPENDIX A.....	282
APPENDIX B	281
APPENDIX C.....	294
APPENDIX D.....	302

LIST OF FIGURES

FIGURE 2.1: REPRESENTATION OF DUEL EPISTEMIC RESULTING FROM CONVENTIONAL PHYSICS LEARNING.....	33
FIGURE 2.2: REPRESENTATION OF A CONCEPTUAL CHANGE LEARNING PROCESS.....	34
FIGURE 2.3: CONCEPTUAL REFINEMENT MODEL FOR LEARNING PHYSICS.....	36
FIGURE 2.4: ACTIVITY-THEORY.....	40
FIGURE 2.5: BATTERY.....	76
FIGURE 2.6: A BASIC ELECTRIC CIRCUIT.....	77
FIGURE 2.7: CIRCUIT DIAGRAM	110
FIGURE 3.1: DIAGRAM FOR BULBS CONNECTED IN SERIES.....	137
FIGURE 3.2: DIAGRAM FOR BULBS CONNECTED IN PARALLEL.....	137
FIGURE 3.3: CIRCUIT DIAGRAM FOR PROBLEM 2.....	138
FIGURE 3.4: CIRCUIT DIAGRAM FOR PROBLEM 3.....	142
FIGURE 4.1: PRE-TEST RESULTS FOR NCS STUDENTS (N=50).....	153
FIGURE 4.2: PRE-TEST RESULTS FOR OSC STUDENTS (N=50).....	154
FIGURE 4.3: COMPARISON OF THE PRE-TEST RESULTS FOR NCS (N=50) AND OSC (N=50) STUDENTS.....	155
FIGURE 4.4: POST-TEST RESULTS FOR NCS STUDENTS (N=50).....	191

FIGURE 4.5: COMPARISON OF LEARNING GAINS OF NCS STUDENTS(N=50).....	192
FIGURE 4.6: POST-TEST RESULTS FOR OSC STUDENTS (N=50).....	195
FIGURE 4.7: COMPARISON OF LEARNING GAINS OF OSC STUDENTS(N=50).....	196
FIGURE 4.8: COMPARISON OF THE POST-TEST FOR NCS AND OSC STUDENTS (N=50)....	200

LIST OF TABLES

TABLE 1:THE RESULTS FOR ELECTRICITY & MAGNETISM (ESEM 03A)FOR THE PAST FIVE YEARS	2
TABLE 2:COMPARISON BETWEEN TRADITIONAL AND OBE APPROACHES.....	61
TABLE 3: COMPARISON OF PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	156
TABLE 4: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 1	158
TABLE 5: COMPARISON OF QUESTION 1 PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	158
TABLE 6: ALTERNATIVE CONCEPTION IDENTIFIED FROM QUESTION 2.....	160
TABLE 7: COMPARISON OF QUESTION 2 PRE-TEST RESULTS FOR NCS ANS OSC STUDENTS.....	161
TABLE 8: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 3.....	162
TABLE 9: COMPARISON OF QUESTION 3 PRE-TEST RESULTS FOR NCS AND OSC STUDENTS.....	163
TABLE 10: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 4.....	165
TABLE 11: COMPARISON OF QUESTION 4 PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	166
TABLE 12: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 5.....	168
TABLE 13: COMPARISON OF QUESTION 5 PRE-TEST RESULTS FOR NCS AND OSC STUDENT.....	169
TABLE 14: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 6.....	171
TABLE 15: COMPARISON OF QUESTION 6 PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	172
TABLE 16: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 7.....	173

TABLE 17: COMPARISON OF QUESTION 7 PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	174
TABLE 18: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 8.....	175
TABLE 19: COMPARISON OF QUESTION 8 PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	176
TABLE 20: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 9.....	177
TABLE 21: COMPARISON OF QUESTION 9 PRE-TEST RESULTS FOR NCS ANS OSC STUDENTS	178
TABLE 22: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 10.....	179
TABLE 23: COMPARISON OF QUESTION 10 PRE-TEST RESULTS FOR NCS ANS OSC STUDENTS	180
TABLE 24: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 11	181
TABLE 25: COMPARISON OF QUESTION 11 PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	182
TABLE 26: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 12.....	183
TABLE 27: COMPARISON OF QUESTION 12 PRE-TEST RESULTS FOR NCS ANS OSC STUDENTS	184
TABLE 28: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 13.....	186
TABLE 29: COMPARISON OF QUESTION 13 PRE-TEST RESULTS FOR NCS ANS OSC STUDENTS	187
TABLE 30: ALTERNATIVE CONCEPTIONS IDENTIFIED FROM QUESTION 14.....	188

TABLE 31: COMPARISON OF QUESTION 14 PRE-TEST RESULTS FOR NCS AND OSC STUDENTS	189
TABLE 32: SUMMARY OF ALTERNATIVE CONCEPTIONS ABOUT ELECTRIC CIRCUITS	190
TABLE 33: COMPARISON OF PRE & POST TEST RESULTS FOR NCS STUDENTS.....	193
TABLE 34: AVERAGE NORMALISED GAIN SCORES FOR NCS STUDENTS(N=50).....	194
TABLE 35: THE EFFECT OF AN OBE-BASED INTERVENTION ON STUDENTS FROM THE OSC CURRICULUM	197
TABLE 36: AVERAGE NORMALISED GAIN SCORES FOR NCS STUDENTS(N=50) AND OSC STUDENTS (N=50)	198
TABLE 37: COMPARISON OF PRE AND POST TEST RESULTS OF THE TWO GROUPS USING MCNEMAR TEST	199
TABLE 38: COMPARISON OF POST TEST RESULTS OF NCS AND OSC STUDENTS	201
TABLE 39: COMPARISON OF QUESTION 1 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	202
TABLE 40: COMPARISON OF QUESTION 2 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	203
TABLE 41: COMPARISON OF QUESTION 3 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	204
TABLE 42: COMPARISON OF QUESTION 4 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	205
TABLE 43: COMPARISON OF QUESTION 5 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	206

TABLE 44 COMPARISON OF QUESTION 6 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	207
TABLE 45: COMPARISON OF QUESTION 7 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	209
TABLE 46: COMPARISON OF QUESTION 8 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	210
TABLE 47: COMPARISON OF QUESTION 9 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	211
TABLE 48: COMPARISON OF QUESTION 10 POST-TEST RESULTS FOR NCS AND OSC STUDENTS.	212
TABLE 49: COMPARISON OF QUESTION 11 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	213
TABLE 50: COMPARISON OF QUESTION 12 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	214
TABLE 51: COMPARISON OF QUESTION 13 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	215
TABLE 52: COMPARISON OF QUESTION 14 POST-TEST RESULTS FOR NCS AND OSC STUDENTS	216

LIST OF ACRONYMS

OBE	Outcome-based education
OSC	Old School curriculum
NCS	National Curriculum Statement
FET	Further Education and Training
CAPS	Curriculum and Assessment Policy Statement
GET	General Education and Training
OECD	Organization for Economic Co-Operation and Development
WCED	Western Cape Education Department
DoE	Department Of Education
DoBE	Department Of Basic Education
L.O.	Learning outcome
A.S.	Assessment Standard
FAL	First Additional Language

CHAPTER 1

INTRODUCTION

1.1 MOTIVATION FOR THE STUDY

The South African education system is in a phase of fundamental reform, as opposed to incremental reform syllabus moving from a curriculum founded on a highly specified content-based, for each learning area in the curriculum, towards an outcomes-based education(OBE) curriculum in which the development of skills and attitudes has been given equal prominence to discipline content (Hobden, 2005:35).

Electricity is one of the themes in the science curriculum in South Africa. Electricity applications encompass many aspects of our everyday lives. Beyond the school/university curriculum or other module types, students need to understand electricity because it constitutes an aspect of energy; energy being a unifying concept in science. In essence, this is what makes it fertile ground for alternative conceptions, in which students develop views and imagery that are conceptually different from scientific ones (Nada, Iman &Waisim, 2009). Indeed, since electricity is very common in everyday situations, it is natural that students should have many alternative conceptions about it (Caillot & Xuan, 1993).

At the university where this study was carried out, many students have been performing poorly in the Electricity and Magnetism module, resulting in many repeaters every year. The results obtained by the students are shown in Table 1.

Table 1: The results for Electricity and Magnetism (ESEM 03A) for the past five years

Year	Registered students	Students Passed	Students Failed	Percentage of students Failed
2007	114	63	51	44.7%
2008	72	26	46	63.9%
2009	150	62	88	58.7%
2010	213	81	132	62%
2011	227	110	117	51.5%
2012	105	37	68	64.8%

It was therefore postulated that one of the reasons for the poor performances may be ascribed to the notion that students have alternative conceptions and as well as conceptual difficulties regarding electric circuits which could be interfering with formal instruction. Another reason for the sorry state of affairs could be ineffective teaching strategies used by the lecturer which may not promote meaningful learning. Most of the examiners' reports have commented on the extremely large number of students who perform very poorly on tasks related to electric circuits, and one of the observations has been that students showed little understanding of certain concepts such as emf, lost volts, internal resistance and external potential difference. Furthermore, students were also typically unable to state Ohm's law with accuracy. This suggests that practical investigations concerning Ohm's law were not conducted with a view to developing practical competence and facilitating understanding of the theory behind the practical activities.

There is a paucity of research in South Africa on alternative conceptions and conceptual difficulties regarding electric circuits, particularly with regard to research within the learning environment where alternative conceptions are used as the building blocks of scientific conceptions. Another contribution that this study seeks to make is to compare the performance of NCS and OSC students to determine whether or not there is a significant difference between the learning gains of the two groups, considering their conceptually different backgrounds. The other contribution that the study sets out to make is to determine whether changes in the curricula, and accompanying changes in teaching approaches, effectively enhanced students' conceptual knowledge of electric circuits. Activity theory (AT) offers an appropriate platform from which to provide OBE-based instruction. One way it does this is to clearly operationalise the specific roles of each player /stakeholder in the implementation of the curriculum.

Activity-based instructional approaches were used together with historical developments of concepts in electricity to ameliorate students' alternative conceptions. In this study, an epistemological approach was used as anecdotal enrichment in order to help students not to feel threatened by being confronted with "raw physics" and also for motivational reasons. The second reason was to introduce philosophical element into physics teaching and thus to familiarize students with scientific thinking patterns and the manner in which scientific knowledge is constructed. The philosophical element is lacking in most of physics textbooks, which deprives students of developing a solid foundation for learning the subject content and for appreciating the marvelous world of physics.

Electricity constitutes an important part of the physics syllabus at secondary school. Its significance in the syllabus is twofold: a study of electricity leads to the understanding of basic properties of matter and also to the understanding of the many practical applications of electricity in the modern world; and the understanding of electricity by an individual will, in all probability, help him/her to better understand an important part of the technological and natural world in which he/she lives (Caillot & Xuan, 1993).

1.2 STATEMENT OF THE PROBLEM

Students' pre-instructional knowledge plays a crucial role in the acquisition of science concepts in the classroom. Researchers such as Nussbaum and Norvick (1982) have demonstrated that students' alternative conceptions may differ from scientific conceptions and this tends to interfere with their learning of science. This finding is consistent with the constructivist notion that the internalisation (selective perception and interpretation) of new information and ideas by a person is a function of his/her existing conceptual framework (Ausbel, 1968). In general, most studies of students' alternative conceptions that have been conducted, so far, are based on assumptions that if learners' conceptions were to grow into more sophisticated understandings of science, educators must first establish the nature of their conceptions, and then choose the teaching/learning strategies that will accomplish the desired changes in the learners' existing alternative conceptions. This should also be seen in light of the belief that alternative conceptions are extremely resistant to change (Scott, Asoko, & Driver, 1992).

Learning and teaching science involves more than simply substituting everyday knowledge with scientific knowledge (Hewson & Thornley, 1989; Crespo, 2004). Although numerous perspectives about conceptual change have been proposed, the one initiated by Posner (1982), is amongst the most influential models and has gained support from research literature and teaching practice (Hewson & Thorley, 1989). According to Posner (1982) students would not abandon their tenaciously held ideas and beliefs and accept new ones unless they were dissatisfied with the former or found the latter intelligible, plausible and fruitful.

Science education researchers have found that interactive teaching strategies such as enquiry and problem-based approaches result in higher gains in knowledge and understanding of scientific concepts (Hake, 1998; Kabapinar, 2004). In a learner-centered science curriculum, such as the one advocated by the National Curriculum Statements (NCS) in South Africa, science learning is mandated to be active and constructivist, involving enquiry and hands-on activities. In such curricula, the purpose of learning activities is to develop critical thinking and problem-solving skills by posing and investigating relevant questions (Department of Education, 2003:2). In so doing, it is envisaged that the use of a wide range of learner-centered activities would improve both the learners' attitudes towards science and the actual cognitive learning of science (Ramsden, 1994), which includes factual recall as well as knowledge of process skills (Taraban, Box, Myers, Pollard & Bowen, 2007).

This study focuses on outcome-based education (OBE), given that it was the official pedagogic orientation of the country's education system before CAPS can be introduced in 2012. Some of the current first year university students have been exposed to this way of teaching during their school years. These students would have brought with them a number of challenges to universities, particularly with regard to the instructional approaches in universities which still remain largely frontal, content-based and lecturer-centred- and taking place in large lecture halls.

The NCS science students come out of an OBE learning paradigm and four cohorts have already written examinations based on the NCS. University lecturers will need to make a paradigm shift from traditional lecturer-centered instructional practices towards approaches akin to OBE in order to accommodate the learning experiences of these students. An understanding of the alternative conceptions that students bring to the tertiary education sector will serve as a very important input into the rearticulation of university programmes. These alternative conceptions in teaching strategies, which may lead to the required conceptual changes, must be studied in the science education modules by prospective science educators. Additionally, science education lecturers must, themselves, use these approaches so that the student teachers learn from experience regarding the constructivist ways of learning and teaching. Students come to university with various ideas about science. This is shaped by a number of factors, one being school instruction, and university lecturers are usually unaware of the alternative conceptions held by students.

1.3. RATIONALE OF THE STUDY

Research on science learning has shown that students come to science classrooms with pre-instructional knowledge or beliefs about the phenomena and concepts to be taught (Novak, 2000). In most cases, these ideas are not consistent with the scientific view, or may even be completely opposite to them (Duit *et al.*, 2002). Furthermore, research on alternative conceptions has shown that such alternative conceptions are very difficult to change; they are stable and well embedded in students' cognitive schemata.

A basic assumption of the constructivist learning theory is that learners' pre-instructional ideas should be taken into account in the preparation of current instruction (Bransford, Brown & Cosking, 2000). A number of conceptual change strategies have been studied with a view to alter unscientific ideas (called alternative conceptions) into more scientifically accepted conceptions (Scott *et al.*, 1992; Duit & Tregust, 1995). The challenging task of the science educator is to select the appropriate teaching strategies and techniques that will enhance the learning of the correct meaning and usage of scientific concepts.

Maloney, O'kuma and Hieggelke (2001) have noted that developing instruments for assessing students' ideas regarding electricity and magnetism is a more different task compared to other areas of physics.

Since electricity is very common in everyday situations, it seems almost natural that students would have many and diverse alternative conceptions about it. Although almost

all textbooks start their sections on electricity with the concept of electric charges, students tend not to have a clear understanding of the 'charge' concepts (Eylon & Ganiel, 1990).

Given that alternative conceptions are very stable, it is not easy to replace them with scientific conceptions (Novak, 2002). This is particular so in cases where traditional instruction is used, as this approach tends not to encourage meaningful learning. Changing alternative conceptions does not simply mean adding new information to an individual's mind, but rather taking care to account for the interaction between *new* knowledge and the existing knowledge in order to provide for the new to replace or modify the *existing* knowledge. Replacing existing (often faulty) knowledge with scientific knowledge is one of the aims of conceptual change strategies (Novak, 2002). Many researchers who study students' alternative conceptions in science have noted that traditional instruction, based on the notion of transfer of knowledge, is ineffective in correcting alternative conceptions, and does not usually result in meaningful learning (White, 1992).

Research has also established that students who are academically and/or economically disadvantaged, benefit from activity-based programmes (Donnellan & Roberts, 1985), particularly where the activities are designed to encourage active learner involvement; and where students are organised into collaborative learning groups (Ramsden, 1994). The greater the student involvement, the better and more long-lasting their learning tends to be (Donnellan & Roberts, 1985). The task of the educator as facilitator is to create

learning conditions in which students actively engage in experiments, interpret and explain data and negotiate understandings of their findings with their peers (Taraban, *et al.*, 2007).

Activity-based learning places particular emphasis on the use of everyday contexts as a starting point from which scientific concepts are developed and scientific ideas explored (Ramsden, 1994). In this way, learning starts from students' experiences and can be guided towards an understanding of concepts, methods and structures of physics as required (Lemmer & Lemmer, 2005). A sequence of activities from contextual to conceptual to formal learning can be established. Concomitantly, an effective shift from students' alternative conceptions towards a conceptual understanding of the scientific concepts can then be formalized. If educators are aware of students' learning experiences and the ideas they hold about science, then they are better able to design instructional approaches that are in line with policy imperatives, and which are guided with current understanding about the way students' learn.

1.4 OBE

According to Spady and Marshall (1991:34) OBE is an educational philosophy organised around several assumptions and principles as expatiated below.

1.4.1 Principles of OBE

The three key assumptions of OBE are that:

- ✓ All students can learn and succeed, but not on the same day in the same way;

- ✓ Successful learning motivates and encourages the learners to strive to learn more and mentally stretch themselves; and
- ✓ Schools control the conditions that directly affect successful school learning (Rapule, 2005)

1.4.2 The Key Principles of OBE are that:

- ✓ Educators need to establish a clear picture of the learning they want students to absorb;
- ✓ Student success becomes the top priority for planning, teaching and assessment;
- ✓ A clear picture of the desired outcome (result), the starting point of the curriculum, teaching, assessment planning and implementation, is necessary, all of which must match the targeted outcome (final result);
- ✓ The teaching process should ideally begins with the teacher sharing and explaining the outcome from day one onwards, so the 'no surprises' philosophy of OBE can be fully realized;
- ✓ One needs to design down, which means essentially working back from the desired final outcome to plan the teaching and curriculum to reach it. This consists of:
 - ✓ Culminating outcomes or exit outcomes - defining what the system wants all students to be able to do by the end of the learning experience;
 - ✓ Enabling outcomes - the building blocks for the culminating outcomes, essential to students ultimate performance success;

- ✓ Discrete outcomes - curriculum details that are 'nice to know' but not essential to culminating outcomes.
- Expanded opportunity, which means that:
 - ✓ Time should be used as a flexible resource, not a predefined absolute, in order to cater for students' different learning rates and aptitudes;
 - ✓ Educators should deliberately allow students more than one uniform, routine chance to receive the necessary instruction and demonstrate their learning successfully.
- High expectations, which means that:

Outcomes should present a high level of challenge for students, which all should be expected to accomplish eventually and be given credit for their performance at the stage during which it occurs (Rapule, 2005).

1.4.3 OBE principles applied correctly will lead to success in that:

- ✓ Time will no longer control the learning process and all learners will succeed, but by being able to develop at their own pace
- ✓ Outcomes will be measured continuously in various ways, not only by examinations
- ✓ Assessment is an integral component and applied broadly to cover different aspects of ability. In addition to subject content, creativity and critical thinking are assessed

- ✓ Learners are encouraged to take responsibility for their learning, they must know what they are learning and why.

Activity-based instructional approaches adhere to OBE principles in that they are student-directed and transactional that is, they use logically occurring antecedents and consequences to develop functional and generative skills by embedding interventions of students' individual goals and objectives in routine, planned or student-initiated activities. In activity-based instructional approaches, clear goals and objectives, which are functional and embedded in play activities or routines, are developed. The educator mediates the students' environment to facilitate learning with the student directing the educator on the pace and duration spent on the objectives (Dada, Granlund & Alant, 2006).

1.5 OBJECTIVES OF THE STUDY

The objectives of this study were to:

- 1.5.1 Identify the alternative conceptions held by first year university science education students regarding electric circuits;
- 1.5.2 Develop and implement curriculum interventions, based on pedagogic aegis of OBE principles, with a view to redressing the identified alternative conceptions;
- 1.5.3 Compare the learning gains of NCS students against those from the OSC.

1.6 RESEARCH QUESTIONS

1.6.1 What alternative conceptions do first year university science education students have about electric circuits?

1.6.2 What curriculum intervention based on pedagogic aegis of OBE principles could redress the identified alternative conceptions?

1.6.3 What are the learning gains of NCS students compared to OSC students following any instructional intervention using activity-based instructional approaches, couched within OBE principles?

1.7 HYPOTHESES

While the first research objective above generates large amounts of descriptive data, the latter two objectives were tested statistically. Accordingly, the following three *priori* hypotheses are formulated:

1.7.1 An OBE-based intervention will significantly alleviate alternative conceptions about electric circuits held by first year science education students who have been admitted from high schools that followed the NCS.

1.7.2 An OBE-based intervention will significantly alleviate alternative conceptions about electric circuits held by first year science education students who have been admitted from high schools that followed the OSC.

1.7.3 Students who studied under the NCS will demonstrate significantly higher learning gains after exposure to an instructional intervention using activity-based

instructional approaches, within pedagogic aegis of OBE, as compared to those who matriculated from the OSC.

1.8 RESEARCH METHODS

In this section, the research design and instrumentation, as well as research sampling techniques used in this study are explained.

1.8.1 Research Design

The pre-experimental one-group pre-test-post-test research design was followed with a view to determine the effectiveness of OBE-intervention. A test was undertaken in order to develop instructional materials aimed at addressing identified areas of difficulty in the field of electric circuits to the students. During the process of developing the instructional interventions that were used in this study, a Research and Development (R & D) protocol was also used. Activity-based instructional approaches within the pedagogic aegis of OBE were then followed with a view to alleviate the identified conceptual gaps in the students' understanding.

1.8.2 Research Instrument

First, a pre-test was administered to students for diagnostic purposes, i.e. to determine their alternative conceptions about electric circuits. The biographical information collected included the names of the previous schools the students had attended, their gender, and the year in which they completed Grade 12. The intervention strategies based on activity-based learning were developed. A variety of activities were chosen and

sequenced so that students' conceptions could progressively be changed from their alternative conceptions into scientifically accepted ones. These were based on succession of activities and discussions, and were aimed to enhance progression from contextual to conceptual, to formal understanding of the concepts. A post-test, the same as the pre-test, was administered at the end of the intervention in order to ascertain the effect of the intervention. The results were analysed using the t-test and McNemmar test. Additionally, normalised learning gains were calculated in order to cross-validate the effectiveness of the intervention. The gains of students from the NCS programme were compared with those from the OSC curriculum.

1.8.3 Research Sample

The study involved hundred (100) first-year university science education students enrolled at a South African University, both from the NCS and the OSC.

1.9 LIMITATIONS OF THE STUDY

The limitations of the study were that:

- a) The lecture rooms were not ideal for OBE instructional approaches as they have fixed seats;
- b) One group was used;
- c) The participants are exclusively from the Faculty of Education; and

- d) Most of the participants have completed their high school education in under-resourced schools, where OBE may not have been properly implemented.

1.10 DEFINITION OF TERMS

1.10.1 Alternatives conceptions

Students' own ideas and understandings of concepts that, which are contradictory to, or inconsistent with, the concepts as understood by scientists, are referred to as alternative conceptions, if these ideals and understanding have a measure of robustness and persistence across all ages and levels of schooling (Wesi, 2001). There are numerous synonyms for alternative conceptions, such as misconceptions, preconceptions, or alternative frameworks. The term misconceptions is, however, felt to be judgemental and since it implies that prior knowledge of students is unfounded and irrational (Wesi, 2001). Therefore, the term alternative conception is used in the current study.

1.10.2 Outcome-Based Education (OBE)

OBE forms the foundation of the curriculum in South African schools and the assessment framework of the NCS for Grade R-12 (Department of Education, 2003). CAPS has not yet influenced those students who are entering universities; therefore, the focus in this study is on OBE. "OBE encourages a learner-centered and activity-based approach to education (Department of Education, 2003:2)." OBE is an approach in an education system where everything is defining, designing, building, focusing and organizing on the

things of lasting significance that we ultimately want every learner to demonstrate experiences”(Spady,2008a:7).

1.10.3 National Curriculum Statement (NCS)

This statement embodies and upholds a democratic vision of society and citizens that should emerge from the South African school system. By means of the learning area statements, the NCS identifies the goals, expectations and outcomes that need to be achieved through related learning outcomes and assessment standards. In the Revised National Curriculum Statement (RNCS) for both the General Education and Training (GET) band and Further Education and Training (FET) band, specific outcomes have been replaced by learning outcomes.

1.10.4 Old school Curriculum (OSC)

OSC was highly structured, prescriptive and not easily adaptable, and left little room for education initiatives. Furthermore, the curriculum was content-based. It was also teacher-centered, as opposed to being learner-centered. The OSC refers to Nated 550 which was teacher centered.

1.10.5 Activity-Based Instructional Approaches

These approaches place particular emphasis on the use of everyday contexts as a starting point, from which scientific concepts are developed and scientific ideas explored (Ramsden, 1994:7).

1.10.6 Learning

Like teaching, the notion of "learning" has different definitions, depending on the particular perspective or viewpoint that is used. A number of theories have attempted to define learning. In the didactical situation, an educator uses various methods and lets learners take ownership of learning. According to De Wet (1971) (quoted by Vreken, 1980) the educator and learners in teaching and learning, respectively, achieve this by means of applying a variety of teaching and learning media. Vreken (1980: 132) aligns himself with the work by Mackenzie, Eraut and Jones (1970) where learning is defined and categorized by Perlberg and O'Bryant as a dynamic and interactive process in which:

- ✓ The role and experience of the learner are vital components in which he should contribute, as well as receive;
- ✓ The learner's perception of what is happening is as important as the perceptions of his/her teacher; and
- ✓ The assessment of whose value may be more relevant than that of the learner's examined.

Vreken (1980) and Mackenzie, *et al.* (1970) argue that good conventional teaching has always sought to take account of the learner. However, its' structure and methods have actually greatly inhibited this. The inflexible style imposed by large numbers, the needs of timetables and the availability of teaching space, the conventional practices by means of which courses are designed; and the teaching based upon the format of an accepted academic discipline; have meant that the emphasis has been mainly on teaching. Once we

accept that learning rather than teaching is the point of departure, we have to ask ourselves different and searching questions.

1.10.7 Model –Based Learning

According to Clement and Rea-Ramirez (2008), a model is considered to be a simplified representation of a system. An explanatory model for a system is a hypothesised, theoretical, qualitative mental model (such as molecules, waves, and fields) that provides a (usually causal) description of a hidden, non-observable mechanism that explains how the system works. These can enable aspects of the system, i.e., objects, events, or ideas that are either complex, abstract or on a different scale to that which is normally perceived, to be rendered more readily visible and are the focus here. Model-centered or model-based learning is grounded in the theory that humans construct “mental models” as internal cognitive representations that support explanation and understanding by simulating the behavior of systems in the real world. In model-based learning, it is assumed that learners construct explanatory mental models of phenomena in response to particular learning tasks, by integrating pieces of information about structure, function/behavior, and causal mechanisms. Learners then use and continuously re-evaluate their models, discarding or revising them as needed (Clement & Rea-Ramirez, 2008),

1.11 ETHICAL CONSIDERATIONS

The researcher has gained the support of the students by emphasising the importance of the research project and its benefits. The researcher has required the necessary consent from students who have participated in the study. However, it would be to their

disadvantage if they do not take part in the study, because the study content forms part of their curriculum.

1.12 PLAN OF THE STUDY

Chapter 1

The motivation of the study to be undertaken, problem statement, aims of the study, research objectives and formulation of hypotheses and research methodology, definitions of terms were outlined in this chapter.

Chapter 2

A literature review focusing on alternative conceptions about electricity was presented, followed by a discussion of contemporary teaching strategies that could be used to promote learning of scientific concepts in the field of electric circuits.

Chapter 3

The literature study that is presented in this chapter serves as a framework for the empirical study. The research methodology is also described in this chapter.

Chapter 4

The results of the empirical study are presented and discussed in this chapter.

Chapter 5

A summary of the study, conclusion and recommendations that emanated from this study are presented in this chapter.

CHAPTER 2

REVIEW OF RELEVANT LITERATURE

2.1 INTRODUCTION

Since early childhood students experience the natural world and formulate intuitive ideas about it; these ideas often differ from accepted scientific ideas (Shuell, 1987). No matter how non-scientific these ideas may be, however, students will attempt to align what is being taught with their own intuitive ideas (Stavy & Berkvit, 1980). In science the intuitive ideas that differ from the scientifically accepted meanings are called alternative conceptions.

Periago and Bohigas (2005:71) argue that “one of the most dynamic lines of research into the teaching of the experimental sciences in recent years has been the study of the alternative conceptions that students use to interpret a range of phenomena both before and after being formally taught the subject in question”. Students have always been prone to giving wrong answers to questions asked in the classroom and, traditionally, the response of teachers has been to impose penalties when this happens (Periago & Bohigas, 2005:71). Nevertheless, students’ mistakes have increasingly been viewed from a different perspective.

This chapter reports on the literature study in the field of alternative conceptions about electricity and studies on electric circuits, specifically, as well as contemporary teaching strategies that may promote meaningful learning based on OBE, this is done, with a view to overcome alternative conceptions using the theoretical framework of activity-theory, which in turn will give rise to a comparisons between the performance of students coming from the NCS and OSC curricula.

Thus, this chapter begins by presenting the theoretical perspectives that frame the empirical study, as more fully set out in chapter three. This is then followed by an overview of the old school curriculum, as well as the NCS, which is based on the theoretical tenets of OBE.

2.2 THE THEORETICAL PERSPECTIVES THAT FRAME THE EMPIRICAL STUDY

This study intended to ameliorate students' alternative conceptions regarding electric circuits by developing activity-based instructional approaches. In order for the researcher to develop effective intervention a review of theories needs to be conducted. The theoretical framework for the intervention was developed out of the selected theories.

2.2.1 THE NCS AS AN OBE CURRICULUM

In this sub-section, the researcher outlines the basic principles of OBE, which is the educational philosophy which forms the bedrock of the NCS. In doing this, the researcher

presents constructivism as the underlying educational psychology upon which OBE is firmly etched.

Within educational theory and practice, constructivism is concerned with the teacher's ability to facilitate conceptual change among his/her learners. Thus, the sub-section that follows constructivism addresses issues regarding conceptual change. The last subsection provides a bridge towards implementation by identifying the activity- theory (AT) as linking well with OBE. In particular, the researcher attempts to demonstrate in this subsection, that activity-based instructional approaches would be appropriate to effect conceptual change within the educational philosophy of OBE.

CONSTRUCTIVISM

It has been proven that learners come to class with personally constructed knowledge and ideas about the world (Scott, Asoko & Driver, 1992). This notion forms the basis of the theory of constructivism. It follows that learners' alternative perceptions are likely to stand in the way of the teaching and learning process (Driver, *et al*, 1985:3). It is also quite difficult to change learners' conceptions about their knowledge before engaging them in the intended learning experience. This process of changing learners' views is referred to as conceptual change (Scott, Asoko & Driver, 1992)

The study of science as a natural philosophy has a very long history (Wesi, 2001). The major developments that took place in science during the eighteenth and nineteenth centuries sparked wide interest in the study of science and from here followed the need to introduce it as a school subject. The introduction of science in schools became a matter of

long and intensive debate, in particular. “One of the issues, which had to be decided upon, was the standardisation of the methodology of the teaching and learning of science in schools so that there was only one uniform method of enquiry” (Wesi, 2001:21).

Up until 1870, science was widely taught by means of lecture demonstrations, with instructor performing experimental demonstrations and supplementing them with information from textbooks (Trumper, 1990). It was later realised that this instructional method produced students who lacked first-hand familiarity with scientific concepts and procedures, because students were not allowed to perform experiments on their own (Wesi, 2001). A discussion of this method of teaching, referred to as the transmission model or the traditional model, is presented below.

The constructivist approach to teaching assumes the existence of students’ conceptual schemata and active application of these responding to and making sense of new situations (Trumper, 1990; Geer & Rudge, 2002). Two important questions, which have aroused the interest of educators in recent times are: “how does the student learn?” and “how can we help the student to learn more efficiently?” These questions are of particular significance to natural science educators because logical and hierarchical structures of the natural sciences place special demands on the cognitive abilities of learners (Wesi, 2001). This relatively new theory is the essence of the newly introduced OBE in South Africa and is based on the following assumptions:

- 1) That knowledge is constructed in the mind of the learner (Collins, 2002). This implies that the learning process involves the characteristics of the learner, his or her abilities,

attitudes and perceptions of the world (Wesi, 2001). The constructivist view takes into account differences among learners or students (Trumper, 1990). Each and every learner is unique, both in terms of abilities and perceptions of the world. The individual's perception of the world is constructed as a result of observations made from surroundings and personal experiences with "the stuff of science". This in turn leads to the formation of alternative conceptions. Thus, in every individual's mind, there are constructs of how the world operates (Wesi, 2001). These constructs influence the way in which incoming knowledge is interpreted and understood. It is thus possible that the same set of information can be interpreted differently by different people. This point illustrates the critical role played by individual differences in learning (Collins, 2002). In terms of abilities, constructivism recognises the fact that it is impracticable to expect learners to achieve success at the same rate.

The constructivist theory also recognises that individual's attitudes towards certain topics could influence their learning (Wesi, 2001). These attitudes are guided by beliefs; value systems and the prior knowledge possessed by individuals. In this regard, learning takes place best when learners feel good about the learning task and have positive attitudes towards it. For this to be achieved, learners must be led to realise the significance of the learning task and its relevance to their everyday lives. The genetic inheritance of individuals and the context in which learning takes place also influence the learning process.

According to the constructivist view, learning does not take place through the transmission of knowledge from the teacher (source) to the learner (the receiver). Knowledge is thus not transmitted but it is rather constructed by the learner (Wesi, 2001). Learning can thus not be achieved through drilling information into learners. The role of the teacher is also conceptualised differently. The teacher is not perceived as the only source of information and knowledge but as a facilitator of learning. His/her role is to enable learners to access information and to guide them through the learning process. He/she is also responsible for supporting, nurturing and assessing learners to help them improve. In this case, the teacher is not perceived as the overall authority who is in control of the learning process.

2) Upon entering science classrooms, it is accepted that students bring with them some prior knowledge about science (Collins, 2002). This prior knowledge, which was referred to as preconceptions in previous sections, is seated within the mental structures of the child. The constructivist theory asserts that the prior knowledge of the child has a direct impact on his/her learning and should not be ignored. The assumption that students' minds are like 'empty vessels' waiting to be filled with knowledge is in vast contrast to the constructivist view of learning.

According to the constructivist theory, therefore, learning is not purely a receptive process. Instead, it is an active process where students construct their own knowledge (Collins, 2002). What matters is not what learners abstract, but the construction that they make from what is presented. They create meaning from information presented to them.

These meanings are compared with already existing knowledge structures. If this new knowledge is found to be inconsistent with the existing structures, the individual may abandon and reject the new material as not making sense, or he or she may decide to memorise it for the purpose of passing examinations. In this case no learning would have taken place since new knowledge is not assimilated into the person's mental structure and therefore, prior knowledge is still retained (Wesi, 2001). We say that learning takes place if, upon realising the inconsistency between the new and the prior knowledge, the student consciously modifies his/her mental structures with a view to accommodate the incoming knowledge. Thus the restructuring of existing structures is crucial to the learning process.

Science teachers are well aware that even when they explain ideas slowly, carefully, and clearly students often fail to grasp the intended meaning (Driver, 1989). Understanding how students learn and when they tend to struggle to grasp intended meanings constitute the foundation of informed teaching. To achieve robust long term understanding, multiple connections of learning must be erected and grounded in experience, but unfortunately these links cannot simply be given to students (Driver, 1989). Fundamental to our understanding of learning is that students must be mentally active, selectively taking in and attending to information; connecting and comparing the new information to prior knowledge in an attempt to make sense of what is being received (Driver, 1997). However, in attempting to make sense of instruction, students often interpret and sometimes modify incoming stimuli so that it is made to fit (i.e. to connect) with what they already believe. Consequently, students' prior knowledge that is at odds with

intended learning can be extremely resistant to change (Driver, 1989). The failure of individuals to modify their own mental structures explains the difficulties encountered in the teaching and learning of science. In nature, preconceptions are very resistant to instruction (Chi, 2005). Restructuring such concepts is thus not an easy exercise by any stretch of the imagination. It is the most difficult and yet the most essential aspect of learning. Strategies of dealing with this problem will be discussed in the section below. If on the other hand, there is a match between the incoming knowledge and the existing knowledge, the new knowledge is understood and incorporated in the mental structures of the individual. In this case, the new knowledge is internalised and form part of the individual's mental structures.

3) That learning is a lifelong process, and it is not confined to a specific period in the life of individuals. It is a continuous process and does not take place in stages (Wesi, 2001). Learning can take place anywhere, both inside and outside of the science classroom. The traditional way of looking at learning is that learning takes place only when information is presented to the learner by the teacher in the classroom situation, or when the learner obtains information from textbooks.

2.2.2 CONCEPTUAL CHANGE THEORY

The necessary conditions for conceptual change are disequilibrium, assimilation and accommodation (Piaget, 1950). If the result of an event does not fit the student's existing conceptions, this situation disequilibrates the student with respect to his/her current conception. If students can assimilate the concepts presented to them, then there is no

disequilibrium, which is the result of an unexpected event. Therefore, teaching should aim to disequilibrate students for conceptual change (Dykstra, 1992).

Science teaching should make use of a conceptual framework which promotes conceptual change. Over the years, different researchers have, used different terms for conceptual change such as weak and strong restructuring (Carey, 1985), branch jumping and tree switching (Thagard, 1992), conceptual capture and conceptual exchange (Hewson & Hewson, 1992), differentiation and reconceptualisation (Dykstra, 1992) and enrichment and revision (Vosniadou, 1994)

Posner, Strikes, Hewson and Gertzog (1982) and Vosniadou, (2007) assert that there are two distinguishable phases of conceptual change in science. The first is based on ordinary scientific work that is undertaken against the background of central commitments, or paradigms. The second phase of conceptual change occurs when these paradigms require modification. According to Kuhn, this leads to a scientific revolution (in Posner, *et al*, 1982)

Too often, educators of physics consider their learners to be "clean mental slates" and act accordingly in order to fill their "empty vessels" (Cosgrove, 1985; Carl, 2008). The problem with this approach is that the vessels are not empty but contain numerous preconceptions. Learning cannot be a passive process of simply absorbing knowledge, because it includes modifying and restructuring ideas to fit into one's existing framework (Driver, *et al*, 1985; Carl, 2008). On the other hand, learners' naive theories or

preconceptions may lead to misconceptions and may thus interfere with the acquisition of scientifically accepted concepts.

Posner, *et al.* (1982) have proposed a model of conceptual change that involves a series of conditions, namely:

- (1) Learners become dissatisfied with existing alternative conceptions because the conceptions appear useless for solving a problem.
- (2) A new conception must be intelligible.
- (3) A new conception must appear initially plausible.
- (4) A new conception should be fruitful, have more explanatory power and is useful to solve problems.

Science educators (e.g., Hewson & Thorley, 1989) also suggest that the learners are the ones who should judge whether these conditions are being met.

Scott *et al.* (1992) provide a review of strategies that can be used with a view to accomplish conceptual change in the science classroom. Many researchers have claimed that conceptual change occurs through cognitive conflict in what Gilbert and Watts (1983) call a revolutionary change process. However, some alternative conceptions, such as the one in which energy is associated with human beings, is not an unacceptable – conception because it conflicts with accepted scientific conceptions (Gilbert & Watts, 1983). Rather, it is limited, and should be expanded to an understanding that the principle of conservation of energy holds for all objects. In this case, researchers talk about an

evolutionary change, which involves the facilitation of extension in richness and precision of meaning in terms of learners' conceptions (Gilbert & Watts 1983).

Most traditional science instruction does not pay sufficient attention to learners' intuitive conceptions and explanations (Lemmer, 2011). The result of this state of affairs is that students often perceive science as an isolated, separate academic world (Kruckenberg, 2006). Their conceptions that have been formed based on everyday experiences differ from the formal knowledge gained from activities in the science classroom. The result is a dual epistemic in which the everyday life and science conceptions co-exist, as illustrated in Figure 2.1 (Lemmer & Lemmer, 2010). Accordingly, students use their intuitive knowledge in everyday life, but algorithmically apply the physics definitions and laws in the science classroom (Lemmer, 2011)

Traditional instruction induces only small changes in students' intuitive ideas (Hake, 1998). Science education researchers have studied learners' intuitive conceptions and with a view to determine how to foster conceptual change. According to Posner, Strike, Hewson and Gertzog (1982) for conceptual change to be successful, learners have to be dissatisfied with their current conceptions and find the scientific ideas intelligible, fruitful and plausible. A conception is intelligible when its meaning is understood by the student, it is plausible when the student finds the conception believable and is fruitful if it helps the students to solve other problems (Lemmer, 2011)

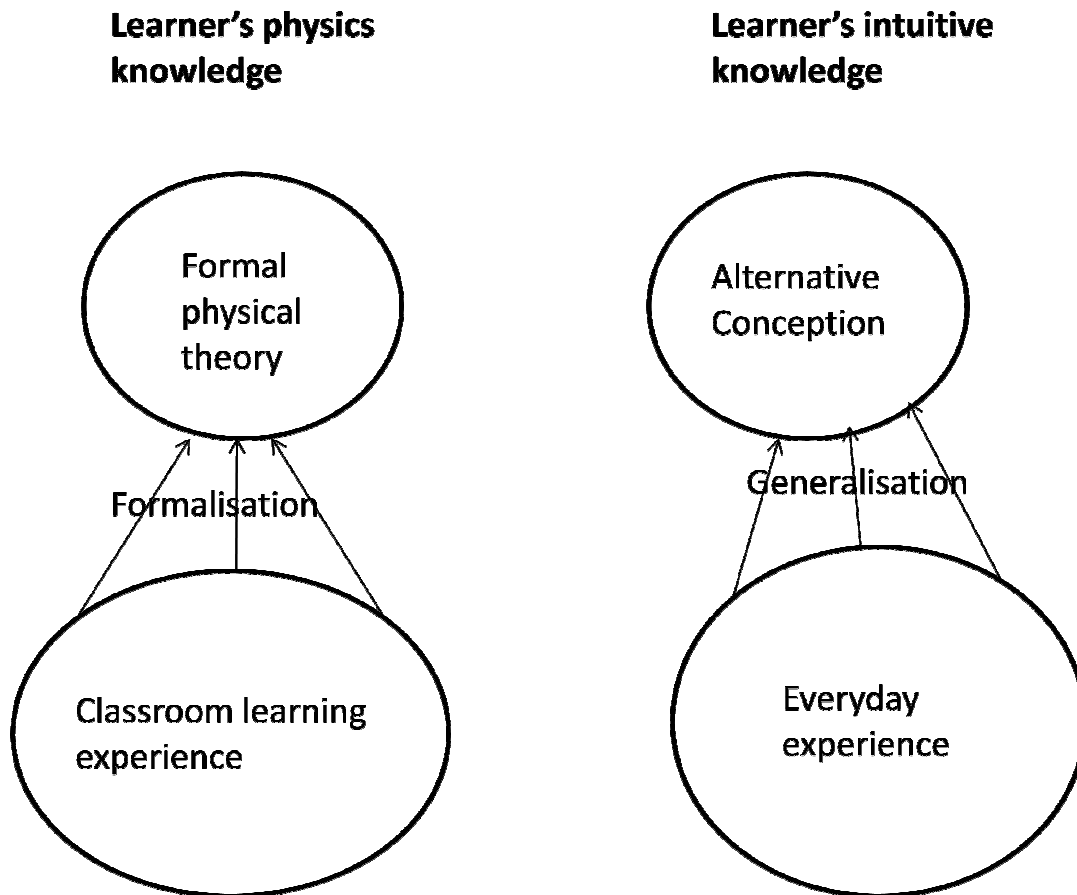


Figure 2.1: Representation of dual epistemic resulting from conventional physics learning (Adopted from Lemmer, 2011:6)

According to Hewson and Hewson, (1984), as well as; Caravita, (2001) cited by Lemmer, (2011:6), cognitive conflict or conceptual conflict approaches are generally used to foster conceptual change. Students' dissatisfaction, i.e. their feeling that something is not as good as it should be with their own conceptions, is established in a conflict situation. Students' efforts are then directed towards resolving this conflict (Lemmer, 2011; 6).

Accordingly, Posner *et al.* (1982) cited by Lemmer, 2001:6, argued that a possible true, or able to be believed conception, must first be clear enough.

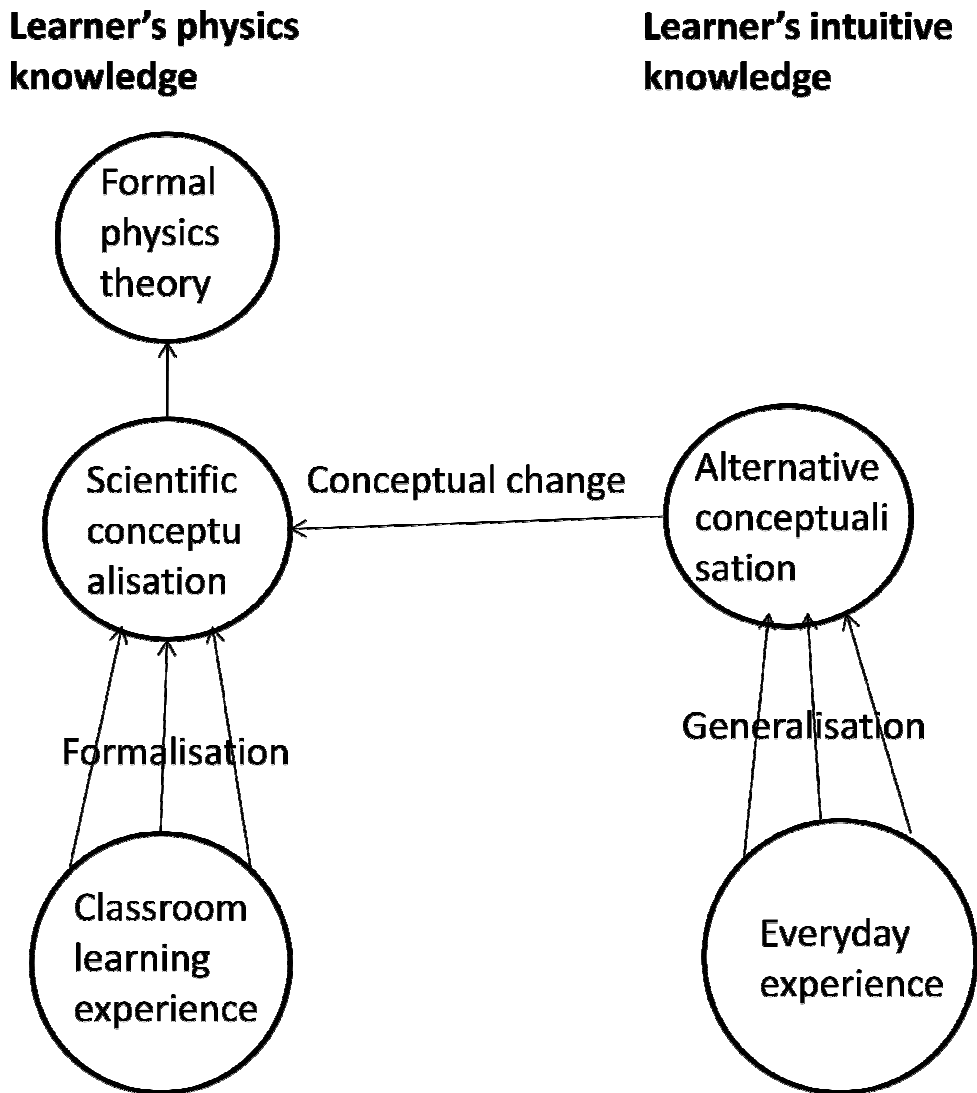


Figure 2.2: Representation of a conceptual change learning process (Adopted from Lemmer, 2011:6)

Conceptual change represents learning pathways where learners' conceptions can be

fundamentally changed in order to allow understanding of the intended knowledge (Duit & Treagust, 2003). Many of the conceptual change strategies, such as cognitive conflict, intended to replace learners' alternative conceptions with physics concepts, as illustrated in Figure 2.2 (Lemmer & Lemmer, 2010). However, learners' conceptions have been found to be resistant to change and also their intuitive knowledge often remains intact (Driver, Guesne & Tiberghien, 1989). An example of a resistive intuitive conception is the generally found perception that a force always acts in the direction of motion (Dekkers&Thijs, 1998; Halloun & Hestenes, 1985). This conception is evident in learners' explanation that the force exerted by the foot when a ball is kicked, is maintained after the ball has left the foot. It is difficult to achieve the revolutionary replacement of learners' incorrect conceptions with the scientific physics concepts (Lemmer, 2011:6). Lemmer and Lemmer (2010) proposed a conceptual refinement model as a teaching and learning framework according to which learners' productive intuitive resources are gradually refined towards the accepted scientific concepts (Figure 2.3).

Learner's knowledge

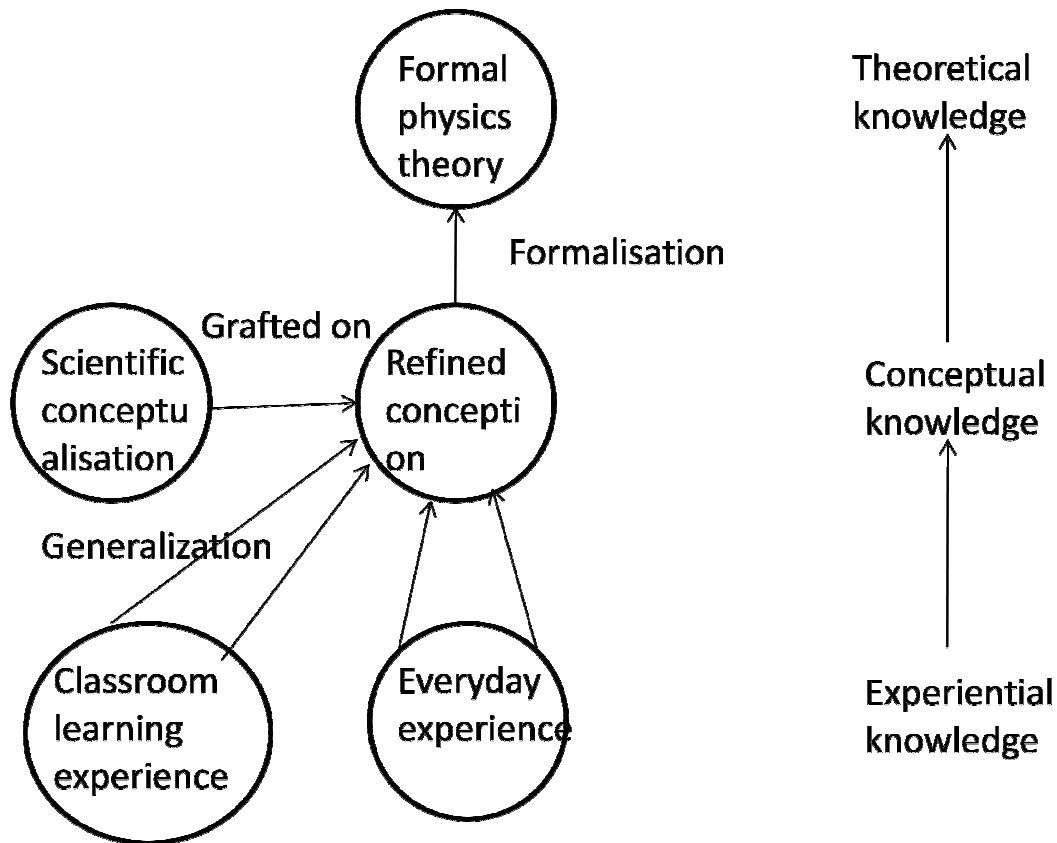


Figure 2.3: Conceptual refinement model for learning physics(Adopted from Lemmer, 2011:6)

Aspects of learners' initial knowledge that contain elements of the physics concept (i.e. productive conceptual resources) are identified and refined (Hammer, 2000). Learners are then guided to generalise a conceptual understanding from the similarities and differences in a variety of selected everyday and classroom experiences. In this way, physics knowledge is grafted onto the learners' experiential knowledge as they systematically

develop coherent conceptual knowledge. In the conceptual refinement model, conceptual knowledge refers to the conceptual understanding of physics that can be expressed in relations between concepts and that can be used to explain different situations, i.e. a conceptual explanatory model (Lemmer, 2011)

Students' conceptual knowledge that has been based on a combination of their experiential (everyday) and experimental (physics) knowledge now becomes the resource for the abstraction of their formal physics knowledge that includes advanced explanation and problem-solving skills, operational definitions, generalised laws, mathematical relations between concepts and multiple representations thereof. The conceptual refinement model requires an adequately refined conceptual understanding before formalisation can take place. It is important to note that the knowledge levels (experiential, conceptual and theoretical) are not discretely defined nor are they stepwise; rather, they indicate gradual growth in knowledge, which does not take place linearly (Lemmer, 2011:6). Mastering former levels enhances the learning of later ones, but later levels also deepen the understanding or provide new perspectives for the former ones (Lemmer, 2011).

The conceptual refinement model as a teaching-learning framework is supported by the studies of researchers such as Dekkers and Thijs (1998), who explained that learners use the 'motion-implies-force' idea correctly in limited contexts, namely where objects collide, are being pushed, hit, bent or stretched. Concept refinement and context

expansion then help learners to develop the scientific meaning to the concept of force. In this way dissonance is resolved before the learners experience it. Dekkers and Thijs (1998) found that a teaching sequence designed on the basis of concept refinement and context expansion was more effective than a teaching sequence that utilised cognitive conflict

2.2.3 ACTIVITY THEORY (AT)

Activity theory (AT) is a theoretical framework for analysing human practices as developmental processes with both individual and social levels interlinked at the same time (Kuutti, 1991). This framework uses 'activity' as the basic unit for studying human practices.

AT has made significant contributions to the fields of computer supported collaborative learning (Bødker, 1997; Mwanza, 2001b; Nardi, 1996), human-computer interactions (Kuutti, 1996), and network communication and education (Engeström & Middleton, 1996), among others.

Activity, or 'what people do', is reflected through people's actions as they interact with their environment, studying different forms of human praxis as developmental processes, both individual and social levels interlinked while at the same time providing an alternative way of viewing human thinking and activity.

The AT framework uses activity as the basic unit for studying human practices and highlights the idea that the relationship between the subject and the object is not direct but rather mediated through the use of a tool. A tool can be something physical (e.g, apparatus) or intellectual (e.g., rules and roles displayed on handhelds). Physical tools are used to handle or manipulate objects while intellectual tools can be used to influence behaviour in one way or another.

Vygotsky (1978) originally introduced the idea that human beings' interactions with their environment were not direct but instead were mediated through the use of tools and signs, and this notion was developed further by Leont'ev (1981), who created a hierarchical

model for analysing an activity. Inspired by this analysis, Engeström (1987) extended Vygotsky's original conceptualisation for the mediated relationship between the subject and the object by introducing an expanded version of the activity triangle model that also incorporates Leont'ev's concepts. Thus, Engeström offers a general model of human activity that reflects its collaborative nature. The model's components, shown in Figure 2.4, are:

- (1) Object of the activity (or objective, i.e., the goals and intentions),
- (2) Subjects in the activity (i.e., the people engaged in it),
- (3) The tools mediating the activity (anything physical, e.g., models or heuristics used in the transformation process),
- (4) Rules and regulations (norms that circumscribe the activity),

(5) Division of labour (e.g., actions undertaken by individuals within the group

versus tasks that are a group responsibility,

(6) Community (individuals directly or indirectly involve in the tasks) and

(7) Outcome (i.e., the results and final products of the defined objectives).

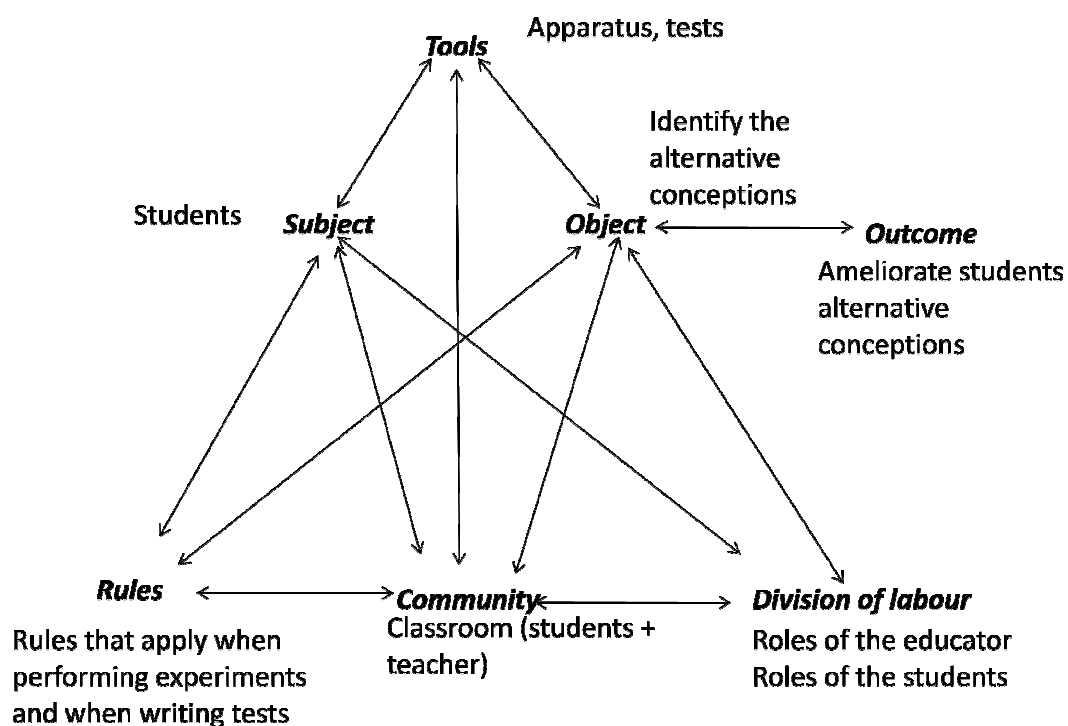


Figure 2.4: Activity-theory in the context of OBE (Adopted from Uden, 2007:86)

Applying the above figure to this study, the students (subject) was required to write a pre-test (tool) before tuition took place, in order to identify the alternative conceptions that they have about electric circuits. They were not supposed to write their names on the pre-test sheet (rules) and they were writing the test in a classroom (community).

The identified alternative conceptions (object) were incorporated in the development of the intervention using them as the basic building blocks for understanding. In order to ameliorate alternative conceptions (outcome) held by the students (subject), the intervention followed the order proposed by Lemmer and Lemmer, (2005), i.e., progression from contextual to conceptual activities to formal problems. The activities were performed in groups so that co-operative learning could take place.

In all the activities, a problem was posed which the learners (subjects) had to solve in groups. The contextual and conceptual activities utilised the strategies of verbalisation (analogical explanations). In the first contextual problem the learners (subjects) were given a bicycle analogy. The researcher facilitated the learning process by managing groups and their activities. This helped to establish data or, put differently, an information structure from which the student can work.

The students (subjects) supported fellow learners over time by guiding / assisting them with their development as learners (discipline-specific and / or general). The researcher facilitated the learning process (division of labor). The students (subjects) applied, analysed, and/or synthesised knowledge or information through writing. The students (subjects) also asked questions, explaining and justifying their opinions, articulated their reasoning and elaborated and reflected upon their knowledge. The researcher acted as a mediator (division of labor) between the groups in order to help resolve disagreements. The activities were hands on because students (subject) were performing experiments.

(rules) using apparatus (tools) with a view to eventually alleviate their alternative conceptions (outcome).

AT is geared towards practice. It embodies a qualitative approach that offers a different lens for analysing a learning process and its outcome, focusing on the activities people are engaged in.

2.3 CURRICULUM CHANGES IN SOUTH AFRICA

This section presents a discussion of curriculum changes in South Africa; the relevance of these to the current research is lodged in the third objective of this study, which sets out to compare the learning gains of students from the NCS and OSC curricula.

According to Edwards (2010:3), changes in the educational system in South Africa have been driven by constitutional imperatives and were characterised by policy changes influenced by international perspectives and global economic trends (OECD, 2008:75). Curriculum policy changes were followed by an implementation phase and subsequently revisions were undertaken to address problems that arose. Curriculum 2005 (C2005) was launched in 1997 and was informed by principles of OBE as the foundation of the post-apartheid schools' curriculum (Chisholm, 2005:193). C2005 was revised and in 2002 the Revised National Curriculum Statement (RNCS) became policy to be implemented in 2004, and culminated in the first Grade 12 cohort to graduate out of the NCS in 2008 (OECD, 2008:81). The DoE also published content frameworks for each subject as well as work schedules and subject assessment

guidelines in response to Grades 10 to 12 teachers' concerns about the content to be taught (Edwards, 2010). Rogan (2007:457) argues, however, that it is not enough to merely publish a new curriculum and assessment standards, particularly in a developing country. Detailed attention must be given to how things will unfold in practice.

The introduction of OBE in South Africa purportedly brought about a move away from norm-referenced testing to criterion-referenced testing. Less emphasis on summative assessment practices (assessment of learning) and more formative assessment (assessment for learning) was envisaged. In reality, however, the final examination in Grade 12 constitutes 75% of the pass requirement in most subjects and thus represents a summative assessment. Edwards (2010) contend that the underlying assumptions regarding the assessments, such as norm-referenced tests and normally distributed achievement can result in misalignment with standards that are targeted for all students. A brief look at the examiners' reports (WCED, 2008a:1-2; WCED, 2008b:1-2) for the final examination in physics and chemistry highlights the following:

- Candidates are unable to explain phenomena by applying principles;
- New work in the curriculum is poorly answered;

- Candidates struggle with concepts requiring higher-order reasoning to solve problems;
- Candidates lack basic understanding (comprehension); and
- Higher-order questions that also occurred in the old curriculum are well answered.

The lack of emphasis on higher-order cognitive skills could possibly lead to teachers not preparing Grade 12 learners adequately for examinations. It has emerged from the findings above that in instances where educators appear to be familiar with the work from the old curriculum, the learners are doing well. However, it would seem that a lack of development of teachers in the new materials hampered the progress of learners. The students also performed worse in the chemistry paper overall and a lower alignment index was one possible explanation for this. Within the knowledge area Matter and Materials in Chemistry, there is a 5% over-representation in the final examination. This contains a great deal of new material based on Organic Chemistry that learners struggle to understand. Perhaps there is also a need to develop teachers in this area, given that many of them do not have an adequate background in Organic Chemistry (Edwards, 2010). Similar problems arose in physics, where learners struggle to understand electric circuits within the knowledge area Electricity and Magnetism (Edwards, 2010)

Grade 12 physical sciences results for the 2009 cohort, that were released in January 2010 showed a high increase in the failure rate of students. One possible explanation for this was that no exemplar question papers for physical sciences were made available in 2009. The purpose of the exemplar question papers' was to familiarise teachers and students with the format and standard of the NCS examinations. The final examinations of 2008 and 2009, and the exemplars of 2008 were fairly consistent across cognitive levels and content areas (Edwards, 2010). What needs to be researched is the issue of test familiarity, since other preparatory examinations were also released in 2008. Umalusi (2009:121) compared the NCS with the OSC and concluded that NCS was far more difficult in terms of breadth of content than was the OSC, but was midway between the Higher and Standard Grade levels of the old curriculum in terms of the levels of difficulty of the content topics. The panel for physical sciences also estimated that up to 35% more classroom time was needed for the NCS content compared with the OSC.

There are huge gaps inherent in the South African education system as far as implementing the new curriculum is concerned. Teachers depend heavily on the published policy documents to give direction to their teaching. It follows that the curriculum documents themselves should be clear and give a balanced weighting across cognitive levels. If this situation can be achieved, then teachers can have a reasonable expectation that the examination will be aligned to the curriculum content. Alignment studies are thus

important in order to elucidate the differences in the intended curriculum and the enacted curriculum (Edwards, 2010:17-19).

2.3.1 OLD SCHOOL CURRICULUM (OSC)

Prior to the promulgation of the NCS, the school curriculum in South Africa, referred to in this study as the OSC, was based on the NATED 550 document.

It was decided that the old South African education system had to be revisited as the curriculum was taken to have the following shortcomings (Rapule, 2005:62):

- ✓ The curriculum was too structured, prescriptive and not easily adaptable, with little room for educational initiative;
- ✓ Traditional curriculum processes were too restricted and without any stakeholder participation in the decision making process;
- ✓ The accent was on academic education, while skills training remained behind;
- ✓ A large gap existed between education in the formal educational sectors and training by employers;
- ✓ Too much emphasis was placed on differentiation in the form of a wide variety of subjects;
- ✓ The curriculum was content-based;
- ✓ The curriculum was teacher-centred, as opposed to being learner-centred.

- ✓ Learner achievement was measured in terms of symbols and percentages which are often no real indication of actual performance; and
- ✓ Learner achievement was compared to that of other learners which led to excessive competition.

The topics covered in the old physical science programme were;

- Vectors;
- Equations & graphs of motion
- Work, energy and power & momentum
- Electrostatics; and
- Resistance & Ohm's Law

Students wrote examinations either in physical science on higher grade or standard grade; the above- mentioned themes were covered in Paper 1, while Paper 2 covered the following themes:

- Chemical principles and their applications; and
- Organic chemistry

The changes in the educational system in South Africa have been driven by constitutional imperatives and were characterised themselves by a whirlwind of policy changes. Curriculum 2005 (C2005) was launched in 1997 and was informed by the principles of OBE as the foundation of the post-apartheid school curriculum (Chisholm, 2005). C2005 was subsequently revised, and in 2002 the Revised National Curriculum Statement (RNCS) became policy to be implemented in 2004. This culminated in the phasing in of the National Curriculum Statement (NCS) Grade 12 in 2008.

In 2008 Umalusi, which is the quality assurance body for schools, needed to review its systems, the main reason being that the first cohort of learners following the NSC for the National Senior Certificate (NSC) qualification had reached Grade 12 level. The first national examinations for this new system took place by the end of 2008. What had to be addressed immediately was the fact that there were no historical norms for the associated examination results. Thus, in order to ensure the integrity of these results, Umalusi sought to achieve a valid understanding of the quality and levels of cognitive demand of the new curricula relative to those just superseded. The research was specifically designed to provide Umalusi's Assessment and Statistics Committee with succinct information on the comparability of the NATED 550 (old school curriculum) and the NCS curriculum, and on the comparative difficulty of the examinations associated with each. The intention was that the findings of the research involving in-depth curriculum evaluation and exam papers analysis had to be used to support the new norms in 2008. The aim was that all of this information would be used to adjudicate the standard of the NSC exam in 2008, in relation to the standard of the previous Senior Certificate exam. The subjects included in the research were English FAL, Geography, Life Sciences, (previously Biology), Mathematics, Mathematical Literacy, and Physical Science.

Teams of four researchers evaluated the NATED 550 Higher and Standard Grade, and NCS curricula for each subject. They also analysed all Higher and SG examination papers from 2005 to 2007, as well as the August 2008 exemplar and final papers for their subjects. The physical sciences, mathematics, and geography teams found that

information on amounts and levels of difficulty of content and skill topics yielded solid evidence of the respective overall levels of difficulty of the curricula, meaning that the three exams were not the same in terms of assessment. In all, three teams (physical science, life Sciences, and mathematics) found their NCS curricula to be midway between the NATED 550 Higher and Standard Grade equivalents, in 50:50 proportions.

The overall cognitive character and difficulty levels of the final 2008 National Senior Certificate examination papers in relation to their Higher and SG counterparts in the years 2005–2007, and August 2008 Exemplars, were based on total counts of items or marks at specified cognitive type and difficulty levels.

Three teams (physical sciences; life sciences; and English FAL) produced diverse and fine-grained results for the respective final 2008 papers for their subjects, but on the whole, their findings demonstrated that the papers were closer to the NATED 550 HG than the SG papers for the subjects. The subject teams raised the concern, again based on accurate counts of the types and difficulty levels of items or marks in the exam papers, on as to whether the August 2008 exemplar and final papers allowed for learners who would have achieved A-grades in the old HG papers to achieve A-grades in the new NSC exams where the A-grades were comparable to the old Higher Grade A's (Umalusi, 2008).

Three Umalusi teams (English FAL, geography and physical sciences) found that because the spread of types and levels of questions in the respective papers were similar, this pattern suggested that the A's in the 2008 NSC papers would indeed be equivalent to A's in the NATED 550 Higher Grade papers.

Three Umalusi teams (geography, life sciences, and physical sciences) found the proportions of easy items in the 2008 NSC final papers lower than those in the average SG papers for the subjects. The Umalusi physical science group found that it would be much harder for a learner at this level to pass the 2008 NSC examination than it would have been to pass the SG exam: the 2008 final exams contained an average of 23% of easy items, while the average for the SG papers between 2005 and 2007 was 39%. The papers for these subjects would clearly have been very difficult for learners at the lower end of the achievement spectrum, and in the case of Physical Science, especially so.

Regarding the overall findings of the current study, a comment can be made. First, in terms of the levels of difficulty of the six NCS curricula evaluated: three of these curricula (those for life sciences; mathematics; and physical science) are judged to be midway between the NATED 550 Higher and Standard Grade curricula overall, but at the same time had pockets of difficulty that way far exceed the difficulty levels in the previous Higher Grade curricula.

This means that NCS students' curriculum was quite challenging as compared to the NATED 550 which was content based.

2.3.2 NATIONAL CURRICULUM STATEMENT (NCS)

The general aims of the curriculum are discussed in this section in order to show the kind of students envisaged by the curriculum.

General aims of the South African Curriculum

According to the Curriculum and assessment policy statement (CAPS) for physical sciences (DoE, 2011:4),

(a) The National curriculum statement Grade R-12 gives expression to the knowledge, skills and values that are considered worthy of learning in South African schools. This curriculum further aims to ensure that children acquire and apply knowledge and skills in ways that are meaningful to their own lives. In this regard, the curriculum promotes knowledge in local contexts, while at the same time being sensitive to global imperatives.

(b) The National Curriculum Statement Grades R-12 serves the purposes of:

- Equipping learners, irrespective of their socio-economic background, race, gender, physical ability or intellectual ability, with the knowledge, skills and values necessary for self-fulfillment, and meaningful participation in society as citizens of a free country;
- Providing access to higher education;
- Facilitating the transition of learners from education institutions to the workplace; and
- Providing employers with a sufficient profile of a learner's competences.

(c) The National Curriculum Statement Grades R-12 is based on the following principles:

- Social transformation: ensuring that the educational imbalances of the past are redressed, and that equal educational opportunities are provided for all sections of the population;

- Active and critical learning: encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths;
- High knowledge and high skills: the minimum standards of knowledge and skills to be achieved at each grade are specified and set high, achievable standards in all subjects;
- Progression: content and context of each grade shows progression from simple to complex;
- Human rights, inclusivity, environmental and social justice: infusing the principles and practices of social and environmental justice and human rights as defined in the Constitution of the Republic of South Africa. The National Curriculum Statement Grades R-12 is sensitive to issues of diversity such as poverty, inequality, race, gender, language, age, disability and other factors;
- Valuing indigenous knowledge systems: acknowledging the rich history and heritage of this country as important contributors to nurturing the values contained in the constitution; and
- Credibility, quality and efficiency: providing an education that is comparable in quality, breadth and depth to those of other countries.

(d) The National Curriculum Statement Grades R-12 aims to produce learners who will be able to:

- Identify and solve problems and make decisions using critical and creative thinking;
- Work effectively as individuals and with others as members of a team;

- Organize and manage themselves and their activities responsibly and effectively;
- Collect, analyse, organise and critically evaluate information;
- Communicate effectively using visual, symbolic and/or language skills in various modes;
- Use science and technology effectively and critically showing responsibility towards the environment and the health of others; and
- Demonstrate an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation.

(e) Inclusivity should become a central part of the organisation, planning and teaching at each school. This can only happen if all teachers have a sound understanding of how to recognise and address barriers to learning, and how to plan for diversity.

Content and context in the NCS.

The contexts from which learning experiences, such as the gathering of information and the processing of it in tables and graphs, are designed play an essential role in the teaching and learning process. They are not to be thought of as simply science activities that form part of the learning process, but rather as a translation from their context that is redirected in order to solve daily problems. The content standards of the curriculum should illustrate important features such as emphasis on major ideas, links to meaningful

experiences, concepts, applications and generalizations that are developmental[^] appropriate for the learner (Gunter *et al*, 1991:43).

South African Grade 12 learners wrote their National Senior Certificate (NSC) examination based on the outcomes-based education (OBE) system for the first time in November 2008. This was also the first time that a nationally set public examination was written in all subjects. Only 62.5% of all the candidates obtained their NSC at the first attempt, while the results of the 2009 cohort of learners showed a decline to 60.6% (DoBE, 2010:41). This decline is indeed a cause for concern, because the new curriculum has been designed to embody the values, knowledge and skills envisaged in the constitution of the new democratic South Africa. It provides learners with the opportunity to perform at the maximum level of their potential and focuses on high levels of knowledge and skills, while promoting positive values and attitudes (DoE, 2008a:2).

The introduction of OBE in South Africa was intended to redress the legacy of apartheid by promoting the development of skills throughout the school-leaving population in order to prepare South Africa's workforce for participation in an increasingly competitive global economy (Le Grange, 2007: 79). The move towards standards-based assessment practices internationally has been incorporated into the OBE system in South Africa, with learning outcomes and assessment standards being specified for each school subject.

The adoption of a radical change of policy on the curriculum was, however, contested and underwent a review in 2000. The current curriculum for Grades R to 9 is a revised version that has been in place since 2002 (OECD, 2008:131). The new curriculum for Grades 10 to 12 was implemented in 2006 and culminated in the NSC examination in 2008.

This curriculum emphasized the notion of outcomes. Learning outcome is a statement of an intended result of learning and teaching. It describes knowledge, skills and values that learners should acquire by the end of the Further Education and Training band (Grades 10 to 12). Assessment standards, in turn, are criteria that collectively describe what a learner should know and be able to demonstrate at the end of a specific grade. Such standards embody the knowledge, skills and values required in order to achieve the learning outcomes. Assessment standards in the context of each learning outcome collectively show how conceptual progression occurs from grade to grade (DoE, 2003:7).

The physical sciences subject area has been divided into six knowledge areas consisting of physics and chemistry components-one of these is an integrated knowledge area spanning both components. Approximately forty-five percent (45%) of the Grade 12 learners who wrote the physical sciences NSC examination in 2008 did not achieve the required pass level (DoE, 2008a: 13). This figure has increased to 63.2% in 2009 (DoBE, 2010:49). This presents a

huge challenge to all science teachers in the country particularly if we are to reach adequate levels of scientific literacy in South Africa. To exacerbate the situation, the performance of South Africa's Grade 8 learners in both the 1999 and 2003 Trends in International Mathematics and Science Study (TIMSS) was disappointing (Edwards, 2010). The TIMSS study showed that learners attained the lowest average test scores in both mathematics and science from all other participating countries. The poor performance of Grade 12 learners in science is perhaps not surprising if viewed against the TIMSS study. These international comparison studies have played a major role in identifying critical factors impacting on student achievement and have contributed to some extent to the current standards-based science education reforms in the United States and many other countries (Liu, Zhang, Liang, Fulmer, Kim & Yuan, 2009:780).

In an era of accountability together with the potential for schools to receive actual monetary rewards for good achievements in mathematics and science, exit examinations that are not aligned to the assessment standards of the curriculum could have serious consequences for schools (Edwards, 2010). The learners could be assigned marks that are not indicative of their true abilities, or instruction may be misguided when inferences are drawn about the extent to which learners have mastered the standards when the test has not adequately covered the content standards (Liu *et al.*, 2009:780). Glatthorn (1999:27) has argued for the reconciliation between advocates and dissenters of alignment to

see it as a tool that should be used wisely in a time of high-stakes testing by making it teacher-friendly and teacher-directed.

Curriculum analysis.

The outlined learning outcomes (LO) of physical science (Department of Education, 2003:13-14) are:

- LO 1-Practical science inquiry and problem solving skills.
- LO 2-Construction and application of scientific technological knowledge.
- LO 3-Science, society and environmental issues.

Assessment standards for each learning outcome are also stated in the NCS (Department of Education, 2003). Below are some examples that are given: Assessment standards (AS) for LO 1 are:

- > Conducting an investigation.
- > Interpreting data to draw a conclusion.
- > Solving problems.
- > Communicating and presenting data and scientific arguments.

Assessment standards (AS) for LO 2 are:

- > Recalling and stating specified concepts.
- > Indicating and explaining relationships.
- > Applying scientific knowledge.

Assessment standards for LO 3 are:

- > Evaluating knowledge claims and science's inability to stand in isolation from other fields.
- > Evaluating the impact of science on human development.
- > Evaluating the impact of science on environmental and sustainable development.

These assessment standards provide guidelines for designing and planning activities for learning experiences that promote effective teaching of concepts such as energy and the conservation of energy in mechanics for grade 10 to 12 learners in the context of OBE (Department of Education, 2003).

The new curriculum for South Africa through the principle of OBE, confirms the assumption that teaching and learning involve interactions between new conceptions and pre-knowledge. As stated by Trumper (1991:2-6) a curriculum has to be considered as a process in which learners are actively involved in constructing a view of the world closer to the scientific views. This view relates to the principle of progression stated in the NCS (Department of Education, 2003).

Specific aims of physical sciences

The purpose of physical sciences is to make learners aware of their environment and to equip them with appropriate investigating skills relating to physical and chemical phenomena, for example, lightning and solubility (DoE, 2011:8). Examples of some of the skills that are relevant for the study of physical sciences are classifying,

communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesising, identifying and controlling variables, and inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills. Physical sciences promotes knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; as well as an understanding of the nature of science and its relationships to technology, society and the environment.

Physical sciences, furthermore, prepare learners for future learning, specialist learning, employment, citizenship, holistic development, socio-economic development, and environmental management. Learners choosing physical sciences as a subject in Grades 10-12, including those with barriers to learning, can have improved access to: academic courses in Higher Education; professional career paths related to applied science courses and vocational career paths. Physical sciences play an increasingly important role in the lives of all South Africans owing to the influence of this field on scientific and technological development, which is necessary for the country's economic growth and the social wellbeing of its people.

In South Africa the NCS for physical sciences (Grades 10-12) has been divided into six core knowledge areas:

- Two with a chemistry focus - Systems; Change;

- Three with a physics focus - Mechanics; Waves, Sound and Light; Electricity and Magnetism; and
- One with an integrated focus - Matter and Materials. (DoE, 2003:11).\

Green and Naidoo (2006:79) are cited by Edwards (2010); they studied the content of the Physical Sciences NCS and found that:

- It reconceptualises valid science knowledge.
- It values the academic, utilitarian and social-reconstructionist purpose of science.
- It is based on a range of competences, from the metacognitive level through to the simple level.
- There is a shift to greater competence complexity in the field, and thus to correspondingly higher expectations for teachers and learners.

2.3.3 OSC VERSUS NCS

Olivier (2002: 99) provides a comparison between the OSC and the NCS in the following table.

Table 2: Comparison between OSC and NCS approaches

OSC	NCS
Passive learners	Active learners
Examination-driven	On-going assessment-driven
Rote-learning (parrot fashion)	Critical thinking, explanation, reflection and action
Syllabus/ curriculum is content-based and broken down into subjects	Integration of knowledge and learning relevant and connected to real-life situations
Teacher-centred and textbook or worksheet focused	Learner-centred with the teacher as a facilitator guiding group work / teamwork
Syllabus/ curriculum is rigid and non-negotiable	Learning programmes are seen as guides that allow teachers to be innovative and creative
Teachers are responsible for learning with learner motivation dependent on the teacher	Learners take responsibility, motivated by constant feedback and affirmation of their worth
Emphasis on what the teacher hopes to achieve	Emphasis on what the learner achieves and understands
Rigid time-frames	Flexible time-frames, allowing learners to work at their own pace

From the above table, it can be gleaned that activity-based instructional approaches fall within the pedagogic aegis of OBE

2.4 GENERAL OVERVIEW OF ALTERNATIVE CONCEPTIONS

A literature review of alternative conceptions is presented below. This section begins with an explanation of how alternative conceptions are formed, as well as the origins of such conceptions. A discussion on the historical development of electricity is then presented in order to illustrate the complex nature of science concepts, which enhances the culture of alternative conceptions.

2.4.1 FORMATION OF ALTERNATIVE CONCEPTIONS

It is common practice in the scientific community to arrive at general agreements as to what a particular concept means (Wesi, 2001). These agreements are based on valid investigations and reliable theoretical reasoning, and may take the form of an imposed definition or a generally accepted reasoning (Wesi, 2001:8). Thijis and Van der Berg (1995:326) found that most conceptions held by students in completely different environments and cultural backgrounds were similar, implying that culture and different man-made aspects of the environment have limited influence on students' formation of concepts in physics. The patterns of concept formation in science parallel their historic development and have quality of universality. The influence of culture on concept formation may manifest itself only in remediation strategies aimed at reducing existing alternative conceptions, but not necessarily on the formation of alternative conceptions (Thijis& Van der Berg, 1995:325)

It is generally believed that alternative conceptions are constructed through a process of interaction between the student's cognitive system and his/ her physical and social environment (Driver, 1989). As they grow up, students make observations of the world in which they find themselves. These observations are generalised and are used to see them through the world- to understand and explain what happens around them and to adapt to their environment (Wesi, 2001). Such observations result in the information of students' own understanding and ideas about what they see in their surroundings and what they learn about in science classrooms. According to Wesi (2001), students will also have their own ideas and impressions about what they learn in science.

2.4.2 SYNONYMS FOR ALTERNATIVE CONCEPTIONS

According to Wesi (2001), one of the most commonly used synonym for alternative conceptions is preconceptions. Students' conceptions are often referred to as preconceptions since they are notions and concepts held prior to systematic instruction or teaching of a new topic. Preconceptions may not always be irrational but may lack systemisation and correct explanation (Wesi, 2001). Preconceptions are sometimes referred to as intuitive, pre-instructional conceptions, or spontaneous knowledge. The use of other terms, such as naïve ideas, students' ideas and alternative frameworks is common in the literature.

The other term commonly used to refer to students' conceptions is 'misconceptions' (Wesi, 2001:9). Researchers such as Collins (2002) and Trumper (1990) have, however, criticised the use of this term on the basis that it is rather judgmental and implies that prior knowledge of students is always unfounded and irrational. However, it is interesting to note that there are striking similarities between students' conceptions and difficulties encountered in the historical development of physics (Wesi, 2001:9). For example, Aristotle's view of falling bodies that a heavier body will fall faster than a lighter body was considered a scientific fact by ancient Greeks. Misconceptions may arise in students' minds because of incorrect teaching or because of incorrectly assimilated formal instruction.

2.4.3 ORIGINS OF ALTERNATIVE CONCEPTIONS

Alternative conceptions can haunt students' science learning until they feel that these have been properly confronted and overcome. The discussion in the paragraphs below reflects the notion that alternative conceptions can originate from everyday experiences, terminology, teaching, and textbooks.

2.4.3.1 Everyday experiences

Preconceived notions or preconceptions of the natural world are often popular conceptions rooted in everyday experiences. For example, students observing a moving object slowing down (decelerating) may mistakenly believe that the force responsible for the motion is getting used up (Roberts, 2000). Such alternative conceptions are very common because they are rooted in the commonest activity of young children, namely

unstructured play. When children are exploring their surroundings, they will naturally attempt to explain some of the phenomena that they encounter in their own terms and share their explanations. When children arrive at an incorrect assumption, this preconception could then amount to an alternative conception.

2.4.3.2 Terminology

Vernacular- based alternative conceptions can be distinguished from factual alternative conceptions (Clement, 1987). Vernacular-based alternative conceptions arise from the use of words that mean one thing in everyday life and another in the scientific context. For example, the term work in the physics classroom refers to the result of multiplying a force measured in Newton by the straight-line distance moved in meters in the direction of the force. The introduction of the definition of work in a physics classroom consequently presents many challenges to the teacher (Clement, 1987). Similarly, power (change in energy per unit time), as a scientific concept, is an example of a concept with different meanings in and out of the science classroom. Ordinarily, students perceive the terms energy and power as the same thing because in their everyday usage these two concepts are regarded as the same (Driver, 1989).

These examples illustrate that a mismatch may occur between the scientific meaning of terms and their everyday usage. These mismatches should be attended to before effective learning can take place (Clement, 1987).

2.4.3.3 Teaching

Conceptual misunderstanding arises when students are taught scientific information in a manner that does not encourage them to settle any cognitive disequilibrium they may experience. In order to deal with the confusion, students construct a weak understanding and consequently are very insecure about constructed concepts. An example of this is the very commonly found “force as a property of an object misconception” (Brown, 1977). Forces are dependent upon and related to objects but are not properties of them, yet students continually perceive that forces are intrinsic to objects.

Furthermore, alternative conceptions can result from deficiencies of curricula and methodologies that do not provide the students with suitable experiences to properly understand the new concepts. Thus, alternative conceptions would only rarely result from a lack of explanation abilities that are necessary to assimilate the new concept (Brown, 1997).

2.4.3.4 Cultural beliefs and religion

A study done by Imenda (2005b) revealed the presence of alternative conceptions based on religious and cultural beliefs. This is believed to be the case, because learning is influenced not only by the cognitive elements of learning, but also by the socio-cultural contexts. Consequently, the study found out that alternative conceptions due to students’ spiritual and cultural beliefs posed very difficult challenges for teachers. For instance, Imenda (2005b) asks the moral and philosophical question as to whether or not teachers

have a moral obligation to change their students' cultural and religious beliefs in order to align them with modern scientific thinking. In South African schools, educators are not allowed to talk on issues of religion in their classrooms. Because formal schooling is based on logic and scientific rationality, religious education, in principle, is seen as being incompatible with formal schooling (Coetzee, 2008:20). It is, however, extremely important that research, that embraces African values and cultures should be, is undertaken in order to determine the influence of these factors in inhibiting the formulation of espoused scientific knowledge (Imenda & Muyangwa, 2006).

2.4.3.5 Textbooks

In an educational system, textbooks act as a dominant resource. They influence teachers' practices and are an invaluable resource. However, with inappropriate definitions, textbooks may lead to alternative conceptions (Sanger & Greenhowe, 1999). According to Jones and Childers (1992), when investigated, there are phrases like 'capacitor is a device for storing charge' in some textbooks. This may cause students to think that 'there is a net charge on a parallel plate capacitor when it is charged'. Capacitance is the ability of component to store charge. However, this can be misleading unless it is explained clearly (Baser & Geban, 2007). The total charge at all times on a parallel plate capacitor is zero; when it is charged, it holds equal amounts of positive and negative charges (Ellse & Honeywill, 2001:22). Another challenge in this regard is sound: sound is one of the

physics themes that include concepts that cannot be visualised by the students (e.g.: wave) and are difficult to describe in textbooks.

Indeed, there is some evidence that textbooks' illustrations may reinforce or induce alternative conceptions in students' mind (Sanger & Greenhowe, 1999).

This is unfortunate as South African secondary school educators depend on textbooks. Textbooks can mislead students because of poor writing and /or poor editing.

2.4.3.6 Metaphoric use of terms

Terms such as charge, power, current, energy and voltage are commonly used synonymously in daily language (Pardan *et al.*, 2001) and therefore compound the problem of how to explain these in textbooks.

2.5 HISTORICAL DEVELOPMENT OF CONCEPTS IN ELECTRICITY

A section on the historical development of concepts in electricity is presented in order to illustrate the complex nature of the attendant science concepts, which will likely help to explain the culture and incidence of alternative conceptions.

From an educational point of view, the historical development of concepts in electricity is significant in the sense that many of the naïve conceptions that students with them to their classrooms were in the past, part of the authentic body of scientific knowledge. For example, Plato (427-347BC) held a belief that the human eye emitted light; Aristotle

believed that heavier objects fell faster than light ones. Knowledge of such historical facts by educators will enable them to deal more effectively with problems associated with students' alternative conceptions (Wesi, 2001). Knowledge of history gives the learner some sense, not only of what we now know, but also when we came to know it, and how we came to know it and also that in future this can change. Thus, knowledge of relevant sections of history will empower the student to develop independence of thought, thereby instilling confidence on his/her and stimulate his/her interest in science.

Below, the core concepts in electricity at secondary school are identified and discussed. The discussion will follow the historical epistemological line of developments; emphasising the areas and concepts with which students and educators generally experience difficulties, and aspects that are commonly misunderstood. Core concepts from areas on electrostatics, electric current and electric circuits are dealt with. The discussion of these concepts begins with electrostatics since the earliest work in electricity was on electrostatics, and since concepts in electrostatics form the bedrock of theories in electricity.

The study of electricity is divided in two main sections, namely electrostatics and electrodynamics. Electrostatics is a study of phenomena associated with charges at rest (Cutnell & Johnson, 1998) while electrodynamics deal with phenomena related to moving charges.

A charge is one of the most fundamental quantities of electricity. It is associated with the

atomic and subatomic particles of matters, namely electrons and protons.

2.5.1 CHARGE

2.5.1.1 Historical development of the charge

According to Cajori, 1914: 8), “the development of the concept of charge started about 600 BC when Thales of Miletus (640-546 BC), first observed that when amber was rubbed with fur, it attracted dust particles”. Gilbert showed that most non metal substances attracted small pieces of dust and paper when rubbed with cloth. He was the first scientist to use the term electric force and electric attraction. Gilbert used the term *electrics* to refer to substances which acted in same way as amber did. Substances showing no sign of electrification were said to be electrically neutral (Cajori, 1914:43)

Du Fay (1698-1739) propounded forth several theories to explain the experimental observation of electrical phenomena. These are briefly explained.

Two-fluid theory

The concept of electrification was explained by Charles Francois de Cisternay Du Fay (1698-1739) as follows: Assuming that there were two electrical fluids; these fluids were considered to be weightless and could be separated by friction, and neutralised each other when they combined. Positive electrification way considered to be the result of addition of the positive fluid, and negative electrification on the addition of the negative fluid. A neutral body was considered to contain equal amounts of positive and negative fluids (Cajori, 1914).

One-fluid theory

In 1752, Benjamin Franklin (1706-1790) postulated the existence of only one electrical fluid, which he called positive electricity. According to Benjamin Franklin, positive electrification results from the addition of the fluid to a body, while negative electrification results from the removal of the fluid from a neutral body.

The theory and practical application of electricity was well developed before the fundamental charge carrier, the electron, was discovered. The discoveries of Christian Oersted (1777-1831) in 1819 and Michael Faraday (1791-1867) in 1831 led to the large scale generation of electricity using coal, oil or water powered stations, and to the use of electric current to run electric motors in 1897. In 1897, Joseph John Thomson (1856-1940) discovered an electrical entity later called the electron: he described most of its properties. This discovery led to the explanation of electricity in terms of the nature of atoms.

In 1906, Robert Millikan (1868-1953) determined the magnitude of the electronic charge to be -1.6×10^{-19} C (Mendehall *et al.*, 1956:444). In terms of Millikan's findings, an electron was regarded as the most elementary charge. At the secondary school level, nowadays an electron is considered to be the most elementary charge carrier property associated with an electron.

2.5.2 Electric force

There are four fundamental forces in nature, namely gravitational force, electromagnetic force, weak nuclear force and strong nuclear force. Physicists are constantly trying to find a theory that will unify all these forces. The electromagnetic forces can be seen as a unification of the magnetic force and electric forces. Magnetic and electric forces are related since moving charges (current) gives rise to a magnetic field. The electric and the magnetic forces are treated as separate forces at school.

2.5.3 ELECTRIC FIELD

In 1838, Michael Faraday (1791-1867) described then interaction of charges over an intervening space in terms of a field surrounding electric charges rather than a charge interacting over large distance, as Coulomb did (Thomas, 1991:60).

2.5.4 ELECTRODYNAMICS

Electricity involves a great deal more than just charges at rest. In this section I briefly address charges in motion.

Investigations into electricity, since the time of ancient Greece, were confined to electrostatics until about 1790, when the study of current began (Cajori, 1914:117). Du Fay and Gray made the first discovery of electric current in 1729 by showing that static electric charges could be carried from one body to another by means of substances called

conductors. Faraday discovered electromagnetic induction, which made the large scale production of current a possibility (Mendehall *et al.*, 1956:352).

Animal electricity

In 1780, Luigi Galvani (1737-1793), while dissecting a frog, found that he could make the muscle of the dead frog twitch (i.e., make a quick movement) by touching the main nerve of the frog's leg with a dissecting knife and some other metal instrument simultaneously. Galvani explained this effect as coming from the muscle nerve system. He referred to this effect as animal electricity (Menderhall *et al.*, 1956). At the time, an understanding of animal electricity did not exist: but it is certainly true that small currents of electricity perform various tasks in the human system.

Voltaic pile

Volta (1757-1827), upon observing the effect of the animal electricity argued that a frog was not necessary for such an experiment and that a similar effect could be shown using suitable metals separated by a damp cloth containing a salt solution (Mendenhall *et al.*, 1965:353). Volta continued experimenting along these lines and in 1800 he produced what was called voltaic pile which consisted of zinc and silver separated by paper sheet soaked in salt water. Placing one hand on the top disc and the other on the bottom disc of the voltaic pile, a small electric shock was felt. Later, instead of using a paper soaked in salt water, a cup containing salt water was used and the two metal rods (zinc and copper) were inserted into the cup. This was the first battery and it could give rise to continuous or direct current. The invention and development of batteries provided sources of

continuous electric current. This was a major breakthrough, as previously only small pulses of electric current could be acquired from electrostatically charged objects. Batteries were soon used to study phenomena associated with electric current.

2.5.5 ELECTRIC CURRENT

When the ends of a conductor are connected across the terminals of the battery, charges are propelled from one end of the conductor to the other by the electric field that exists within the conductor (Cutnell & Johnson, 1998). The field lines originate at the positive terminal and end at the negative terminal of the battery. Electric current is a physical quantity whose magnitude depends on the rate of flows of charges. The greater the charge floating through a given point in a conductor, the larger the current.

2.5.6 CONVENTIONAL CURRENT

According to Wesi (2001:83), “there are three types of models in physics used by scientists to explain, describe and predict phenomena”. The first type relates to real existing entities; the second is concerned with hypothetical entities that may or may not exist; and the third type of models is mostly inherited from history and is widely established by a long period of usage. Conventional current is one such model (third type). Its origin can be traced back historically to the fluid theories of electricity by Du Fay and Franklin. The conventional current model is regarded as the flow of positive charges in a conductor from the positive terminal of a source through the circuit to the negative terminal of the source (Cutnell & Johnson, 1998).

The conventional current model describes the transfer of energy in circuits quantitatively. No knowledge of the microscopic nature of conducting particles is required in the description of energy transfer in circuits and defining the concept emf, potential difference, resistance and current. The conventional current theory enables the explanation of energy transfer in circuits in the manner consistent with description of energy transfer in electrostatics and in other branches of physics.

There is a reason why the current model, which relates to real existing entities, is not suitable for describing energy transfer. For example, consider the movement of charge carriers at microscopic level in a simple circuit consisting of a battery connected to a florescent lamp by means of copper wire. The electrons in a copper wire move from the negative terminal of the battery to the positive terminal. In a fluorescent tube and in a battery, the positive and negative ions move in opposite directions. This situation makes it very difficult to precisely determine the direction in which current is flowing if real charge carriers are to be considered. Describing the direction of the flow of current by means of electron flow will lead to complications and does not fully describe what takes place in the circuit (Wesi,2001). The advantage of using the conventional current model is that it enables an unambiguous description of the direction of the force acting on the current carrying wire in magnetic field, and the direction of the magnetic field around current carrying conductors.

2.5.7 Battery



Figure 2.5: Battery

When two oppositely charged objects are joined by means of conducting substances, a current is produced as a charge flowing from one object to the other. This current only lasts for a while. For an electric current to serve a useful purpose, it must be produced in large quantities and should last longer. The flow of charge through conductors is due to the electric force exerted on the charges by the electric field. Electric potential difference must be maintained across the ends of the conductor, meaning that excess negative charges must be continuously supplied at one end. In principle, this could be achieved by continuous rubbing, possibly using machines. In fact, until 1800, electricity was only produced by means of rubbing.

However, the battery continuously supplies energy to the charges so that they can move through conductors. This energy is supplied by maintaining a potential difference between the ends of a conductor.

The potential energy of charges at the positive terminal of the battery, in the electric field, is higher than at the negative terminal. When charges reach the other end of the conductor, energy is transferred to the conductor. When the charges reach the other end of the conductor, this potential energy is increased again when passing inside the cell from the negative to the positive terminal (Cutnell & Johnson, 1998).

Electric circuits

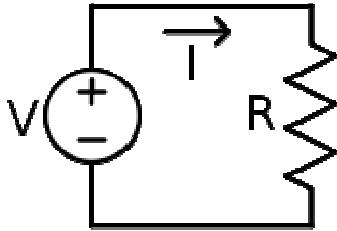


Figure 2.6: A basic electric circuit

In a basic electric circuit, the voltage (V) source drives a current (I) around the circuit, delivering electrical energy into the resistor R . From the resistor, the current returns to the source, thus completing the circuit.

An electric circuit is an interconnection of electric components such that electric charge is made to flow along a closed path (a circuit), usually to perform some useful task.

The components in an electric circuit can take many forms, which can include elements such as resistors, capacitors, switches, transformers and electronics. circuits contain

active components, usually semiconductors, and typically exhibit non-linear behaviour, requiring complex analysis. The simplest electric components are those that are termed passive and linear: while they may temporarily store energy, they contain no sources of it, and exhibit linear responses to stimuli.

The resistor is perhaps the simplest of passive circuit element. As its name suggests, it resists the current through it, dissipating its energy as heat. The resistance is a consequence of the motion of charge through a conductor. In metals, for example, resistance is primarily due to collisions between electrons and ions. Ohm's law is a basic law of circuit theory, stating that the current passing through a resistance is directly proportional to the potential difference across it. The resistance of most materials remains relatively constant over a range of temperatures and currents; materials under these conditions are known as 'ohmic'. The ohm, the unit of resistance, was named in honour of Georg Ohm, and is symbolised by the Greek letter Ω . One Ω is the resistance that will produce a potential difference of one volt in response to a current of one ampere.

The capacitor is a device capable of storing charge, and thereby storing electrical energy in the resulting field. Conceptually, it consists of two conducting plates separated by a thin insulating layer. In practice, thin metal foils are coiled together, increasing the surface area per unit volume and therefore the capacitance. The unit of capacitance is the farad, named after Michael Faraday, and given the symbol F: one farad is the capacitance that develops a potential difference of one volt when it stores a charge of one coulomb. A capacitor connected to a voltage supply initially causes a current as it accumulates

charge. This current will, however, decay overtime as the capacitor fills, eventually falling to zero.

The inductor is a conductor, usually a coil of wire that stores energy in a magnetic field in response to the current through it. When the current changes, the magnetic field also changes, inducing a voltage between the ends of the conductor. The induced voltage is proportional to the time rate of change of the current. The constant of proportionality is termed the inductance. The unit of inductance is the henry, named after Joseph Henry, a contemporary of Faraday. One henry is the inductance that will induce a potential difference of one volt if the current through it changes at a rate of one ampere per second. The inductor's behaviour is in some regards converse to that of the capacitor: it will freely allow an unchanging current, but opposes a rapidly changing one.

Alternative conceptions are very stable and, since traditional instruction does not encourage meaningful learning, it is not easy to address them with such an approach (Clement, 1993). White (1992) reported that traditional instruction (transfer of knowledge) is ineffective on correcting alternative conceptions and does not result in meaningful learning. However, Coetzee (2008) found both the traditional and OBE-based instructional approaches to be effective in addressing students' pre-conceptions. Changing alternative conceptions does not simply mean adding new information to an individual's mind: rather care should be taken to account for conceptual interaction between the new and existing knowledge provided that the new may be replaced with the existing (Novak, 2002).

Ohm's law

The first systematic investigations of the effect of potential difference on the current through a conductor were made by George Simon Ohm (1787-1854). He formulated the result of his findings into a law called by his name: the current between any two points in a conductor is proportional to the potential difference between the two points provided the temperature remains constant ($V \propto I$).

The significance of Ohm's law is that it predicts that under physical condition, the resistance of a conductor is independent of the potential difference across it and the current through it. The physical conditions referred to include temperature and tension of conductors. Other factors such as bonding and changing the shape of conductors can also significantly influence its resistance.

Resistance

The resistance of the conductor is defined as the number of volts needed to drive one ampere of current through the conductor (Cutnell & Johnson, 1998). A conductor has a resistance of 1 ohm if it passes a current of 1 ampere when a potential difference of 1 volt is maintained between its ends.

According to Johnstone and Mughol (1978:47), the significance of defining the resistance is to enable scientists to determine the voltage that must be supplied across a specific conductor to enable a specific amount of current to flow,-thus enabling them to describe energy transfer from the source to the appliances in the circuit.

Emf and potential difference

Cells supply energy to charges that move through it in an electric circuit. Emf is a measure of the quantity of electric energy that can be supplied per coulomb of charge. Emf is measured in volts just like potential difference. Potential difference is however associated with the energy drop experienced by each coulomb of charge when passing through a component in a circuit, while emf is associated with the total energy gained by each coulomb of charge passing through the cell (Cutnell & Johnson, 1998).

Historically, it was believed that a certain kind of force is responsible for pushing charge through the cell or battery. This force was referred to as the electromotive force (emf). It was later found that the concept of electromotive force is not descriptive of the actual situation and was discarded. However the use of the term emf was retained, and the term refers to the total amount of energy supplied to one coulomb of charge passing through the cell. Potential difference refers to the energy one coulomb of charge, when passing through a current element (appliance), can transfer to that element. The concept of emf and potential difference are defined to allow for a quantitative description of energy transfer in a circuit.

Internal resistance

Batteries or cells also offer resistance to the flow of current through them. When a cell supplies current, charges flow through the entire circuit simultaneously, and thus also in the cell itself. It is therefore logical that the charge carriers will also experience resistance

inside the cell due to collision. This resistance is called internal resistance of the cell. Energy is therefore also used in the cell to move the charge in the cell. Not all the energy of a cell is therefore available for conversion in the external circuit(Cutnell & Johnson, 1998).

2.6. ALTERNATIVE CONCEPTIONS ABOUT ELECTRIC CIRCUITS

Electricity is one area of science where many alternative conceptions exist. In view of the problem posed by alternative conceptions in learning electricity a number of researchers have focused on identifying these alternative conceptions, so that remedial strategies to address them can be attempted (Wesi, 1997:46).

Students' understanding of the concepts in electric circuits before and even after traditional instruction often differs from scientific meanings (Brown, 1977). Some students reveal an idea of the battery being like a fountain where only one terminal is needed to produce current. This view has been actually reported amongst students at various educational levels (Cohen, Eylon & Ganiel, 1983).

The notion reflects the idea that batteries are electric power sources from which current flows, as water flows from a fountain, and that the circuit does not need to be closed for current to flow through it (Cohen, *et al.*, 1983). Cohen, *et al* (1983) lament that some second-year university students still accept this interpretation-and this is indicative of the persistence of preconceived notions about electrical currents

Another deeply rooted alternative conception amongst the students is the belief that the intensity of the current in a circuit diminishes as it flows around the circuit (Shipstone, 1984). Thus, the students believe that current 'is used up' as it flows or goes through a resistor.

Previous research has also shown that the concept of potential difference is a difficult one for students to master. The main explanation for this difficulty is that everyday experience with regard to potential difference is probably lacking for most people (with the exception perhaps of those who travel frequently from Europe to America, and vice versa, and who are therefore familiar with voltage adaptors) (Liégeois & Mullet, 2002). The students view the electrical current as the origin of potential difference and potential difference as a mere measure of electric flow, more or less synonymous with intensity of current (Liégeois & Mullet, 2002).

Electric current is viewed as dissipating through the diverse elements of the circuit, especially bulbs (resistors) (Liégeois & Mullet, 2002). In particular, students and most non-professionals in the field, tend to view resistors essentially as sources of heat (or light); that is to say, as the locus of the dissipation of current (Cohen *et al.*, 1993). This, it would appear, is due to people's everyday experiences with resistors mainly through the use of light bulbs or radiators. Other domestic appliances are not typically viewed as resistors (Liégeois & Mullet, 2002).

Periago *et al.*, (2005), Pardhan *et al.*, (2001) and Nada *et al.*,(2009) found the following alternative conceptions about electric circuits.

Alternative conception (series and parallel connections)

The students think that in a series circuit, the terminals of one bulb are joined to the terminals of another bulb through a wire making one path for the flow of electrons. (.Pardhan *et al.*, 2001). The students also tend to think that in a parallel circuit, wires of each bulb are directly connected to the cell or through main wires to the cell (Pardhan *et al.*, 2001). Each bulb has its own path for the electric current to go through it.

Alternative conception (Unipolar model)

Often students think that the current leaves the cell and go to the bulb (Pardhan *et al.*, 2001). This claim is a result of, misunderstanding of the fact that the screw-thread of the bulb does not only serve the purpose of securing the bulb in its holder, but also serve as one of the terminals. The electric cords used in radios; electric kettles; electric irons; e.t.c. start at the source and end at the appliance. This creates the impression that current is only carried in one direction-towards the appliance and is consumed there. Little do students know that electrical cords actually consists of more than one wire which carry current in two ways (Periago *et al.*, 2005).

Alternative conception (consumer model)

Many students think that current is consumed in a circuit (Pardhan *et al.*, 2001).Students are current orientated; they believe that current leaves the battery (which is perceived to

be the source of current) at a particular value and is modified thereafter, depending on what it encounters in its path. According to this model little or no current may return to the battery. Students thus fail to understand that, current only conveys energy to the bulbs.

Alternative conception (cell as sources of constant current)

Periago *et al.*, (2005) have found that many students think that a cell is the source of constant current, which is independent of the conductor used. They fail to understand that a cell is a source of energy and supplies constant emf, while current depends on the resistance of the external circuit.

Alternative conception (no current, no resistance)

The study by Nada *et al.*, (2009) found that students think that there would be no resistance if there is no current. They failed to realise that the resistance of a component depends only on its own properties.

Alternative conception (no current, no voltage)

Many students believe that if there is no current in a circuit, then there should be no voltage distribution. This confusion between voltage and current manifests itself also in the way that students attributed the properties of current to voltage (Nada,et al., 2009).

2.7 CONTEMPORARY TEACHING STRATEGIES

From early childhood, learners experience the natural world and formulate intuitive ideas about concepts related to their world. According to the constructivist theory, learning involves the construction of meaning that is to a large extent influenced by the learner's existing knowledge. Some of this knowledge could represent alternative conceptions. Thus science educators must be able to identify and deal with learners' alternative conceptions in order to accomplish change. If not treated, learners will encounter problems in learning science. Learner-centered strategies should be implemented particularly from an activity-based learning platform.

Learner-centered science teaching begins with the background experiences and knowledge of the learners (Weld, 2002). This approach recognises that each learner must construct his/her own knowledge and that new concepts and propositions are built upon existing ones (Novak, 2004). Constructing knowledge is a lifelong process that requires significant mental engagement from the learner (Mestre & Cooking, 2002). The constructivist view of learning has two important implications for teaching. The first implication is that the knowledge that learners already possess affects their ability to acquire new knowledge. Secondly, instructional strategies that facilitate the construction of knowledge should be favoured over those that do not.

The transmission model of teaching

Traditionally, the teaching of science was seen as a transmission process, whereby knowledge was transferred from the teacher to the student (Wesi, 2001:56). The teacher was an active participant, while the student was a passive recipient of information. The teacher and the textbooks were the only sources of information. According to this model of teaching information is absorbed by the students and was assimilated in the same order and sequence as presented in textbooks and or as organised by the teacher. In this case, the teacher was the one who carried the responsibility to ensure that student learned. Students' performance and motivation were thus significantly influenced by the teacher's personality (Klassen, 2006). A well prepared lesson, presented in a formal setting, in a logical and clear manner; and an experimental demonstration properly carried out by the teacher in front of a quietly seated and attentive class were, according to the transmission model of teaching, a fulfillment of all essential aspects of good teaching.

The Heuristic Approach to Teaching

Upon realising the ineffectiveness and the failures of the transmission model of teaching in science, Henry Edward Armstrong in the early twentieth century, proposed the heuristic approach to teaching of school science (Wesi, 1997:57). According to Wesi (2001), the heuristic approach of teaching implies that students must be placed absolutely in the position of the original discoverer, so that they discover information and knowledge for themselves. Armstrong argued that the main significance of science teaching was to teach

scientific method (process) rather than merely teaching information and knowledge content as is the case with the transmission model.

Armstrong's rather uncompromising approach, which tended to over-emphasise the scientific method over the learning of content, did not win much support in the scientific and education circles. The final blow to Armstrong's heuristic approach came when psychologists issued reports of their research in favour of the transmission model as being a better teaching method for science (Wesi, 2001). Due to a great deal of evidence being lodged against the heuristic approach, science teaching shifted once again entirely towards the transmission model.

Armstrong's heuristic approach was revived in the late 1950's as a result of the work done by the Nuffield Science Teacher Project, Piaget, Brunner and Bloom. The Nuffield science teacher project designed a set of science teaching objectives, which could not be accomplished by means of the transmission model. Change in science teaching approaches was inevitable. The Piagetian developmental theory and theories on approaches to learning that were developed in the early sixties influenced science teaching towards observation, exploration and discovery approaches. In particular Brunner emphasized that the methodological structure of learning science must resemble the way that science has advanced. The method of learning by discovery was embraced more fully in the 1960's. Then Ausbel (1968) proposed a learning theory called constructivist learning theory. This theory provided a new and significant way of looking at how learning took place

Over the last decade an active research programme has been established in the area of students' conceptual understanding in science (Scott, Asoko & Driver 1992; Periago & Bohigas, 2005). Learning is seen in terms of conceptual development or change (Scott, *et al.*, 1992). Various models of learning based upon this viewpoint have been proposed, some emanating from epistemological literatures (Posner, Strikes, Hewson & Gertzog, 1982), and others from cognitive psychology (Osborne, 1983; Geer & Rudge, 2002). All of this work has strong implications for classroom practice.

The importance of students' prior knowledge for the acquisition of new knowledge and the need to sequence instruction to build upon students' existing concepts and propositions has been long established (Novak, 2004). Approaches to teaching that acknowledge students' alternative conceptions have been researched, developed and tested. These teaching approaches involve a range of different pedagogical strategies, drawing upon various aspects of the underlying theory of constructivism (Osborne, *et al.*, 1983). The challenge for the educator is to select the appropriate teaching strategy and techniques that will enhance learning within a particular learning context (Trowbridge, Bybee & Powell 2004).

2.7.1 CONSTRUCTIVIST TEACHING APPROACHES

A constructivist approach to teaching and learning acknowledges and recognizes the existence of learners' pre-knowledge that exists prior to formal teaching and learning

experiences. This pre-knowledge is actively applied by learners in responding and making sense to new situations (Fraser & Tobin 2003: 250-349).

In order to overcome deficiencies in students' pre-knowledge, educators and lecturers are faced with the problem of devising different and better teaching and learning strategies that will enhance science learning.

The constructivist model of teaching looks differently at the roles of the teacher and of the students in the science classroom. The teacher's role is that of a facilitator of the learning process and not an instructor. Students are not just passive recipients of what is taught, but are actively involved in interpreting and constructing knowledge (Trumper, 1990).

The constructivist approach to teaching is furthermore, based on the assumption that students' alternative conceptions have direct impact on their learning (Collins, 2002). Since the teaching of scientifically accepted concepts does not necessarily result in the necessary restructuring of students' alternative conceptions, the chances of successful teaching in science seem fairly slim, as no learning can take place if there is no restructuring of one's non-scientific knowledge. According to Wesi (2001) the constructivist view emphasises the importance of considering students' alternative conceptions in the teaching and learning of science. According to this view, students' alternative conceptions must be taken into consideration and be addressed accordingly. If they are ignored, they remain firmly entrenched within students' mental structures, and

persist long after formal instruction has ceased (Chi, 2005). Wesi (2001) proposes the following steps that can be followed in the classroom using the constructivist approach.

Establishing existing knowledge.

According to the constructivist approach to teaching, the nature of student's prior knowledge must first be established before the scientific concepts can be introduced. This can be achieved by asking leading questions prior to any formal instruction with a view to using students' prior knowledge to direct the course of learning activities. If students' prior conceptions are scientifically acceptable, they can be led through a process of knowledge construction on the basis of what they already know. If on the other hand, their prior knowledge is not scientifically acceptable, it is necessary to lead them through a process of discrediting their existing notions in order to pave the way for establishing of the acceptable new concepts

Discrediting Students' Ideas

Discrediting students' ideas does not imply that the teacher must criticise and rule out students' ideas. The teacher must instead allow students to explore their own alternative conceptions and use them to generate their own hypotheses and interpretations. In the process, the teacher must provide materials and opportunities for students to test their ideas and to construct relationships between concepts. In this way, a conflict situation arises in students' minds and their attention is drawn to the contradictions between knowledge and realities of the new situation. This conflict in mental structures serves as

the source of motivation for the child to seek closure. The efforts of the child are directed towards resolving this conflict. Where applicable, a conflict situation in students' minds can be created by means of an experimental demonstration, which yields contradictory results to their alternative conceptions. In this way, students will begin to doubt their conceptions and opt for one which is not contradictory to experimental observations.

The construction of knowledge

After students' conceptions have been discredited, they will be ready to assimilate scientifically acceptable knowledge; the knowledge does not lead to contradictions and is not contradictory to experimental observations. This knowledge should however not be presented to students by the teacher. Instead, students must be allowed to construct this knowledge themselves; this is the essence of constructivism. Steps involved in leading students through the process of knowledge construction include allowing them to discuss and interpret phenomena or experimental observations in such a way that they make sense to them. Through the guidance of the teacher, the acceptable scientific concept can be established. If the scientific concept is accepted, the learners will discard their own naive concepts in favour of the scientific one. In this way, learning has taken place.

Rote learning and memorisation were all that it took for students to succeed in the transmission approach to teaching, since internalisation of content and understanding were not emphasised. This approach was only aimed at enabling students to remember information so that they could pass examinations by reproducing what they had been taught, and no emphasis was placed on the acquisition of problem solving and logical

reasoning skills (Wesi, 2001). This approach however does not yield the type of results one would expect in a situation where higher order learning is required. The heuristic approach to teaching, which is a radical departure from the transmission model, is discussed below.

2.7.2 ACTIVITY-BASED LEARNING (ABL) AND PROBLEM-BASED LEARNING (PBL)

Activity-based learning draws upon a family of closely related theoretical perspectives and conceptual orientations. Most notably, these include problem-based learning among others.

Activity-based learning or ABL describes a range of pedagogical approaches to teaching. Its core premises include the requirement that learning should be based on doing hands-on experiments and activities. The idea of activity-based learning is rooted in the common notion that students are active learners rather than passive recipients of information. If a child is provided with the opportunity to explore on his/ her own and provided with an optimum learning environment the learning process becomes joyful and long-lasting.

Activity-based learning enables the construction of learners' mental models. The goal of activity-based learning is for learners to construct their own mental models that allow for 'higher-order' performances such as applied problem solving and transfer of information and skills. New information and communication technologies make it possible to develop and deliver multimedia learning objects for activity-based learning.

In a learner-centred science curriculum, learning science is active and constructive, involving enquiry, hands-on activities as well as minds-on analyses of problem-oriented scenarios (Taraban, Box, Myers, Pollard & Bowen, 2007:961). What a student does is actually more important in determining learning than what the educator does. The greater the learners' involvement, the better and more long-lasting their learning (Donnellen & Roberts, 1985). The aim of activity-based learning is to develop critical thinking and problem-solving skills by posing and investigating relevant questions (Taraban, *et al*, 2007:961). The task of the educator as facilitator is to create learning conditions in which learners actively engage in experiments, interpret and explain data and negotiate understandings of their findings with peers. Research has established that disadvantaged (academically or economically or both) learners are especially benefited by activity-based programmes will be (Donnellan & Roberts, 1985).

In activity-based learning a variety of learner-centred instructional strategies are implemented to teach science (Ramsden, 1994; Taraban,*et al*, 2007). The activities are designed to encourage active learner involvement. Learners are usually organised into collaborative learning groups. The use of a wide range of learning activities improves both motivation and learning of science (Ramsden, 1994). In particular, activity-based learning places particular emphasis on the use of everyday contexts as starting points from which scientific concepts are developed and scientific ideas explored (Ramsden, 1994:7). In this way learning starts from learners' experiences and can be guided towards an understanding of the concepts, methods and structures of physics (Lemmer & Lemmer, 2005).

The goals of PBL are to help students develop flexible knowledge, effective problem solving skills, self-directed learning, effective collaboration skills and intrinsic motivation. Working in groups, students identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. The role of the educator in PBL is that of facilitator of learning who provides appropriate scaffolding and support of the process, modelling of the process, and monitoring the learning.

PBL follows a constructivist perspective in learning as the role of the instructor is to guide and challenge the learning process rather than strictly providing knowledge (Dolmans *et al.*, 2005; Hmelo-Silver & Barrows, 2006). From this perspective, feedback and reflection on the learning process and group dynamics are essential components of PBL. Students are considered to be active agents who engage in social knowledge construction. PBL assists in processes of creating meaning and building personal interpretations of the world based on experiences and interaction. PBL assists to guide the student from theory to practice during his/her journey through solving the problem (Edens, 2000).

The adoption of PBL as a teaching strategy fits in well with contemporary science education (Cashion & Karen, 2006). PBL is much more than an instructional strategy. It has been adopted by educators with a view to foster not only the development of content knowledge, but also a range of skills and dispositions, such as curiosity, problem-

solving, communication and collaborative skills, decision-making, and self-directed learning (Edens, 2000).

PBL originated from the work of Dewey (1944), who emphasised the connections amongst doing, thinking, and learning. Learners' scientific knowledge and understandings are socially constructed through talk, activity and interaction around meaningful problems and tools (Bransford, *et al*, 2000). The educator guides and supports learners as they explore problems and define questions that are of interest to them. On their part, learners share the responsibility of thinking and doing. According to Hmelo-Silver and- Barrows (2006), the six core characteristics of PBL the following:

- It consists of student-centred learning;
- Learning occurs in small groups;
- Teachers act as facilitators or guides (referred to as tutors);
- A problem forms the basis for organised focus and stimulus for learning;
- Problems stimulate the development and use of problem- solving skills; and
- New knowledge is obtained by means of self-directed learning.

In PBL, students are encouraged to take responsibility for their group and to organise and direct the learning process with the support of a tutor or educator. Advocates of PBL claim that it can be used to enhance content knowledge, while simultaneously fostering the development of skills related to communication, problem-solving, critical thinking, collaboration, and self-directed learning (-.Edens, 2000).

PBL may position students in a simulated real world working and professional context which involves policy, process, and ethical problems that must be understood and resolved to achieve a particular outcome. By working through a combination of learning strategies to discover the nature of a problem, understanding the constraints and options to its resolution; defining the input variables; and understanding the viewpoints involved; students learn to negotiate the complex sociological nature of the problem and see how competing resolutions may inform decision-making.

While each of these theoretical perspectives used different learning strategies, they share a common assumption that meaningful learning involves the engagement of activity, which entails the unity of learning, doing and thinking.

2.7.3 VERBALISATION

Learners' confrontation of alternative conceptions through verbalisation of understanding is common to many stepwise approaches to teaching and learning strategies for conceptual change (Clement, 1982; & Olive, 2003). If learners can express their difficulties verbally, they are a step closer to overcoming them. This requires an educator to place greater emphasis on listening in the classroom when learners verbalise their conceptual understanding. In a constructivist classroom, peers may constructively criticise each other's statements and thus each other's understanding. Thus, in this way learners can refine each other's sample answers to problems. This approach will also sharpen the learners' critical thinking skills (Clement, 1987).

It is productive to have learners make verbal statements of their understanding to clarify and confront their alternative conceptions. Brown and Clement (1989) emphasise learners' oral and written explanations of their conceptual understanding as a method of isolating their alternative conceptions.

2.7.4 ANALOGICAL REASONING

The ability to reason by analogy is central to human cognition and learning. Analogy is a higher order reasoning skill which allows successful performance on novel problems, the ability to transfer knowledge to new situations, and learning by taking in a variety of information from different contexts (Richland; Morrison & Holyoak, 2006). Reasoning by analogy is thought to involve specific processes such as the ability to exert inhibitory control, keeping multiple relations in mind, and accumulating relevant domain knowledge (Richland *et al.*, 2006). Analogy is thus a complex skill that is essential for higher-order learning and thinking.

Alternative conceptions are not addressed by standard teaching in science classrooms and science textbooks. Simply presenting students with the logical arguments of scientific concepts during teaching does encourage conceptual learning to the extent that such reasoning actually makes little sense in the context of students' own beliefs (Baser & Geban, 2007). According to Carey (1985) students reading a science text or listening to a science teacher must gain a proper understanding by relating what they are reading (hearing) to what they know, and this requires active, constructive work. This notion is

the cognitive rationale for making science lessons relevant to students' concerns (Baser & Geban, 2007).

Teaching strategies in science are important in terms of facilitating meaningful learning and preventing alternative conceptions. Numerous studies (e.g. Harrisson & Treagust 1994; Gilbert, 1989 Richland *et al.*, 2006) have shown that careful use of analogies is effective in refining students' alternative conceptions in science, given that analogies are closely related to constructivist learning theory in two aspects, namely: promoting an environment in which students are active learners and that new concepts are based on old concepts.

Typically, analogies involve the presentation of an abstract new concept with a concrete familiar one to help learners to conceptualise it (Lawson, 1993). Analogies can also be used to facilitate the development of conceptual models of newly presented scientific mechanisms or structures by comparing them to something that is familiar to the learners (Iding, 1997).

The use of analogy instruction helps learners understand theoretical concepts, or change their alternative conceptions. For example, Stavy (1991) used analogies to overcome learners' misconceptions about conservation of weight. Analogical reasoning, as a tool for helping learners overcome misconceptions, is described by different researchers as for example, bridging analogies or chains of analogies (Clement, 1987). Analogical

reasoning has been refined for use in the classroom and is encapsulated well in the bridging of analogical strategies. The educator's correct use of bridging analogies can help learners to span the conceptual gap between anchor (a mastered) concept and target (misconceived) concepts (Clement, 1987; Bartlett, 2004).

The analogical reasoning strategies can involve a series of analogous demonstrations presented sequentially for comparison. An example from Newton's third law is (Brown *et al*, 1989): 'a book is lying on a table; gravity pulls the book towards the centre of the earth (action force)'. Many learners cannot identify the reaction force when given the action force (weight) of a book lying on a table. The educator may use the analogy of a hand pressing down on a vertical spring where the hand is analogous to the book and the spring is analogous to the table. The concept of reaction force may be clarified by this analogy. The idea is that most learners will understand the book on the table (target concept) after the educator has taught the more comprehensible hand on the spring example (anchor concept). Regardless of the concept to be taught, this approach is heavily predicated on the need for concrete examples and demonstrations, as these help learners to develop visual models of the concepts being studied (Brown, *et al*, 1989).

2.7.5 ENQUIRY AND INQUIRY TEACHING AND LEARNING

Enquiry learning is a learner-centred approach that emphasises higher- order thinking skills. It may assume several forms, including analysis, problem- solving, discovery and creative activities, both in the classroom and the community. Most importantly, in

enquiry learning students are responsible for processing the data that they are working with in order to reach their own conclusions (Trowbridge-*et al*-2000)

Inquiry-based learning is a constructivist approach- in which students have taken ownership of their learning. Its starts with exploration and questioning and leads to investigation into a worthy question, issue, problem or idea. It involves asking questions, gathering and analysing information, generating solutions, making decisions, justifying, conclusions and taking action(McBride & Muhammad,2004).

It is possible to describe enquiry issues from different aspects. Kaska and Rannikmaee (2006) emphasise two aspects of inquiry, namely: inquiry as means, and enquiry as ends. According to McBride and Muhammad (2004) enquiry, as a way of learning about the world, should be taught in the context of real -life scientific problems involving real life science knowledge. These problems should be relevant to the learners. The learners should initiate the study of these problems as they probe, search, explore and investigate questions of interest to them.

Observing learners in an enquiry laboratory is startlingly different. Instead of learners following descriptive paragraphs during the laboratory, they are provided with a series of challenging questions that they attempt to answer through an investigation they have to design. Biology learners may be asked to design an experiment that demonstrates

molecular movement through a membrane or to find observable variations between plant and animal cells by scanning a variety of tissue specimens. In an inquiry-based classroom, learners discuss which procedures will and will not lead them to a valid conclusion; they acknowledge variables that will interfere with their outcome's validity, and learn the importance of maintaining a control sequence to compare to their results (Marbach & Solokove, 2000). Class members are no longer content to sit passively through a lecture or in a laboratory activity; rather, today's learners need to be engulfed in the classroom experience. Learners who do not become involved in the lesson mentally tend to tune out what is going on and passively await the end of the class with their brains turned off. However, involving learners in enquiry is much more difficult than simply providing activities for them to do in the classroom (Enger & Yager, 2001).

While active learning suggests that learners are physically participating in the lesson, enquiry learning requires that they are also mentally participating in it (Enger, *et al.*, 2001). In fact, scholars agree that it is mental participation rather than the physical participation that is the important ingredient to enduring understanding (Wiggins & Mctighe, 1998). Learners need to consciously consider the events they are exploring; they also need to actively examine what they possess and predict the ramifications of intervening with the action (Wiggins *et al.*, 1998). Teaching science by enquiry involves teaching learners the science process skills used by scientists to learn about the world and helping the learners apply these skills when learning science concepts (McBride

& Muhammad, 2004). In particular, learners are helped to learn and apply science process skills by conducting problem-centred discovery.

Within the context of enquiry, teachers involve learners in investigations such as (a) challenging the validity of currently accepted science concepts, (b) going beyond their present understanding of currently accepted science concepts, and (c) investigating different explanations for specific science phenomena (Schwab, 1962; Banchi & Bell, 2008).

Towards this end, effective laboratory experiences are highly interactive and make explicit learners' relevant prior knowledge, engender active mental struggling with that prior knowledge and new experiences, as well as encourage metacognition. Without this, learners will rarely create meaning similar to that of the scientific community (Driver, 1989). That is why typical cookbook laboratory activities do not promote, and often actually hinder, deep conceptual understanding; they do an extremely poor job of making apparent and playing off learners' prior ideas, engendering deep reflection, and promoting understanding of complex content. Such activities mask learners' underlying beliefs and make desired learning outcomes difficult to achieve (Driver, 1989).

Enquiry-based learning is a constructivist approach, in which students' take ownership of their learning. It starts with exploration and questioning and leads to investigation into a worthy question, issue, problem or idea. It involves asking questions, gathering and

analysing information, generating solutions, making decisions, justifying conclusions and taking action (Harpaz, & Lefstein, 2000).

Inquiry-based learning approaches, when correctly implemented, can help develop higher-order, information literacy and critical thinking skills. They can also develop problem-solving abilities and develop skills for lifelong learning. Teaching science by enquiry involves teaching students the science processes and skills used by scientists to learn about the world and helping the students apply these skills involved with learning science concepts (McBride *et al.*, 2004). Students are helped to apply these process skills through conducting problem-centred investigations designed for specific science concepts.

When students learn science by enquiry, the process of enquiry becomes the means by which the currently accepted science knowledge is better understood. Through learning science as enquiry, students also better understand how scientists developed the currently accepted body of science knowledge. According to Songer *et al.* (2003) enquiry-based science has also provided great benefits in diverse classrooms, so that students are able to better respond to open-ended and multiple choice questions.

2.7.6 DISCUSSION BASED TEACHING

According to Applebee, Langer, Nystrand and Gamoran, (2003), classroom discussions in the form of both student-to-student and students and teacher serve as important means for facilitating the construction of scientific knowledge. In particular, the idea that

students' explanation abilities can be supported through whole-class discursive interactions with others draws on the early work of Vygosty (Langer; Nystrand & Gamoran, 2003). Sprod (1998) and Roschelle (1992) also believe that teaching with a focus on discussion can improve scientific explanation ability.

2.7.7 JUST-IN TIME TEACHING (JITT)

The Just-In Time Teaching (or JiTT) approach was developed by Novak (1999). The method is a synergistic curriculum model that combines modified lectures, group-discussion problem solving, and web technology. The JiTT approach can improve conceptual understanding, hone problem-solving skills, develop critical thinking abilities, build teamwork and communication skills and help learners to connect classroom learning with real world experience. JiTT focuses on two critical cognitive principles, one from each side of the teaching /learning gap, namely what

- ✓ Students learn more effectively if they are intellectually challenged; and
- ✓ Educators teach more effectively if they understand what their students think and know (Redish, 2003).

These principles are implemented by using web technology to change students' expectations with regard to their role in the learning process and to create a feedback loop between students and educator.

2.7.8 THE EPISTEMOLOGICAL APPROACH TO TEACHING ELECTRICITY

The study of electricity dates back to the time of Thales of Miletus in 600 BC. It is one of the sections in physics which has undergone a series of dramatic developments

throughout history (Jung, 1994:115).The immense influence of technological developments, followed important scientific developments on the human race cannot be underestimated. In order to understand the impact of major scientific developments on society, it is necessary to understand the major trends that char their development (Wesi, 2001:117). We thus need the type of science teaching that will take the wider context of the antisocial system. It is therefore necessary not only teach electricity content but also to teach students about the historical development of electricity to enable them to see this specialised knowledge in its proper perspective (Jung,1994:115).

The epistemological developments of the subject can be utilised in a number of ways during teaching. Firstly, it can be used as an organising principle of the curriculum by delineating the historical development of today's knowledge from its beginning, or by going back to the origins, beginning with the recent knowledge. Secondly, it can be used to enrich students with the knowledge of the emergence of important conceptual schemes, ideas, experiments, major arguments and historical circumstances. Thirdly, it can be used as an anecdotal enrichment, in order to relax students from the strains they might experience by working with raw physics and for motivational reasons. Fourthly, one may use the history of the subject in order to introduce a philosophical element into physics teaching and to familiarise students with the scientific thinking patterns and the manner in which scientific knowledge is constructed.

2.7.9 THE MODELING APPROACH TO TEACHING ELECTRICITY

The study conducted by Smit and Nel (1997) amongst South African teachers indicates that teachers generally have problems with the use of scientific models and with models of electric current in particular. Halloun (1996) proposed a schematic modelling approach which can be used to help students to learn physics in a meaningful way and to resolve learning deficiencies. In his proposal, Halloun (1996) argues that modelling is a major process used for constructing and employing the core content of scientific knowledge. Students fail to make correct qualitative predictions about the behaviour of electric currents because of a lack of an appropriate conceptual model for electric circuits. When used correctly, the models are effective in dealing with conceptions associated with electric current. However, Cohen, *et al* (1983) lament that when second year university students still accept this interpretation, this is indicative of the persistence of preconceived notions about electrical currents. According to McDermott (1991), scientific realism can take place at any level where the structures of physics theory and physicists mental processes are represented explicitly

Clement and Rea-Ramirez (2008), notes that in approach to learning electricity by way of explanatory models, students are encouraged to focus on the causes behind what is happening in the wires. The mathematical quantification of voltage, current, etc., is usually left until later in instruction, serving to verify and support students' working mental models. Clement and Steinberg (2002) present an approach to teaching complex models of electricity based on the model of construction cycle of Generation, Evaluation, and Modification (referred to as the GEM cycle). By means of this process of model

evolution, or incremental growth in sophistication of a model, students are led to reassess and revise their model many times. Their learning approach is centred around Steinberg's CASTLE (Capacitor Aided System for Teaching and Learning Electricity) curriculum, which utilises the introduction of large, non-polar capacitors into basic electric circuits as a way to focus students' attention on the transient states of potential differences that exist throughout the circuit. This uses the analogy of voltage as a type of "pressure" that exists in the "compressible electric fluid" of a circuit to explain how these capacitors go through their charging and discharging cycles. Studies by Brown, 1992 and Williams and Clement (2006) found that students in these model-based learning classes recorded significantly greater gains in electric circuit problem-solving and reasoning abilities than their counterparts who learned the concepts of electricity through more traditional, lecture and equation-based means.

A great deal of research has been published that identifies the different alternative conceptions about current, voltage, resistor, resistance and other electric circuit-related concepts (Nada, Osta & Zoubeir, 2009). Findings reveal common alternative conceptions held by students across the board, from primary to secondary and university, as well as by prospective science educators (Arons; 1997; McDermott & Shaffer, 1992). It has also been established that alternative conceptions are not confined to one country or to one educational system, but are indeed common to different countries with different educational systems (Shipstone, 1988). Furthermore, other studies indicate, inter alia, that students do have different conceptual models of how electric current works in electric

circuits (Pardhan & Yasmeen, 2001). For instance, Liégeois and Mullet (2002) found an alternative conception among young children and young adolescents which indicated that electric current was frequently considered as being transferred from batteries to light bulbs in a way similar to how orange juice is transferred from a bottle to the mouth using a straw (the sink model). The light in a bulb is frequently considered as the result of the 'clashing' between the positive current coming from the positive side of the battery and the negative current coming from the negative side (Osborne, 1983). For young adolescents and even for some university students, an electric circuit does not need to be closed to be functional. Also in a related vein, short circuits in an electrical circuit are not easily detected or identified in the circuit if the students have an inaccurate conception (Liégeois & Mullet, 2002:552).

Previous research has shown that in explaining an electric circuit, many students are unwilling to consider it as a whole, rather seeing the circuit as an entity where elements are totally independent (Liégeois & Mullet 2002:552). Students usually approach electric circuits in localistic ways and in also a sequentialist way (Cohen, Eylon & Ganiel, 1983). The localist approach is characterised by treating and visualising each part of the circuit separately thus, in a circuit, the battery, the ammeter, the resistor and its associated voltmeter are considered to be separate (Liégeois & Mullet 2002:552). The sequential approach is characterised by considering some parts of the circuit before other parts (Liégeois & Mullet, 2002).

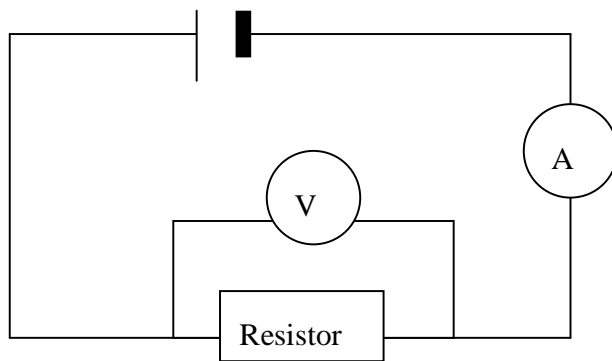


Figure 2.7: Circuit diagram

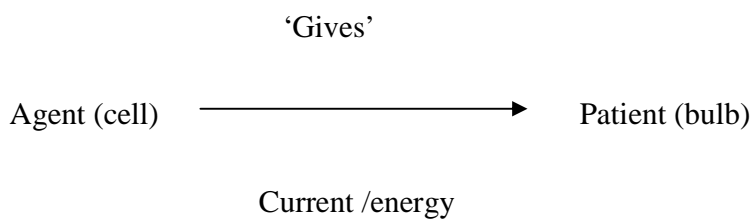
In the circuit given in Figure 2.7, the right segment with its ammeter portion will therefore be considered before (or after) the resistor and its associated voltmeter portion, and the resistor and its associated voltmeter portion will in turn be considered before (or after) the right segment. As a result, a phenomenon affecting one part of the circuit will be reflected in the subsequent portions of the circuit without affecting the preceding portions.

Pardhan and Yasmeen (2001), and subsequently Nada *et al* (2009), have identified alternative conceptions of electric circuits amongst students as follows; these are:

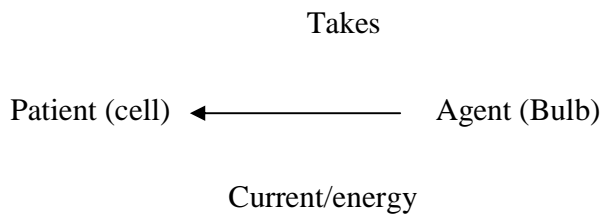
- The attenuation model - whereby a cell is regarded as a reservoir of current and as current moves through successive components, the current gradually wears out.

- The sharing model - in which it is envisaged that if components are identical, current will be shared equally, but current is not conserved (i.e. current out of the cell is more than current back to the cell).
- The unipolar model - where students do not recognise the need for a closed circuit, and therefore treat electric components as electric sinks that transform the current sent by a battery into light and/ or heat.

The studies cited above provide evidence that students perceive the cell as an agent which gives out a fixed amount of current and the bulb as a patient which consumes current.



In studies by Koumaras, Kariotoglou and Psillos (1997), it was found that when students were exposed to more complex circuits (i.e. with resistors or combinations of parallel and series connections), or when the time element was introduced (e.g. given two circuits, one with a bulb connected to a single cell and the other bulb connected to two cells in parallel and students were asked in which case the bulb would stay longer), their explanation using the Give model did not fit the observation (Pardhan & Yasmeen 2001:303). In trying to explain the new experiences the students reversed their thinking, that is; that the bulb and cell switched roles in the Give model, thereby giving way to the Take model.



The bulb and cell switched roles, whereby the bulb acted as an agent which gave a fixed amount of current and the cell as a patient, taking away current.

Stocklmayers and Treagust (1996) probed the ideas of young children and students from different age levels, as well as a experiences about the nature of ‘current’ and some electric circuit terms. Overall, a ‘Mechanical’ model was used whereby children perceived current as a lot of tiny particles, whereas adults imagined it to be like small balls moving along tunnel-like wires (Pardhan & Yasmeen 2001:303).

Invariably, all studies of conceptual understanding, especially prior to formal instruction, indicate that alternative conceptions are held by individuals on most science concepts. Most of the studies, though not always explicit, also include possible explanations for these alternative conceptions (Gilbert, Osborne & Fensham 1986; Driver, 1989; Wandersee, Mintzes & Novak, 1994; Duit & Treagust, 1995). In a nutshell, alternative conceptions are held by individuals because of the diverse set of personal experiences including direct observations, perceptions, culture, language, teachers’ explanations and

instructional materials like textbooks (Coetzee, 2008; Pardham & Yasmeen, 2001). In short, alternative conceptions held by individual learners have strong implications for science educators, because they pose immense challenges for quality science education. With a view to improve university students' conceptual understanding of electric circuits, current policy and standards in science education, this study suggests using a constructivist approach.

2.7.10 A MORE PRACTICAL APPROACH TO TEACHING ELECTRICITY

It is generally believed that effective teaching of physical science and electricity in particular is not possible without exposure to practical work. However, studies by Van der Linde *et al.*, (1994) in South Africa indicate that very little effort is being made to introduce a more practical approach to the teaching of science. A practical approach in science teaching has been justified by Van der Linde, *et al.*, 1994) who claim that practical work in the classroom is significant in the sense that it:

- Develops learners' practical skills and techniques;
- Encourage the development of scientific attitudes and creativity; and
- Enable students to get the “feel phenomena”.

The spirit of enquiry as well as appropriate manipulative skills can only develop through hands-on experience. In addition practical work makes the learning experience enjoyable for the students by stimulating their interests and mental skills

This study argues that practical work must form the basis on which theory is formulated. The correct procedure here is to place students in the situation of the original discoverer

and to guide them to make observations on the basis of which conclusions are made (Wesi, 2001). For instances, when teaching Ohm's law, it is necessary to allow students to carry out the experiment, record their observations, make generalisations and draw conclusions before the statement of the law as such is brought to their attention. In this manner, students shall have constructed their own knowledge. This act is absolutely essential for effective learning. In this regard, Gunstone and White (1992) proposed three essential steps for practical work namely:

- Predict;
- Observe; and
- Explain.

These steps comprise the so called POE method, involves making predictions of the outcome of the experiment or demonstration, before actually performing it; making observations and recording the measurements and lastly explaining and arriving at conclusions based on the recorded data and the observations made. These three steps are essential in the sense that they enable the learner to extract a great deal of useful information from the experiment. The POE method can be a useful tool towards effective teaching of electricity and can be very rewarding for use in practical work.

2.7.11 THE QUALITATIVE PROBLEM SOLVING APPROACH

Problem solving does not develop a deep understanding of concepts and principles, even amongst students who become proficient problem solvers. Leonard (1996) proved wrong the perception that teaching students how to solve problems will develop in them the

actual understanding of concepts and principles. Although emerging instructional approaches emphasize conceptual development, the problem of adhering to traditional teaching approaches still exists, despite the desire to change. A great deal of effort is required to turn the situation around, and thus to improve instruction. At the centre of the approach to improve the situation, are the qualitative strategies towards approaching physics problems.

Physicists use mathematical expressions to describe or formulate the laws of nature, which convey not only qualitative but also quantitative information related to the nature and amount of the participating quantities. Ohm's law, for example, gives the qualitative relationship between current, resistance and potential difference. This description only explains the nature of the relationship between these three quantities, but does not tell anything about the extent to which these quantities influence one another.

Leonard (1996) proposes that, the qualitative problem solving strategy involves three elements. Firstly, the identification of the major physics principles and concepts those are useful in solving the problem; secondly, the articulation of the rationale for using a particular principle or concepts; and lastly, the application of these concepts to solve the problem at hand.

2.7.12 USING MULTIPLE REPRESENTATIONS

The presentation of physics often takes place in an algorithmic and procedural manner during which students are assigned problems which they solve by mimicking the way

similar problems are solved by the teacher and the text books. This type of presentations emphasises qualitative problem solving which involves selecting and manipulating one or two appropriate equations to obtain the solution. Unfortunately, this type of problem-solving does not result in deep understanding of concepts nor does it succeed in developing robust problem solving skills. The reasons for this are that students usually select and apply the equation without checking its appropriateness and also without seeking to understand its content. As a result students emerge from the electricity classroom with a shallow understanding of concepts and with a narrow set of problem-solving skills.

Students must be provided with sets of examples in order for them to learn how to solve problems. A variety of representations can be used, including field line diagrams, free body diagrams, equations and so forth. These representations can be used in a large variety of problem situations to enhance both the quality of teaching and the learning of electricity. Free body diagrams can be used effectively to sketch the physical situation to explain a problem and summarize the given information.

Free body diagrams can also be used effectively in electrostatics to solve problems involving interactions between stationary charges. Sketches showing relative positions and distances between interacting charges help to explain the problem. The use of a linear model for the teaching of the concepts emf and potential difference is an example of how graphical representations can be used to analyse energy changes taking place in electric

circuits. This analysis of energy changes in an electric circuit is usually done by means of calculations involving the use of a number of equations. Teachers and students routinely carry out these calculations without proper visualisation and understanding of the physical set-up behind the problem (Dufresne *et al.*, 1997).

When assisting students to learn how to use multiple representations in problem solving, it may be necessary to engage them in activity involving description of a problem using at least three different representations for example, diagrams, equations and graphs. After working with all three representations, students may be led to compare three representations.

2.7.13 CONCEPT MAPPING

A concept map is a way of representing relationships between ideas images or words in the same way that a sentence diagram represents the grammar of a sentence, a road map represents the locations of highways and towns, and a circuit diagram represents the workings of an electrical appliance. In a concept map, each word or phrase is connected to another and linked back to the original idea, word or phrase (Anderson, Byrne, Douglass, Lebiere, & Qin, 2004). Concept maps are a way of developing logical thinking and study skills by revealing connections and helping students see how individual ideas form a larger whole

Concept maps were developed to enhance meaningful learning in the sciences. A well-made concept map grows within a *context frame* defined by an explicit "focus question", while a mind map often only has branches radiating out from a central picture. There is

research evidence that knowledge is stored in the brain in the form of productions (situation-response conditionals) that act on declarative memory content which is also referred to as chunks or propositions. Because concept maps are constructed to reflect the organisation of the declarative memory system, they facilitate sense-making and meaningful learning on the part of individuals who make concept maps and those who use them (Anderson *et al.*, 2004).

2.7.14 CONTEXTUALISATION AS A DIDACTICAL APPROACH IN PHYSICS EDUCATION

In the science-educational setting, the word "context" can have two different but related usages, the one being knowledge-centred and the other activity-centred (Klassen, 2006). According to Lemmer and Lemmer (2005), the following aspects form part of the context of physics.

- 1) The philosophical context, which concerns aspects such as the world view of physics;
- 2) The historical context of the development of physics;
- 3) The technological context, which includes the development of measuring techniques, empirical and technological equipment, as well as everyday applications;
- 4) The mathematical context which is based on the mutual interaction between mathematics and physics;

- 5) The relational context in which physics is related to other sciences, such as chemistry and biology as well as social sciences;
- 6) The experiential context that refers to everyday experiences and learners' practical experiences of the world; and
- 7) The natural context, i.e. naturally occurring phenomena or events such as lunar eclipses.

The experiential context is used mostly frequently in science education. Contextualisation in the learning process emanated from the learning psychologies of Piaget, Ausubel, Gagne' and Vygotsky (Klassen, 2006). The contextual approach is constructivist in nature and this is what OBE advocates. It starts from learners' primordial paradigm, subsequently proceeds towards conceptualisation and then to formalism (Lemmer & Lemmer, 2005). New concepts are introduced in a context that is familiar to the learners. Anchoring ideas (Duit, 1981; Clement, 1983) are used to explain the contextual events or phenomena. After conceptual understanding has been assured, the concept is formalised, usually by means of scientific formula and definitions. Contextual, conceptual and formal applications enhance learners' understanding of the concept. In contextualisation, learners are made aware of differences between their paradigm and physics, and guided towards an understanding of the concepts, methods and structures of physics (Lemmer & Lemmer, 2005).

According to Clement (1989), mechanical energy may involve many different things that are familiar to learners. A discussion of the ways things move might be very helpful for learners to visualise mechanical energy. A description of the motions of the human body would be a suitable problem for the learners to model. Likewise, a discussion of simple machines could be used to describe how mechanical energy is transferred from one type of motion to another type of motion.

Duit (1981) proposes the use of semantic anchors to improve students' understanding of energy conservation. An example of such a semantic anchor is to link energy to learners' everyday experience of fuels, namely that energy is necessary when something is to be set in motion, quickened, lifted, illuminated, and heated, and so on. This means that energy conservation is approached in a step-by-step manner by means of examples and experiments.

2.8 CONCLUSION

The teaching of science has been an ever-changing educational exercise (Wesi, 2001). In the old school curriculum, the teaching objectives of science were to produce individuals who could memorise and retrieve information from memory. Activity-based approaches to education have constructivist aims which view knowledge as socially constructed. Addressing students' alternative conceptions with activity-based instructional approaches, couched within OBE principles, holds great promise for the amelioration of students' learning difficulties. The central tenet of activity-based instructional approaches

is that knowledge is in some sense relational and as such students become more actively involved in the learning process.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

Students' underachievement in science has been the subject of major concern in many countries for many years. Among the salient factors contributing to this problem, two of the most frequently mentioned in the extant literature are: (a) students' alternative conceptions and (b) poor instructional practices (Osborne, *et al*, 1981). The question arises as to the most appropriate instructional strategies that could be used to accomplish conceptual change? This question has guided the choice of the researcher (the author of this thesis) in the selection of a combination of a number of instructional strategies to include in his activity-based lessons, with a view to addressing the alternative conceptions that may have prevented the university science students, involved in the study, from developing valid scientific conceptions about electric circuits.

From the literature it is apparent that students' inability to apply memorised facts and procedures is a worldwide problem. In this regard, some educators see the constructivist approach as part of the solution particularly for addressing alternative conceptions.

3.2 ACTION RESEARCH AS THE METHODOLOGY FOR THE STUDY TEACHING AND LEARNING OF SCIENCE

The research methodology followed in this study made use of action research as a central point of reference. Leedy and Ormrod (2001:105) characterise action research as a type of applied research that focuses on finding a solution to problems of practice in a local setting. By engaging in action research, educators research their own practice of teaching (Feldman & Minstrell, 2000). It is an enquiry into their teaching in their classrooms. This research focused on the work of the researcher as an educator it was developmental in nature and was intended to improve the educator's practice in order, in turn to enhance the learners' quality of learning.

According to Feldman *et al* (2000), there are several types of action research products, including increased understanding of practice, and improvements in teaching and learning, whereby teaching and learning are evaluated relative to a specific benchmark or standard.

Thus, in action research knowledge is generated by doing research (Feldman *et al.*2000). If action research sets out to generate knowledge, it must be a legitimate form of research and the results must be regarded as to be valid. This means that educators must systematise their enquiries and subject them to critiques from within and from outside the classroom. The goals of action research are often interpretative, rather than explanatory (Feldman *et al*, 2000). Educators need to show that what they have learnt is appropriate for the specific case of the teaching in their classrooms.

The central concern of action research is to facilitate a systematic and collaborative search for solutions to problems of common concern amongst a number of stakeholders, through an experiential and reflective process (Imenda & Muyangwa, 2006). Action research goes beyond the spiral phases of planning, acting, observing and reflective action when it is appropriately used. In addition, it engages the participants (practitioners) in a critical analysis of both the research process and of issues being investigated. To this effect, any constraints which emerge are critically analysed, debated and/or even removed if they are found to impede desired improvements, innovations and/or change (Imenda & Muyangwa, 2006).

Action researchers can evaluate the effectiveness of new instructional methods or materials through outcome measures, or they can use ongoing formative assessment within the context of the teaching situation (Feldman *et al*, 2000). Educators obtain an immediate evaluation of how implementable the suggested improvements are. Some ideas can therefore be rejected out of hand.

According to Feldman, *et al* (2000), action research reduces the time lag between the generation of new knowledge and its application in the classroom. Educators spend a large amount of time in schools working with learners; they are there in the most appropriate situation to investigate the effectiveness of their practice.

The research design and instrumentation, as well as other research methods used in this study are explained below.

3.3 RESEARCH DESIGN

In order to investigate the extent to which an activity-based approach could help to alleviate or overcome the incidence of alternative conceptions about electric circuits, a pre-experimental one-group pretest-post test research design was followed (Imenda & Muyangwa, 2006). The design is represented as follows:

O_1 X O_2

O_1 = pre-test

X= Experimental treatment (Intervention)

O_2 = post test

A research and development (R&D) protocol was followed for the purpose of assessing the appropriateness and adequacy of actual implementation during the pilot-testing phase. It is always important to evaluate the implementation of a programme before attempting its effectiveness in achieving the intended outcomes (Imenda & Muyangwa, 2006). The identification of areas of difficulty to the students was followed by an activity-based intervention within the pedagogic aegis of OBE in order to alleviate the identified conceptual gaps in the students' understanding of sciences content.

The steps of the design were as follows:

- (i) The students were given a test to write, consisting of two sections. In section A the students were required to indicate the names of the high schools they had attended prior to coming to university, their gender, and the year in which they completed Grade 12. The

main objective of the pre-test was to determine the alternative conceptions that they held about electric circuits as they started the university programme (see Appendix A).

(ii) The intervention strategies based on activity-based learning were then developed in accordance with the OBE pedagogic approach which is an approach based on the constructivist philosophy. A variety of activities were chosen and sequenced so that students' conceptions could progressively be challenged, in order to allow students to change their alternative conceptions into scientific ones. The succession of activities and discussions typifying the activity-based intervention strategies were aimed at enhancing progression from contextual to conceptual, and finally to formal understanding of the concepts (refer to paragraph 3.5).

(iii) The students wrote a post-test, the same as the pre-test, at the end of the intervention to verify the effect of the intervention. The results were analysed and normalised learning gains were calculated to indicate the effectiveness of the intervention. The gains of students from the NCS were then compared with those from the OSC. The following three *a priori* hypotheses were tested

- An OBE-based intervention will significantly alleviate alternative conceptions about electric circuits held by first year science education students admitted from high schools which followed the NCS.
- An OBE-based intervention will significantly alleviate alternative conceptions about electric circuits held by first year science education students admitted from high schools which followed the OSC.

- Students who studied under the NCS will demonstrate significantly higher learning gains after exposure to an instructional intervention using activity-based instructional approaches, within the aegis of OBE.

3.4 DATA COLLECTION

3.4.1 RESEARCH INSTRUMENT

The Electric Circuits Concept Evaluation (ECCE) test was developed by Prof David Sokoloff to assess students' understanding of simple circuit concepts (Sokoloff, 1992). The questions assessed students' understanding of current and potential difference in simple series and parallel circuits. During the development of the test, Prof David Sokoloff administered it during the spring term of 1992, both as a pre and post-test to students in one lecture section of the physics course (PHYS 203) at the University of Oregon where it was found that students did not master simple circuits by a traditional instructional approach. Using the ECCE test McDermott and Shaffer (1992) as cited by Sokoloff (1992) found that the pre- and post-testing showed dramatic gains in students' understanding of current and voltage in simple series and parallel direct current circuits.

The validity and reliability of the test were established by Engelhardt, (2004), who examined the feasibility of assessing students' conceptual understanding and potential use in evaluating the curricula using the ECCE test. The Kuder-Richardson formula 20(KR-20) was found to be less than 0.70 because of low discrimination and high difficulty indices. The low average discrimination values indicated that the test does indeed uncover students' alternative conceptions. Content validity was established by

presenting the test and its objectives to an independent panel of experts to ensure that the domain was adequately covered. The panel took the test and matched items with its objectives. This process yielded an agreement for the answer key as well as for the objectives. The researcher was granted permission by the author to use the test.

Eleven questions were taken from this test to probe targeted alternative conceptions regarding electric circuits for this study. The reliability coefficient for the assembled test is reported on in section 3.4.3.

The test (see Appendix A) developed and utilised in this study was administered to hundred (100) first year university science education students. The students were enrolled for the Bachelor of Education (B.Ed) programme in the Faculty of Education, and were registered for the module Electricity and Magnetism. The test probed the learners' alternative conceptions about electric circuits. The students were allowed sixty minutes (1hour) to complete the test. The researcher supervised the writing of the test to ensure that the students understood all the questions. As a measurement of any instrument that is used is that it must be valid and reliable (Leedy & Ormrod, 2001:203). This matter is briefly discussed below.

The items in the test used in this study were compiled to cover the objectives of the study (section 1.4), and focused on alternative conceptions that students possessed about electric circuits. One mark was allocated for each choice and three marks for the motivation.

3.4.2 Validity of the instrument

In general, the validity of a measuring instrument can be described as the extent to which the instrument measures what it is supposed to measure (Leedy & Ormrod, 2001:98). The researcher established validity of the instrument by discussing the questions in the test with the study leader. Subsequently, the draft question paper was peer-reviewed by a researcher at another university for content validity. This researcher was served with the study guide and module outline for the Electricity and Magnetism module. The instrument assessed whether the intervention strategy used in the three activity-based lessons enhanced conceptual development in electric circuits to be in line with the hypotheses (section 1.5) and the objectives (section 1.4) stated.

3.4.3 Reliability of the instrument

The reliability of a measuring instrument entails the extent to which it yields consistent results when the characteristics being measured have not changed (Leedy & Ormrod, 2001:98). The motivations were considered to be reliable measures of students' understanding more so than the assumptions drawn simply on the basis of the students' choices from the multiple choice test. The split half (odd-even) reliability coefficient of the entire test was computed, using Spearman-Brown formula and it yielded 0.68. This reliability coefficient of larger than 0.68 falls within an acceptable range.

3.5 ACTIVITY-BASED INTERVENTION

On the basis of the identified alternative conceptions, interventions consisting of activity-based lessons were implemented for a period of two weeks (Appendix B) comprising 1.5 hour sessions. A total of 9 hours of contact intervention time was used. The identified alternative conceptions were incorporated into the development of the intervention using them as the basic building blocks for understanding. In order to ameliorate alternative conceptions held by the students, the intervention followed the order proposed by Lemmer and Lemmer (2005) i.e. progression from contextual to conceptual activities and, final to formal problems. The intervention was developed by the author. His own ideas and activities were integrated with examples given in the study guide by Watson (2003) and Wesi (2001). The activities were also performed in groups so that co-operative learning could take place.

For the activities a problem was posed that the learners had to solve in groups. The contextual and conceptual activities utilised the strategies of verbalisation and analogical explanations.

In the contextual problem, students were given a bicycle analogy (Appendix B). They had to answer questions related to the bicycle analogy. During the post-activity discussion, the researcher introduced the concepts; electrical resistance, battery, current intensity, electric charges, electric field, electromotive force (emf) and the Law of

Energy Conservation. With the acceptance of the analogy, students would have been able to understand and accept the interpretation of electric circuit experiments. After the students had understood the contextualised concepts and principles from the bicycle analogy, they were able to explain emf, the function of the battery and the law of energy conservation.

To ensure conceptual understanding of electric resistance, battery, current intensity, electric charges, electric field, an emf, a conceptual problem (experiments) was used to conceptualise these concepts. This analogy is related to a move from contextual to conceptual development.

As a way of preparing them for the second phase which focuses on conceptual development. The researcher linked use of analogies (bicycle analogy) and modeling to foster a move towards the contextual problem.

In the first contextual problem (Appendix B), the students were given a bicycle analogy and the researcher together with the students discussed how energy is transferred when a bicycle is pedaled. When the bicycle is pedaled or when the pedal is pushed pushing the pedal with a constant force and with constant obstacles (electrical resistance), the flow rate of the wheels (current intensity) will be the same at each point (no losses). The pedals (battery) maintain the movement by tiring the muscles (energy exhaustion of the battery). The chain which serves as a link (it is like electric charges) moves slowly but the energy (the pushing on the pedal) is instantly available. The energy is only

transferred from the source (pedal) to the user (wheels) when the links move. The links never get lost or are used up and this is how Law of Energy Conservation was introduced, and the concept of electric field was also brought in. It was explained that a cell is a device which separates + and – charges and charge the separation in the cell sets up an electric field between the charges. Further discussion made it clear that when a disaster happens like the chain breaking, the students foresaw that the wheel of the bicycle would still rotate for a while. In applying this example to the notion of electrical circuit they could understand that the bulb may continue to shine for a little while after its source of electricity has been cut off. This contradicted their normal experience with electrical switches.

Correspondence between the Bicycle analogy and a simple Electric Circuit

Bicycle Analogy

Electric Circuit

Pedals

Source of energy (battery)

Wheels

Bulbs

Muscular fatigue of person

Wearing out of the battery

Chain

Electric charges

It was explained that a battery is a device which converts chemical energy into electrical energy on a continuous basis, and which tries to maintain a constant potential difference across its terminals.

In very broad terms, a battery comprises of a chemical reaction that is in some way constrained to create an electrical current. Any chemical reaction is caused by electrons moving between atoms. Clearly, when all the chemical reagents that in the battery have been used up (i.e. they have all completed the chemical reaction, so there are no more unreacted chemicals left waiting to form the reaction), then there will have no more electrons to move from one reagent to another, and thus the battery is dead (worn out). Once an explanation for the battery's wearing out was understood, the crucial point of acceptance was students' recognizing that the bicycle speed was the same everywhere.

With the acceptance of the above analogy, students were able to understand and accept the interpretation of the electric circuit experiment (the current is the same everywhere, although the battery wears out).

According to Michael (2003), "learning is most effective when the concepts under consideration can be aligned with one's present understanding or knowledge". In this sense analogies are useful because they allow students to learn intuitively. Analogies may be used in two ways. First, they may be used as a bridge between familiar and new situations. The success of this strategy depends on both the students' understanding of the familiar situations and on the persuasiveness of the argument that draws out similarities between the two situations. The second use of analogies is in representing abstract ideas in terms of concrete or physical structures. The success of the second

strategy depends largely on whether the concrete structures that are used fall within most students' life experiences, as well as on the persuasiveness of the argument that maps them to the abstract idea under study (Michael, 2003).

The use of analogies as a cognitive tool can be found in almost all societies and cultures and at almost any time in human history. Analogical thinking is a way of understanding new or novel situations by building models based on one's existing knowledge of familiar scenarios (Michael, 2003). The new situation may, at least superficially, could be quite unlike the familiar domain, but relationships among elements of the new scenario may closely resemble relationships shared by elements of the familiar domain. The familiar domain is referred to as the source analogue, the new domain as the target analogue.

Analogies can be useful but if they are not well-chosen could give incorrect information to students, or even create further alternative conceptions. It is important to keep in mind that if teachers describe what electricity is like, they should use a useful and appropriate analogy.

In the second phase, students used experiments to conceptualise basic concepts of a complete circuit, current, potential difference, resistance and electromotive force (emf). In this phase, the concept of equivalent resistance was developed and applied to parallel

and series circuits. The students were also introduced to cells in series, the connection of light bulbs in series and parallel. They were also asked to record the brightness of the bulbs in the first experiment when the number of cells were increased and on Part 1 of the second experiment when they increased the number of bulbs and recorded the bulbs' brightness on the work sheet. In Part 2, the students were asked to measure the current strength and potential differences across the circuit element. When they read a series of potential difference, keeping the one pole of the battery and changing the other to different points along the circuit, a noticed the drop in potential difference whenever a resistor (bulb) was added. Subsequently, the students were introduced to concepts such as current, potential difference and resistance. They were encouraged to use both deductive and inductive explanations to synthesise these concepts. The conclusions arrived using inductive reasoning in Experiment entailed that an increase in the number of cells led to an increased in the brightness of the bulbs in a series connection. The relationship that could be deduced is that if the numbers of cells in increased while the temperature remains constant the voltmeter reading and ammeter reading both increases.

Deductive explanations were used in Experiment 2 part 1, where the numbers of bulbs in series connection was increased. They came to realise that in a series connection, when the number of bulbs increases resistance also increases. The conclusion drawn from this known observation is that the bulbs will be dimmer if one were to increase them in series connection.

In order to deal with persistent conceptual difficulties the researcher used conceptual change strategies to confront students' alternative conceptions. For example in question 2, there was a persistent conceptual difficulty namely that of predicting the brightness of the bulbs as an identical bulb was added in parallel. Aspects of learners' initial knowledge that contain elements of the physics concept (i.e. productive conceptual resources) have been identified and refined .Learners were then guided to generalize towards a conceptual understanding base on the similarities and differences in a variety of selected everyday and classroom experiences. In this way, physics knowledge was grafted onto the learners' experiential knowledge as they systematically developed coherent conceptual knowledge.

1) In the third phase, learners were asked to complete formal problems. For example, they were asked to predict the brightness of the bulbs by referring to potential difference, current and resistance.

Bulb A glows brighter than bulb B when both are connected to a 12V source as indicated in Figure 3.1.

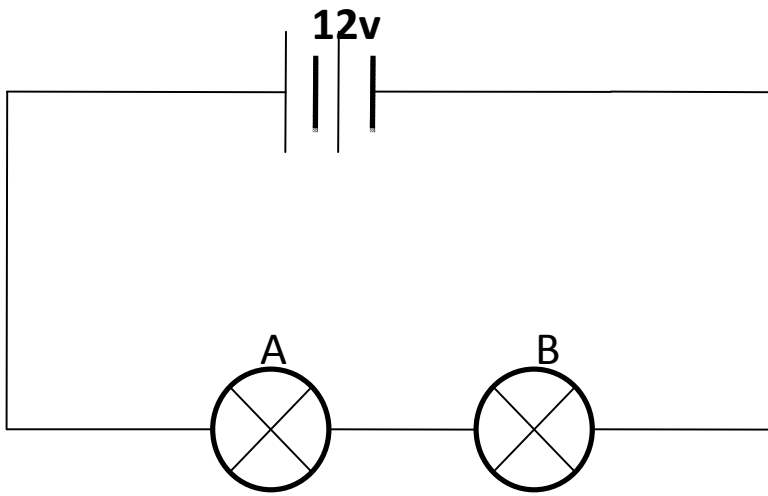


Figure 3.1. Diagram for bulbs connected in series

The same bulbs are now connected to the same 12 V source as indicated in Figure 3.2.

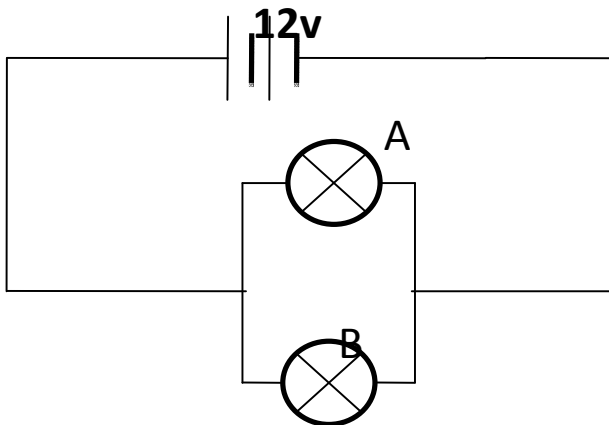


Figure 3.2.Diagram for bulbs connected in parallel

When bulbs are connected in series bulb A glows brighter than bulb B, because the power at bulb A is greater than the power at bulb B (power is the rate at which work is done or number of joules of energy transferred to an element every second). The resistance of bulb A is greater than the resistance of bulb B ($P=I^2R$ and I is the same in each bulb).

In Figure 3.2 it is shown that when they are connected in parallel, the current (I) at A is greater than the current (I) at bulb B, because the resistance (R) of A is greater than the resistance (R) of bulb B. the power (P) at bulb A is less than the power (P) at bulb B ($P=VI$) and if the potential difference (V) is the same for both, then bulb B glows brighter than bulb A).

2) In this formal problem students were introduced to the application of Ohm's law where they were asked to calculate the internal resistance of the battery, the emf and the total resistance of the circuit.

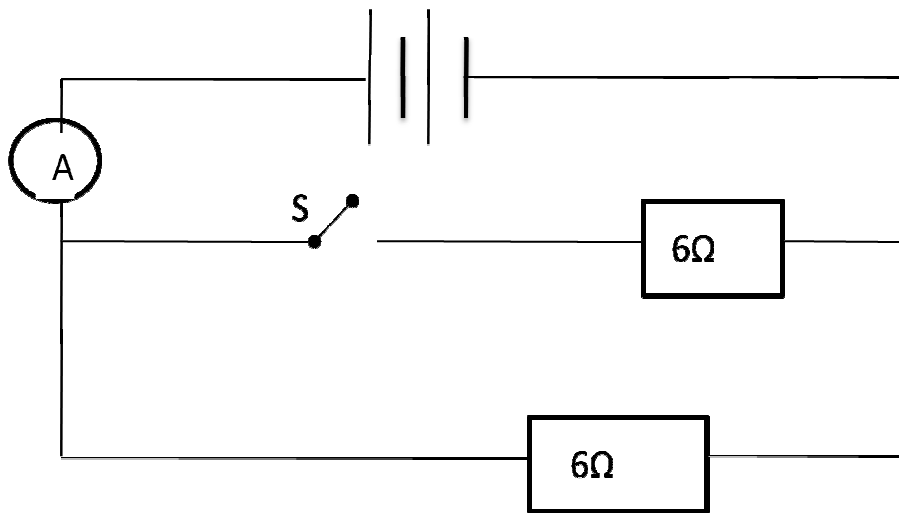


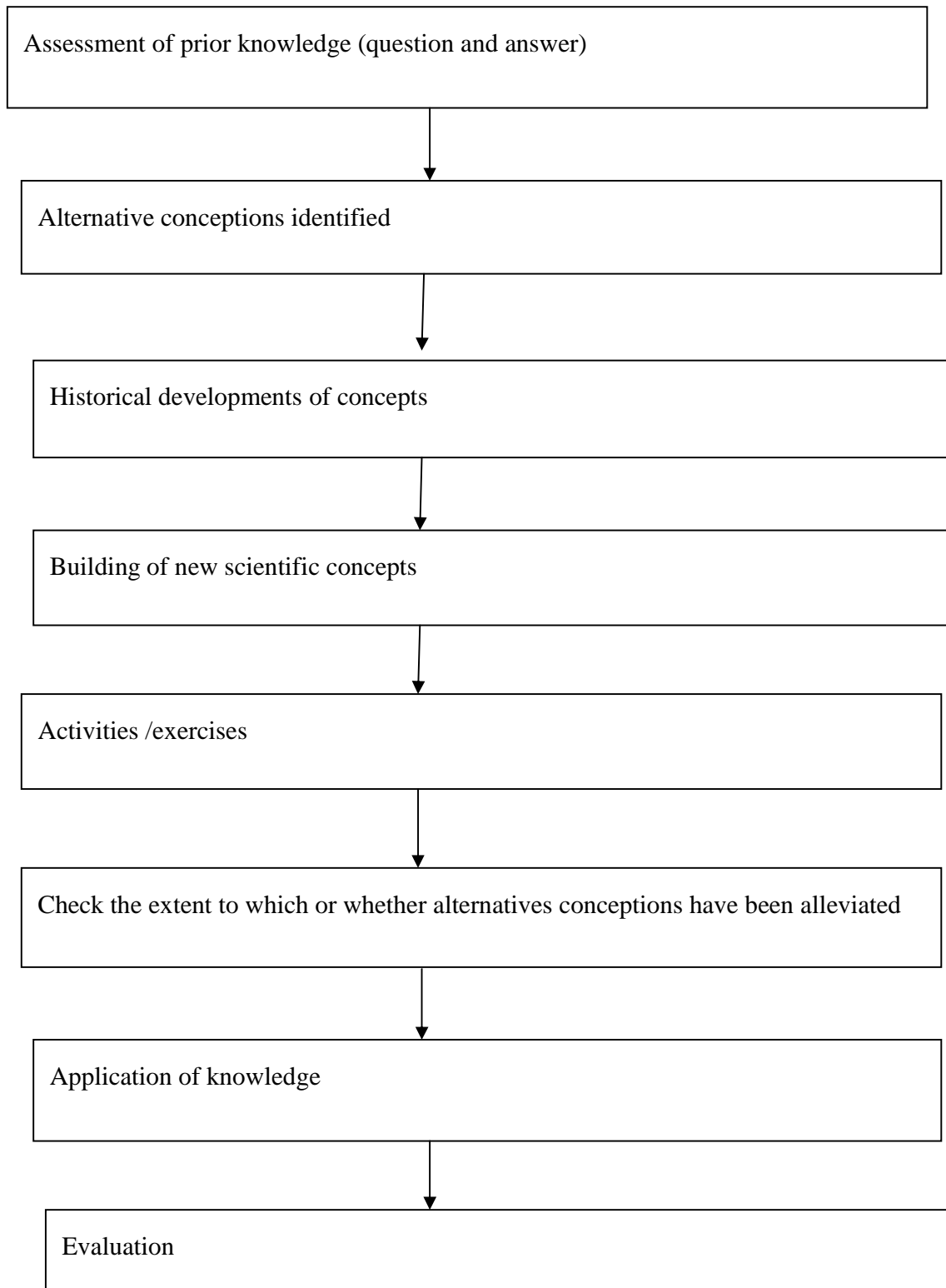
Figure 3.3. Circuit diagram for problem 2.

In the above circuit, the ammeter reads 2A when the switch S is open and 3A when it is closed below the circuit. Each resistance has a value of 6Ω . Calculate the following:

1. The internal resistance of the battery
2. The emf of the battery and

3. The total resistance of the circuit

A number of methods of investigation were used with a view to ameliorate students' alternative conceptions and to bring them towards more profound understanding of scientific conceptions. The following model/process show the methods used to improve students understanding during the activities.



A model used to improve the students' understanding

Questions were posed to students and these were discussed during class: The italics represent student answers.

Is emf and internal resistance (r) always constant?

“No the emf and internal resistance is not constant because the battery gets used up”

What is the reading of a voltmeter across an open switch (S)?

“The reading across switch S is zero because the current is not flowing”

What is the reading of a voltmeter across a closed switch (S)?

“The reading across switch S is not zero because the current is flowing”

After discussions were held with the researcher the alternative conceptions of the students were identified, for example emf and internal resistance are not constant and the reading of voltmeter across switch S is zero. The researcher introduced the historical developments of concepts (emf and potential difference) to provide students with more profound knowledge, because this knowledge empowers students to develop independent thinking, thereby stimulating their interest and instilling confidence in them. After that, alternative conceptions were used as the building blocks of scientific conceptions. Students were introduced to an open and closed switch. The conclusion made about open switch was that in parallel, potential difference across the other branch is equal to potential difference across open switch, they were also asked to calculate the internal resistance to check if it is not constant. This was undertaken in order to ameliorate the alternative conceptions held by the students. Activities were given to students and then the researcher together with the students checked whether or not alternative conceptions

were indeed ameliorated. The students applied knowledge, for example, they put internal resistance (r) as a separate resistor in series with the battery and solved the two equations simultaneously. After that students evaluated their answers and arrived at a number of some conclusions, for example emf and internal resistance are always constant (refer to Appendix C, problem 2 for the solution).

3) In the last formal problem students were introduced to an application of Kirchhoff's rules. They were asked to solve the circuit for three currents I_1 , I_2 and I_3 , assuming that the terminal voltage was equal to the emf for each battery

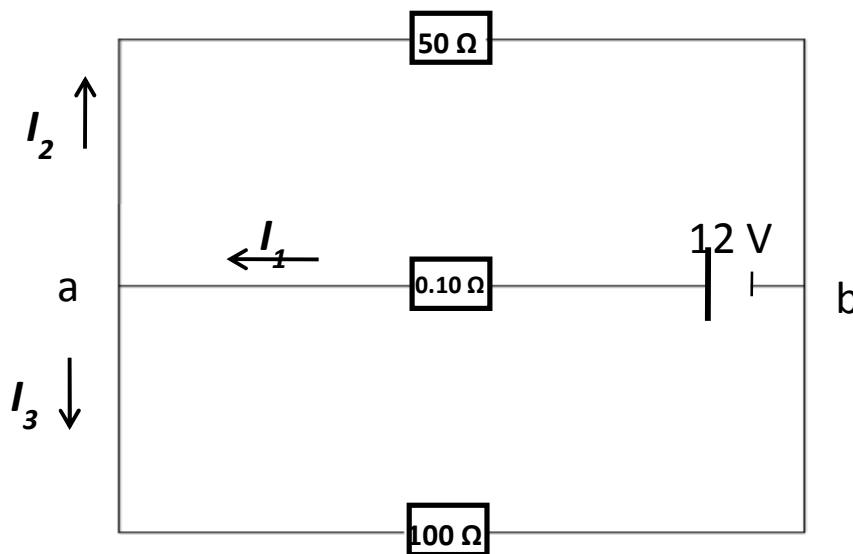


Figure 3.4. Circuit diagram for problem 3.

The model used to ameliorate alternative conceptions in formal problem (2) was also used in this problem.

The first difficulty posed by this problem whether it matters which direction, left to right or right to left, has been chosen for each current. During our discussion we found that it does not matter, if we initially select the wrong direction for a current. The value obtained for that particular current will turn out to be a negative, indicating that the actual current is in opposite direction. The second difficulty was concerned with the following; when we place the positive (+) and negative (-) signs at the ends of each resistor, does it matter which end is positive and which is negative? It was found that yes, it does. Once the direction of the current has been selected, the + and - signs must be chosen so that the current proceeds from the + end toward the - end of the resistor. The third difficulty was concerned with this about, when we evaluate the potential drops and rises around a closed loop, does it matter which direction, clockwise or counterclockwise, is chosen for the evaluation? During the discussion it was found that it does not matter because the direction is arbitrary. If we choose a clockwise direction for example, we will have a certain number of potential drops and rises. If on the other hand for example we choose a counterclockwise direction, all the drops become rises, and therefore it does not matter which direction is picked for evaluating them.

A number of points were given to improve students understanding. These are:

- Draw the current in each branch of the circuit. Choose any direction. If your choice is incorrect, the value obtained for the current will turn out to be a negative number.

- Mark each resistor with a positive sign at one end and a negative sign at the other end, in a way that is consistent with your choice for the current in Step 1. Outside the battery, conventional current is always directed from a higher potential (+) toward a lower potential (-).
- Apply the junction rule and the loop rule to the circuit, in the process obtaining as many independent equations as there are unknown variables.
- Solve the equations obtained in Step 3 simultaneously for the unknown variables (refer to Appendix C, problem 3 for the solution).

3.6 PILOT STUDY

A pilot study was conducted during the second semester of 2010, to determine whether the proposed study was viable. The pilot study sample consisted of thirty (30) first year science education students at the participating university. In the pilot study the entire research procedure was carried out, which included the administration of a pre-test and a post-test, and the analysis of the data collected, following closely the procedures planned for the main study.

The aim of the pilot study was to:

- (i) Identify alternative conceptions and other learning difficulties about electric circuits experienced by first year science education students;
- (ii) Identify ambiguous and unclear items in the instrument;

(iii) Test the intervention and sequence of activities aimed at accomplishing conceptual change.

While the students needed to make quite an effort on completing the test it was explained for that although their scores on the test would not count towards the course, their scores will be confidentially returned to them. This would assist both themselves and the lecturer to gain insight into the degree and type of effort required of them to understand electric circuits. Ambiguous and unclear items were identified, leading to improvements to both the instrument and the interventions of the main study. The duration of the pre-test and for the post-test was an hour in the pilot study. To enable meaningful pre/post - test comparison, the time allowed given to students to complete the pre-test and the post test must be the same.

3.7. MAIN STUDY

The main study was conducted two weeks after the pilot study, following the same procedure as described for the pilot study. To avoid contamination between the groups students were not allowed taking either the pre-test or post-testing anonymously and they had to indicate whether they were NCS or OSC students. The researcher took care that all question papers were returned, and verified such return by counting those given out against those returned. The main study sample consisted of hundred (100) first -year physics education students at the participating university.

3.8 AVERAGE NORMALISED GAIN

According to Meltzer (2002), a single examination (e.g. only a post-test) yields information about a learner's knowledge state at one point in time. The primary interest of instructors in learning is transition between states. In addition to being inadequate by itself for measuring that transitional performance, a single examination might be strongly correlated with a learner's pre-instructional preparation and knowledge.

Thus, in order to assess learning, *per se*, it is necessary to have a measure that reflects the transition between knowledge states, and which has a maximum dependence on instruction, with concomitant minimum dependence on learners' pre-instruction scores (Meltzer, 2002). In addition, the ideal measure would be reliable if minor differences in testing instruments yielded approximately the same value of learning gains. Furthermore, a measure of learning gain should be reliable so that simple modification of the testing instrument would not lead to widely disparate results (Meltzer, 2002). The absolute gain (post-test minus pre-test) score tends to correlate negatively with pre-test scores and is also an obstacle in isolating a measure of learning from confounding effects of pre-instruction state (Meltzer, 2002). One way of dealing with this problem is to derive a measure that normalises the gain score in a manner that takes some account of the variance in the pre-test score. The use of such a measure in physics education was introduced by Hake (1998). This measure is called the average normalised gain. According to Hake (2002a:3), the average normalised gain affords a consistent analysis

of pre- and post-test data over a diverse learner population. The average normalised gain can be calculated by means of the following formula:

Average normalised gain ($\langle g \rangle$) = Actual learning gain divided by Maximum possible gain. The difference of the pre- and post-test percentages gives the actual learning gain. The maximum possible gain is calculated as the difference between the actual gain and the maximum possible gain (100%). Dividing the actual gain by the maximum possible gain gives the average normalised gain, $\langle g \rangle$.

Overall, average normalised gain is regarded as a much better indicator of the extent to which a treatment is effective-more so than is either the actual learning gain or the post-test results alone (Hake, 2002b: 2; Meltzer, 2002). If the treatment (e.g. an intervention) yields an average normalised gain larger than 0,3 for a course, the course can be considered to be in the "interactive-engagement zone" (Hake, 2002b).

The best empirical support for the use of the normalised gain as a reliable measure is most likely lodged in the fact that $\langle g \rangle$ has now been determined for literally tens of thousands of learners in many hundreds of classes worldwide, with extremely consistent results (Hake, 2002a; Meltzer, 2002). The values of $\langle g \rangle$ observed for both traditional courses and those taught by using interactive engagement methods both fall into relatively narrow bands that are reproduced with great regularity for classes at a broad range of institutions with widely varying learner demographic characteristics (including

pretest scores). This provides a strong argument that normalised gain $\langle g \rangle$ is a valid and reliable measure of learners' learning gain due to instruction (Meltzer, 2002).

A t-test is a statistical examination of two population means. A t-test in this study was used to assess whether the means of the two groups are statistically different from each other.

3.9 ETHICAL CONSIDERATIONS

Given that this was an Action Research Project involving the researcher and his students, a number of pertinent ethical issues had to be considered. The researcher sought the support of the students by emphasising the importance of the research project and its benefits. A letter of consent was given to the students, and they all accepted to participate in the study (see Appendix C for a sample of this letter). The researcher also pointed out that, it would have been to their disadvantage if they chose not to take part in the study, because the study was part of their curriculum, and the researcher believed that the planned intervention would be beneficial for addressing the group's alternative conceptions and learning difficulties. The issue was confounded by the research design being a one-group pretest-posttest research design, which meant that there was no alternative group to which the students would have belonged, should they not have wanted to participate in the study. These circumstances, therefore, meant that a decision not to participate in the study would have disadvantaged the students in-so-far as their performance in the module (which was part of the curriculum) was concerned. So, although informed consent was obtained from all the participants, the choice to

participate or not to participate may have been seen as having been manipulated. All the information provided was considered completely confidential; indeed, the name of the participants were not included or in any other way associated, with the data collected in the study. Furthermore, because the interest of this study was in the average responses of the entire group of participants, individual participants were not identified (nor were they identifiable) in any way in any written reports of this research.

3.10 SUMMARY

In this chapter the research design of the study and justification of action research as a technique for determining and rectifying learners' alternative conceptions about electric circuits have been presented. As explained in the chapter, the intervention consisted of a sequence of six activity-based lessons that progressed from contextual, to conceptual, to formal problems related to electric circuits. The average normalised gain used to measure the effectiveness of the intervention was motivated and defined. The results of the study are presented and discussed in Chapter 4.

CHAPTER 4

RESULTS AND DISCUSSION OF RESULTS

4.1 INTRODUCTION

This chapter presents the major findings of this study in accordance with the research objectives and hypotheses. As a first point of departure, the biographical profile of the respondents is presented. The findings to the research objectives are then presented; starting with the findings related to the identified alternative conceptions about electric circuits amongst first-year science education students. Secondly, the effectiveness of the interventions developed is presented and discussed on the basis of three hypotheses:

- An OBE-based intervention will significantly alleviate alternative conceptions about electric circuits held by first- year science education students admitted from high schools that followed the NCS.
- An OBE-based intervention will significantly alleviate alternative conceptions about electric circuits held by first year science education students admitted from high schools that followed the OSC.
- Students who studied under the NCS will demonstrate significantly higher learning gains after exposure to an OBE-based intervention, compared to those who matriculated from the OSC.

The field of electric circuits was the topic selected to be investigated in this study. The motivation for this choice is that this is a topic where there is evidence of particular learning difficulties. In order to address, this, an activity-based intervention was followed over two weeks.

A pre-test was written at the beginning of the intervention. The two weeks' intervention followed and a post-test was written after the intervention. The interventions focused explicitly on the alternative conceptions identified by the literature and the pilot study. These alternative conceptions were explicitly addressed. The intervention took place during the scheduled lecturing timetable.

4.2 BIOGRAPHICAL PROFILE OF THE RESPONDENTS

The number of female students who participated in this study from the NCS group was 31(62%) and 30 (60%) from the OSC. The number of males who participated in this study from the NCS was 19(38%) and 20 (40%) from OSC. In total, the number of males who participated in this study was 39 (39%) against 61(61%) females. The number of female students was higher than the number of male students and most of these students were not repeaters. The official language of instruction at the university where the study was conducted is English.

4.3 PRE-TEST RESULTS AND IDENTIFICATION OF ALTERNATIVE CONCEPTIONS

The first research objective was concerned with the identification of alternative conceptions held by first year university science education students about electric circuits. The prevalent alternative conceptions relating to electric circuits were identified from the qualitative analysis of the explanations given by the students on the pre-test, from both groups of the main study.

4.3.1 Performance of NCS and OSC groups on the pre-test

The quantitative results on the multiple-choice questions of the pre-test for NCS and OSC are illustrated in Figures 4.1 and 4.2.

In the response distribution graphs the correct responses are indicated in blue and the incorrect ones is indicated in red.

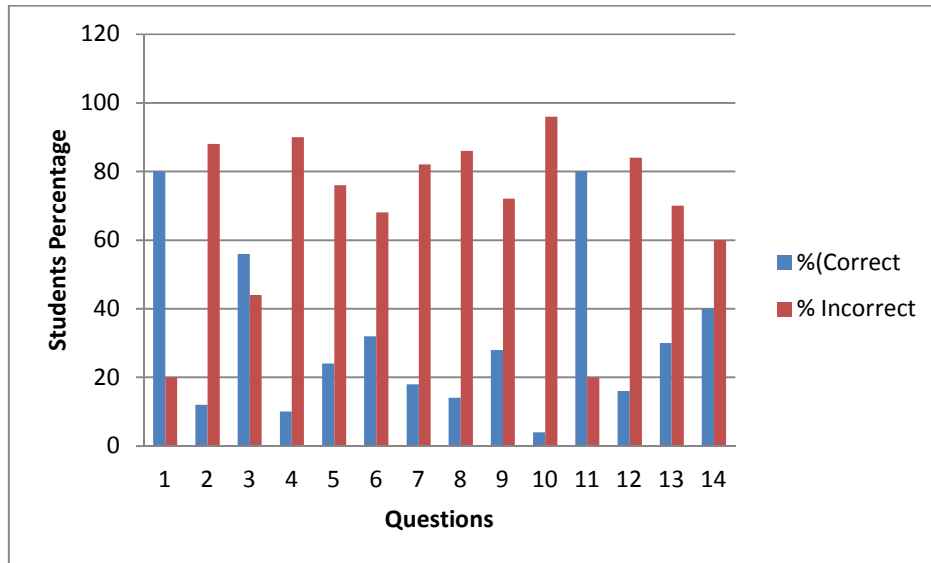


Figure 4.1: Pre-test results for NCS students (n=50)

Figure 4.1, shows that for the majority of questions, the percentages of incorrect responses (indicated in red) were higher than the correct responses (indicated in blue) except for questions 1, 3 and 11). In most of the questions, the students performed badly- scoring below 50%.

The pre-test results for the OSC students are presented in Figure 4.2.

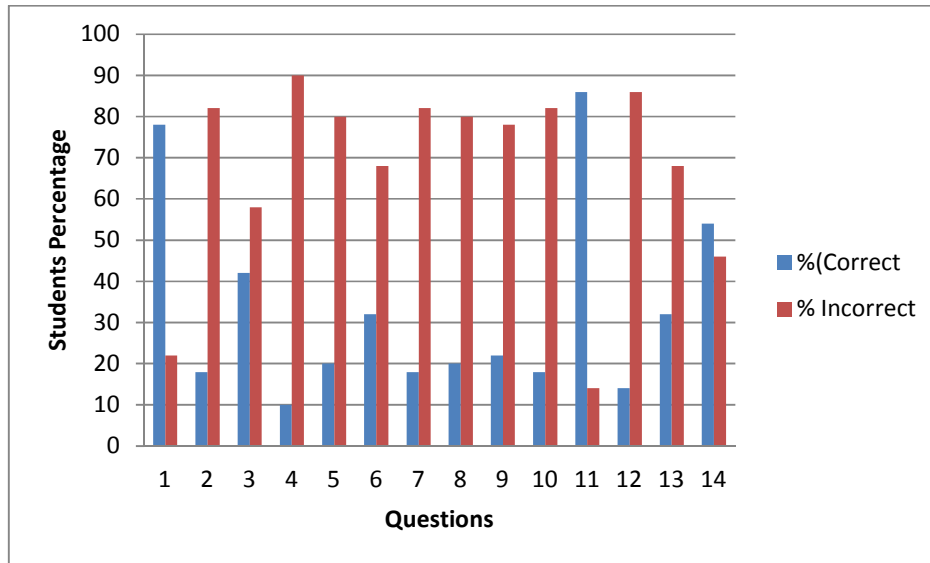


Figure 4.2: Pre-test results for OSC students (n=50)

In Figure 4.2, as was the case for Figure 4.1, the percentages of the incorrect responses were also higher for most of the questions, except for questions 1, 11, and 14. In most questions, the OSC students also performed poorly.

4.3.2 Comparison of the performance of the NCS and OSC groups on the Pre-test

Figure 4.3 presents a comparison of the two groups regarding their performance on the pre-test. The NCS students are represented in blue, and the OSC indicated in red.

Generally the performance of the two groups did not differ significantly on most of the questions.

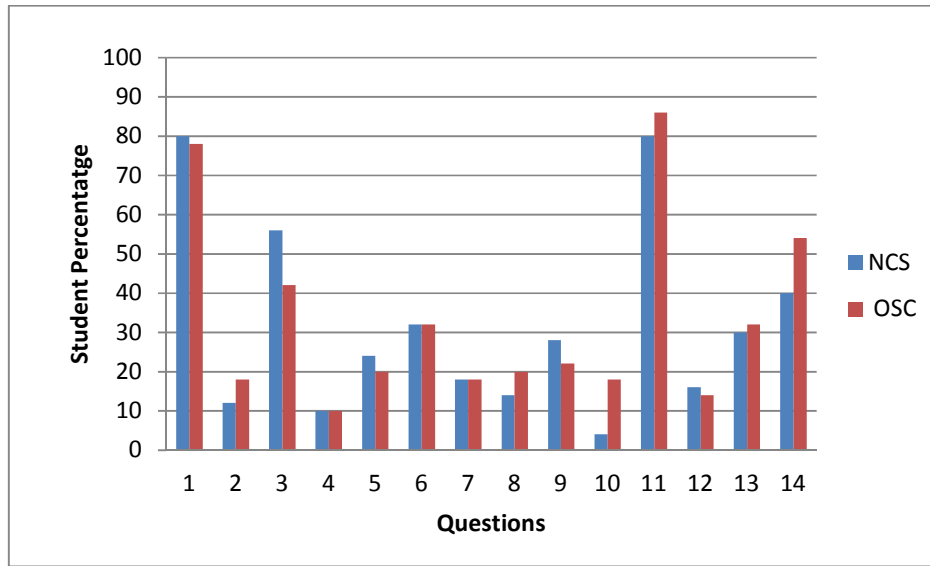


Figure 4.3: Comparison of the pre-test results for NCS (n=50) and OSC (n=50)students

In Figure 4.3, The OSC and NCS students performed the same on most questions.

The t-test comparison was conducted to ascertain the equivalence of the two groups at the onset of the investigation. The results are presented in Table 3.

Table 3: Comparison of pre-test results for NCS and OSC students

Group	Means	Sd	df	t_c	t_0	Results
NCS	31.7	24.5	26	2.04	0.01	P > 0,05
OSC	33.1	23.8				

The t-test did not yield a statistically significant difference between the pre-test scores of the two groups. The mean for the NCS pre-test was 31.7 (sd= 24.5) while the mean for the OSC pre-test was 33.1(sd= 23.8), $p > 0.05$. This test was conducted to ascertain the equivalence of the two groups at the onset of the investigation. Thus, this result is important in that any difference between the two groups that may be observed after the intervention may only be attributed to the intervention and not to any pre-existing conditions.

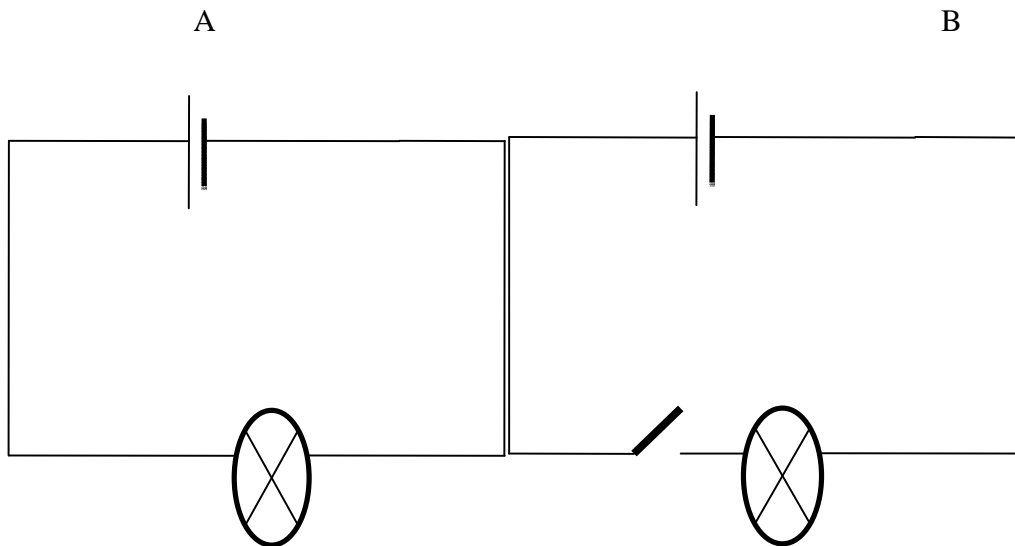
4.4 ANALYSES OF PRE-TEST RESULTS FOR NCS AND OSC STUDENTS

A discussion of the analysis and the identification of possible alternative conceptions on each question in the pre-test (questions 1 – 14) follow below (see Appendix A for a copy of the pre-test and complete multiple choice questions).

For each question a table is presented which identifies alternative conceptions from the question with one or more quotations from the students' motivations to illustrate the point. Furthermore, the number of students from a total of 50 OSC students and 50 NCS who made that choice is also indicated.

Question 1

Which bulb will glow in the following scenario? Diagram A or B



Option A was the intended option. One alternative conception unfolded from the motivations, as presented in Table 4.

Table 4: Alternative Conceptions Identified from Question 1

Alternative Conceptions and “Quotation(s)”	Number of OSC Students (n = 50)	Number of NCS STUDENT (n = 50)
(i)There is no need for a circuit to be closed in order to work. <i>“We don’t need a closed switch for the bulb to glow”</i> <i>“The bulb can glow without a closed switch in the circuit as long as we have wires”</i>	11	6 2

Alternative conception (i) listed in Table 4, appears to emanate from the notion held by students that connecting wires do not amount to a switch. Students thus think that a bulb will glow when it is connected to only one of the battery terminals, thereby revealing the idea of a battery as being like a fountain where only one terminal is needed to produce current. The comparisons of the pre-test results are presented in Table 5.

Table 5: Comparison of question 1 pre-test results for NCS and OSC students

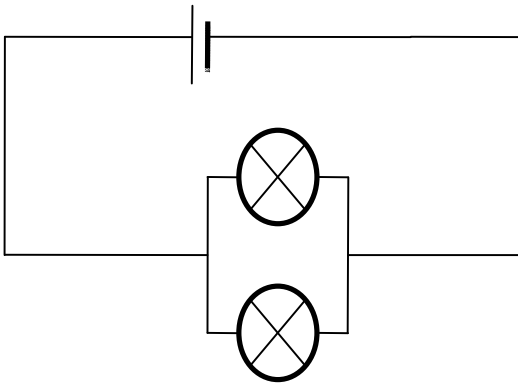
		Wrong	Right	P	Phi
Question 1	NCS	10 (20%)	40 (80%)	> 0.05	-0.025
	OSC	11 (22%)	39 (78%)		
	Total	21 (21%)	79 (79%)		

The percentage of NCS students who answered question 1 wrong was 20% against 80% who got it right. This was close to the 22% OSC students who answered the question wrong and 78% who got it right. The Chi-square test yielded a probability greater than 0.05, meaning that there was no significant difference between the two groups in their performance on this question.

Question 2

What happens to the brightness of the bulb as an identical bulb is added in parallel? Does it

- A. become brighter,
- B. become dimmer, or
- C. remain the same?



Option C was the intended option. One alternative conception unfolded from the motivations, as presented in Table 6.

Table 6: Alternative Conception Identified from Question 2

Alternative Conceptions and “Quotation(s)”	Number of OSC Students (n = 50)	Number of NCS student (n = 50)
(i) Difficulty in predicting the brightness of bulbs in series and parallel connections.		
<i>“The same amount of flow has to light twice as many bulbs, and we have added more resistance to the current ”</i>	26	26
<i>“The brightness will be the dimmer because they will share the same current”</i>	16	20
<i>“When the bulb are connected in parallel it means current pass straight to the bulb without delay and they become brighter”</i>	9	4

The alternative conception (i) listed in Table 6 appear to emanate from the fact that students think that current is shared between components in a circuit. If identical bulbs are connected in series in a circuit, students assert that current is not conserved and is shared equally among the bulbs. In a series circuit, the terminals of one bulb are joined to the terminals of another bulb through a wire, making one path for the flow of electrons. In a parallel circuit, the wires of each bulb are directly connected to the cell or battery or through main wires to the cell or battery. Each bulb has its own path for the electric current to go through. The comparisons of the pre-test results are presented in Table 7.

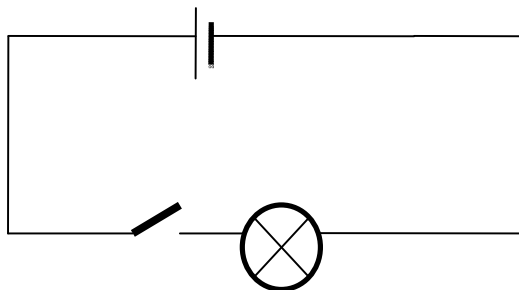
Table 7: Comparison of question 2 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 2	NCS	44 (88%)	6 (12%)	<0.05	0.123
	OSC	41 (82%)	9 (18%)		
	Total	85 (85%)	15(15%)		

The percentage of NCS students who answered question 2 wrong amounted 88%, against 6% who got it right. This figure was significantly different to the 82% OSC students who answered the question wrong and 18% who got it right; $p < 0.05$ from the Chi-square test, meaning that there was a significant difference between the two groups in their performance on this item.

Question 3

If the switch is open, what happens to the resistance of the bulb (resistor)?



- A. The resistance increases
- B. The resistance decreases
- C. The resistance becomes zero
- D. The resistance stays the same

Option D was the intended option. Two alternative conceptions unfolded from the motivations, as presented in Table 8.

Table 8: Alternative Conceptions Identified from Question 3

Alternative Conceptions and “Quotation(s)”	Number of OSC Students (n = 50)	Number of NCS Students NCS (n = 50)
(i) Concept of resistance		
<i>“Resistance will increase because of the current flow”</i>	10	8
<i>“If there is no current flowing in the circuit they will be no resistance”</i>	54	60

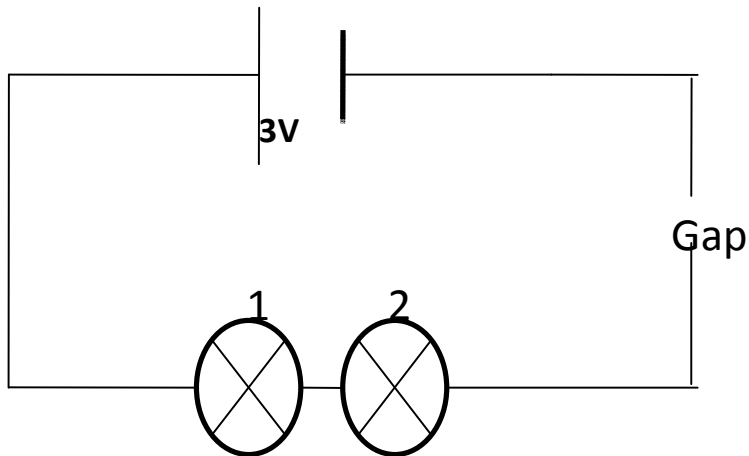
Alternative conception (i) listed in Table 8 appears to emanate from the notion that students failed to realize that resistance of a component depends only on its own properties. Consequently, they either considered that there would be no resistance if there is no current, or failed to differentiate between the equivalent resistance of a branch and an individual resistance within the branch. The comparisons of the pre-test results are presented in Table 9.

Table 9: Comparison of question 3 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 3	NCS	22 (44%)	28(56%)	>0.05	0.020
	OSC	21(42%)	29 (58%)		
	Total	43 (43%)	57(57%)		

The percentage of NCS students who answered question 3 wrong was 44%, against 56% students who got it right. This was a similar trend with the OSC students:42% answered the question wrong against 58% who got it right; $p>0.05$ from the Chi-square test, meaning that there was no significant difference between the two groups in terms of their performance on this item.

Question 4



Bulbs 1 and 2 are identical. Then:

- A. $V_{\text{gap}}=V_1=V_2=1\text{V}$
- B. $V_{\text{gap}}=V_1=V_2=0\text{V}$
- C. $V_{\text{gap}}=V_1=V_2=3\text{V}$
- D. $V_{\text{gap}}=3\text{V}, V_1=V_2=0\text{V}$

Option D was the intended option. One alternative conception unfolded from the motivations, as presented in Table 10. The three quotations amount to one alternative conception.

Table 10: Alternative Conceptions Identified from Question 4

Alternative Conceptions and "Quotation(s)"	Number of OSC Students(n = 50)	Number of Students NCS (n = 50)
(i)Voltage and current		
<i>"Voltage is something that flows."</i>	6	5
<i>"If there is no current in a circuit, then there is no voltage."</i>	33	31
<i>"Since current exist in a closed circuit, there is zero potential in an open switch."</i>	7	3

Alternative conception listed in Table 10 appears to emanate from the notion that students tend to regard current and voltage assimilar in nature. Students find it difficult to accept that voltage across bulbs in parallel is equal to the supplied voltage while the (constant) current in the circuit is divided up. Students that believe that current and voltage should always appear together, and that since current can only exist in a closed circuit, there is zero potential difference in an open circuit. The comparisons of the pre-test results are presented in Table 11.

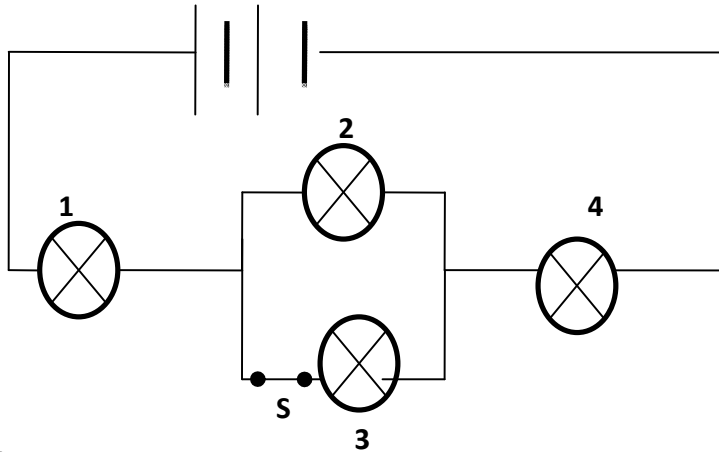
Table 11: Comparison of question 4 pre-test results for ncs and OSC students

		Wrong	Right	P	Phi
Question 4	NCS	46 (92%)	4 (8%)	>0.05	0.035
	OSC	45 (90%)	5 (10%)		
	Total	91 (91%)	9(9%)		

The percentage of NCS students who answered question 4 wrong was 92% against 8% students who got it right. This was similar to the 90% OSC students who answered the question wrong , against 10 % who got it right; $p>0.05$ from the Chi-square test, meaning that there was no significant difference between the two groups in their performance on the item

Question 5

Questions 5-12 refer to the circuit below in which four identical bulbs are connected to a battery. (The switch S, is initially closed as shown in the



diagram

Which of the following correctly ranks the bulbs in brightness?

- A. All bulbs are equally bright
- B. Bulb 1 is brightest; bulb2 next brightest, bulb3 next brightest and bulb4 dimmest
- C. Bulb 1 is brightest; bulbs2 and 3 are equally bright, and each is dimmer than bulb1, bulb4 is dimmest
- D. Bulbs 1 and 4 are equally bright; bulbs 2 and 3 are equally bright, and each is dimmer than bulb1 or 4
- E. Bulbs 2 and 3 are equally bright; bulbs1 and 4 are equally bright, and each is dimmer than bulb 2 or 3

F. Bulb 1 is brightest, bulb 4 is next brightest: bulbs 2 and 3 are equally bright, and each is dimmer than bulb 4.

Option D was the intended option. Two alternative conceptions unfolded from the motivations, as presented in Table 12.

Table 12: Alternative Conceptions identified from Question 6

Alternative conceptions and “Quotation(s)”	Number of OSC students (n = 50)	Number of NCS students (n = 50)
(i) Consumer model		
“Current goes to bulb 1 because it is near the positive terminal of the battery and bulb 2 and 3 shares the current. Current will start going to bulb 1 and become weak as it flows through the other bulbs.”	8	7
“Current will be shared by bulb equally by bulb 1 and 4 and their brightness will be the same and bulb 3 and 2 will be dimmer	11	10
“Current flows to bulb 1 and when it reaches parallel connections the potential difference split into two equal halves”	5	2
(ii) Undifferentiated concepts: Potential and potential difference		
“Bulbs 1 is the brightest because the potential is the highest at bulb 1 and bulb 2 and 3 are next and bulb 4 is the dimmest due to the lowest in potential.”	8	8
“ Bulb 1 and 4 are in series they share equal potential.”	5	2

Alternative conceptions (i) and (ii) listed in Table 12 likely emanate from students’ failure to discriminate between concepts ‘potential’ and ‘potential difference’. The

brightness of the bulbs is mistakenly associated with the value of the *potential* at one of its terminals, rather than with the *potential difference* between both its terminals.

Students also appear to think that current is consumed in a circuit. They are current-orientated, and seem to believe that current leaves the battery (which is perceived to be a reservoir of current) at a particular value and is modified thereafter depending on what it encounters in its path. According to this model little or no current may return to the battery. Students that fail to understand that current only conveys energy to the bulb. Table 13 presents the results of the pre-test comparison between the NCS and OSC groups.

Table 13: Comparison of question 5 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 5	NCS	38 (76%)	12(24%)	> 0.05	-0.048
	OSC	40 (80%)	10 (20%)		
	Total	78(78%)	22(22%)		

The table shows that there was no significant difference in the performance of the two groups, $p > 0.05$.

Question 6

Which of the following correctly ranks how much current is flowing through the bulbs?

- A. All bulbs have the same current flowing through them
- B. The current through bulb 1 is largest, bulb 2 next largest, bulb 3 next largest and bulb 4 smallest.
- C. The current through bulb 1 is largest; bulb 2 is the same as bulb 3, and each is smaller than bulb 1. bulb 4 is smallest.
- D. The current through bulbs 1 and 4 is the same; bulb 2 is the same as bulb 3, and each is smaller than bulb 1 or 4.
- E. The current through bulbs 2 and 3 is the same; bulb 1 is the same as bulb 4, and each is smaller than bulb 2 or 3.
- F. The current through bulb 1 is largest, bulb 4 is next largest; bulb 2 is the same as bulb 3, and each is smaller than bulb 4.
- G. None of these is correct

Option D was the intended option. One alternative conception unfolded from the motivations, as presented in Table 14.

Table 14: Alternative Conceptions Identified from Question 6

Alternative conceptions and “Quotation(s)”	Number of OSC students (n = 50)	Number of NCS Students (n = 50)
(i) Current is shared between components in series circuits		
<i>“Bulbs 1 and 4 must be brighter than bulbs 2 and 3 because they share the same current and they are connected in series.”</i>	16	16
<i>“Bulb 1 will have large current and bulbs 2 and 3 will share the remaining current from bulb 1 and bulb 4 will have the lowest current.”</i>	4	7
<i>“It is the same current that flows in the circuit, the brightness of the bulbs will be the same because they receive equal amount of energy.”</i>	17	12
<i>“Bulb 1 and 4 will share current equally because they are in series”.</i>	4	2

The alternative conception in Table 14 appears to originate from the notion that current is shared between components in a circuit. If identical bulbs are connected in series in a circuit, students seem to contend that current is not conserved and is shared equally amongst the bulbs. Bulbs that are in series will be brighter than the ones in parallel. Table 15 presents the results of the pre-test comparison between the NCS and OSC groups.

Table 15: Comparison of question 6 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 6	NCS	34(68%)	16(32%)	>0.05	0.000
	OSC	34 (68%)	16 (32%)		
	Total	68 (68%)	32(32%)		

According to Table 15, 68% NCS students answered question 7 wrong, against 32% students who got it right. In comparison, 68% OSC students answered the question wrong, against 32 % who got it right; $p>0.05$ from the Chi-square test, meaning that there was no significant difference between the two groups in their performance on this question.

Question 7

Which of the following correctly ranks the potential differences across the bulbs?

- A. All bulbs have the same potential difference across them
- B. The potential difference across 1 is largest, 2 next largest, 3 next largest and 4 smallest.
- C. The potential difference across bulb 1 is largest. Bulb 2 is the same as bulb 3, and each is smaller than bulb 1; bulb 4 is smallest

D. The potential difference across bulb 1 is the same as bulb 4; bulb 2 is the same as bulb 3, and each is smaller than bulbs 1 and 4.

E. The potential difference across bulb 2 is the same as bulb 3; bulb 1 is the same as bulb 4, and each is smaller than bulbs 2 and 3.

F. The potential difference across bulb 1 is largest, bulb 4 is next largest; bulb 2 is the same as bulb 3, and each is smaller than bulb 4.

G. None of these is correct.

Option D was the intended option. One alternative conception unfolded from the motivations, as presented in Table 16.

Table 16: Alternative Conceptions Identified from Question 7

Alternative conceptions and “Quotation(s)”	Number of OSC students (n = 50)	Number of NCS students (n = 50)
(i) Misunderstanding of causal relation between current and voltage: current is seen as the primary concept in the circuit, while potential difference is seen as the consequence of current flow and not as its cause.		
<i>“The bulbs are connected to the same battery potential difference across the bulb is the same through the circuit.”</i>	20	24
<i>“The current has more power at the starting point”.</i>	16	6
<i>“Potential difference in bulbs that are connected in series is higher than that in parallel.”</i>	7	4

The above alternative conception most likely arises from students' failure to understand the correct causal connection between *potential difference* and *current*. Current is seen as the primary concept in the circuit, while potential difference is seen as the consequence of current flow, and not as its cause. Table 17 presents the results of the pre-test comparison of the NCS and OSC groups

Table 17: Comparison of question 7 Pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 7	NCS	41(82%)	9 (18%)	>0.05	0.000
	OSC	41 (82%)	9 (18%)		
	Total	82 (82%)	18(18%)		

The table shows that the two groups performed identically on this item, $p > 0.05$.

Question 8

What happens to the current through bulb 1 if the switch, S, is opened?

- A. It increases
- B. It remains the same
- C. It decreases
- D. Not enough information is given

Option C was the intended option. One alternative conception unfolded from the motivations, as presented in Table 18.

Table 18: Alternative Conceptions Identified from Question8

Alternative conceptions and “Quotation(s)”	Number of OSC students (n = 50)	Number of NCS students (n = 50)
(i) Misunderstanding of causal relation between current and voltage: current is seen as the primary concept in the circuit, while potential difference is seen as the consequence of current flow and not as its cause.		
<i>“ If the switch is open the current in bulb 1 will remain the same because the bulb is now not in series.”</i>	10	7
<i>“ If the switch is open the current in bulb 1 will remain the same because the switch will disturb only bulb 3and potential diffrence will be equal in all the bulbs.”</i>	17	14
<i>“If the switch is open the current in bulb 1 will increase because the current goes up because bulb 3 is short- circuited.”</i>	14	15

The above alternative conception appears to emanate from the students’ failure to understand the effect of open and closed switch. Table 19 presents the results of the pre-test comparison between the NCS and OSC groups.

Table 19: Comparison of question 8: Pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 8	NCS	43 (86%)	7 (14%)	< 0.05	0.080
	OSC	40 (80%)	10(20%)		
	Total	83 (83%)	17(17%)		

From Table it is evident that 19,86% NCS students answered question 9 wrong, against 14% NCS students who got it right; 80% OSC students answered the question wrong and 20% got it right; $p < 0.05$ from the Chi-square test, meaning that there was a significant difference between the two groups in their performance on this question.

Question 9

What happens to the current through bulb 2 if the switch is opened?

- A. It increases
- B. It remains the same
- C. It decreases
- D. Not enough information is given

Option A was the intended option. One alternative conception was picked up from the motivations, as presented in Table 20

Table 20: Alternative Conceptions Identified from Question 10

Alternative conceptions and “Quotation(s)”	Number of OSC students (n = 50)	Number of NCS students (n = 50)
(i) Incorrect application of Ohm’s law::(when potential difference increases, resistance also increases		
Ohm’s law is often expressed as $V = IR$		
<i>“The current in bulb 2 will remain the same if the switch is open because bulb 1 consumes more current than bulb 2.”</i>	14	13
<i>“The current in bulb 2 will decrease if the switch is open because the current gets lost along the way.”</i>	15	13

This alternative conception comes from a topologically mistaken interpretation of the circuit. The conclusion that we can draw from this alternative conception is that the application of Ohm’s law is not significantly learnt because students do not seem to be able to apply it in situations that are somewhat removed from those they are normally presented with when studying the subject. Table 21 presents the results of the pre-test comparison between the NCS and OSC groups.

Table 21: Comparison of question 9 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 9	NCS	36 (72%)	14 (28%)	< 0.05	-0.069
	OSC	39 (78%)	11 (22%)		
	Total	75 (75%)	25(50%)		

The above table shows that there was a significant difference between the two groups in their performance on this question, $p < 0.05$.

Question 10

Based on your answers to questions 9 and 10, compare the current through bulb 2 with the switch, S, opened to the current through bulb 1 before the switch was opened.

- A. The current through bulb 2 equalled the current through bulb 1 before S was opened.
- B. The current through bulb 2 was more than half the current through bulb 1 before S was opened.
- C. The current through bulb 2 was half the current through bulb 1 before S was opened.
- D. The current through bulb 2 was less than half the current through bulb 1 before S was opened.
- E. Not enough information is given.
- F. None of these is correct.

Option B was the intended option. One alternative conception unfolded from the motivations, as presented in Table 22.

Table 22: Alternative Conceptions Identified from Question 10

Alternative conceptions and “Quotation(s)”	Number of OSC students (n =50)	Number of NCS students (n = 50)
(i) Incorrect application of Ohm’s law:(when potential difference increases, resistance also increases. Ohm’s law is often expressed as $V = IR$)		
<i>“The current through bulb 2 now equals current through bulb 1 before the switch was opened because they will share equal amount of current.”</i>	16	15
<i>“The current through bulb 2 is half the current through bulb 1 before the switch was open because bulb 2 and 3 divide the current of bulb 1 and bulb 2 will half of bulb 1.”</i>	6	7
<i>“The current through bulb 2 is less than half the current through bulb 1 before the switch was open because bulb 1 consumes more current than bulb bulb 2.This is due to the fact that current moves from positive terminal of the battery to the negative terminal”.</i>	9	5

These alternative conceptions suggest that students do not understand the relationship between *current*, *potential difference* and *resistance*. Table 23 presents the results of the pre-test comparison between the NCS and OSC groups.

Table 23: Comparison of question 10 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 10	NCS	48 (96%)	2 (4%)	< 0.05	0.224
	OSC	41 (82%)	9 (18%)		
	Total	89 (89%)	11(11%)		

The table shows the results from the Chi-square test where $p < 0.05$, meaning that there was a significant difference between the two groups in their performance on this question.

Question 11

Bulbs 2 and 3 are connected

- A. In series
- B. In parallel
- C. In series and parallel
- D. Neither in series nor parallel

Option B was the intended option. One alternative conception was identified from students' motivations, as presented in Table 24.

Table 24: Alternative Conceptions Identified from Question 11

Alternative conceptions and “Quotation(s)”	Number of OSC students (n = 50)	Number of NCS students (n = 50)
(i) Difficulty in identifying series and parallel connections: when a single element is in series with two elements connected in parallel, that single element is in series with one of the elements in a parallel combination.		
<i>“Bulbs 2 and 3 are connected in series because the each bulb is connected to the cell through the wires.”</i>	10	8
<i>Bulbs 2 and 3 are connected in parallel because terminals of one bulb are joined with terminals of another bulb through a wire making a path for the flow of electrons.”</i>	8	6

The above alternative conceptions arise from students having difficult recognising the nature of connections when several elements are involved. Table 25 presents the results of the comparison pre-test results for NCS and OSC students.

Table 25: Comparison of question 11 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 11	NCS	10 (20%)	40(80%)	< 0.05	0.080
	OSC	7(14%)	43(86%)		
	Total	17 (34%)	83(83%)		

The table shows that 20% NCS students answered question 11 wrong, against 80% NCS students who got it right. Similarly, 14% OSC students answered the question wrong and 86% got it right; $p < 0.05$ from the Chi-square test, meaning that there was a significant difference between the two groups in their performance on this question.

Question 12

Bulbs 1 and 3 are connected

- A. In series
- B. In parallel
- C. In series and parallel
- D. Neither in series nor parallel

Option D was the intended option. One alternative conception unfolded from the motivations, as presented in Table 26.

Table 26: Alternative Conceptions Identified from Question 12

Alternative conceptions and “Quotation”	Number of OSC students (n = 50)	Number of NCS students (n = 50)
(i) Difficulty in identifying series and parallel connections: when a single element is in series with two elements connected in parallel, that single element is in series with one of the elements in a parallel combination.		
<i>“ Bulbs 1 and 3 are in parallel because the single element is in series with one element in parallel combination.”</i>	32	31

The alternative conception in Table 26 appears to emanate from the students’ difficulty in recognising the nature of connections when several elements are involved. When a single element is in series with two elements connected in parallel, students often claim that a single element is in series with one of the elements in parallel combinations. The term ‘series’ is used to mean some form of sequentiality rather than specific type of connection. In a series circuit, terminals of one bulb are joined with terminals of another bulb through a wire making a path for the flow of electric charges.

In a parallel circuit, the wires of each bulb are directly connected to the cell or through main wires to the cell. Table 27 presents the results of the pre-test comparison between the NCS and OSC groups.

Table 27: Comparison of question 12 pre-test results for NCS and OSC students

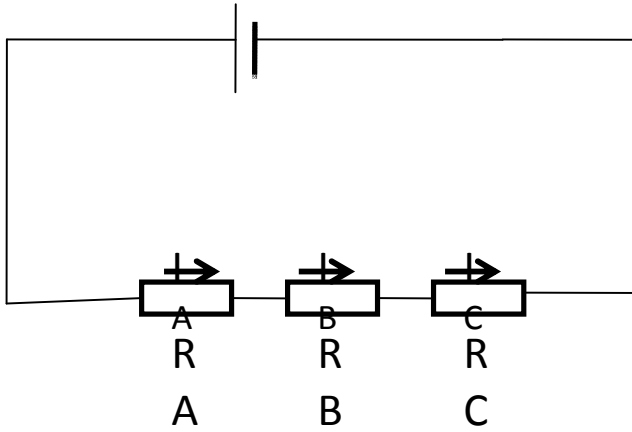
		Wrong	Right	P	Phi
Question 12	NCS	42(84%)	8 (16%)	> 0.05	-0.028
	OSC	43 (86%)	7 (14%)		
	Total	85 (85%)	15(15%)		

The table shows that the two groups performed equally on this item, $p > 0.05$.

Question 13

Questions 13 and 14 refer to the figure below in which three resistors are identical: $R_A = R_B = R_C$.

What can you say about the current I_A through R_A ?



A = I_B , only

B = I_C , only

C = $I_B = I_C$

D = $I_B + I_C$

E = $I_B - I_C$

F. None of these are correct

Option C was the intended option. One alternative conception was discovered from the motivations, as presented in Table 28.

Table 28: Alternative Conceptions Identified from Question 13

Alternative conceptions and “Quotation(s)”	Number of OSC students (n = 50)	Number of NCS students (n = 50)
(i) Current is shared between/among components in series circuits.		
<i>“Current gets consumed as it passes from one resistor to the other in series connections.”</i>	6	11
<i>“Current in the circuit is shared by the resistors connected in series.”</i>	14	15

The alternative conceptions in Table 28 appears to be based on the way in which Ohm’s law is taught_usually by repetitive application but with little conceptual analysis.Table 29presents the results of the comparison pre-test results for NCS and OSC.

Table 29: Comparison of question 13 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 13	NCS	35 (70%)	15(30%)	> 0.05	0.022
	OSC	34 (68%)	16 (32%)		
	Total	69 (69%)	31(31%)		

The 70% NCS students who answered question 13 wrong were fairly close to the 68% OSC students. The value of p is greater than 0.05, implying that there was no significant difference between the two groups in their performance on this item.

Question 14

What is the relationship between I_B and I_C ?

A. $I_B = \frac{1}{3} I_C$

B. $I_B = \frac{1}{2} I_C$

C. $I_B = I_C$

D. $I_B = 2 I_C$

E. $I_B = 3I_C$

F. None of these is correct.

Option C was the intended option. From this item, one alternative conception was identified as presented in Table 30

Table 30: Alternative Conceptions Identified from Question 14

Alternative conceptions and “Quotation”	Number of OSC students (n = 50)	Number of NCS students (n = 50)
(i) Current is shared between components in series circuits.		
<i>“The resistors are connected in series so the current will be divided into three parts.”</i>	4	2

The alternative conception in Table 28 and 30 appears to be based the way Ohm’s law is often taught and learned .Table 31 presents the results of the pre-test as a comparison between the NCS and OSC groups.

Table 31: Comparison of question 14 pre-test results for NCS and OSC students

		Wrong	Right	P	Phi
Question 14	NCS	30 (60%)	20 (40%)	< 0.05	0.140
	OSC	23 (46%)	27 (54%)		
	Total	53 (53%)	47(47%)		

The performance of the two groups differed significantly on this question, $p < 0.05$. Table 32 summarizes the most prevalent alternative conceptions about electric circuits. Some of the alternative conceptions appeared in more than one question.

Table 32: Summary of alternatives conceptions about electric circuits

AC 1	There is no need for a circuit to be closed in order for it to work.
AC 2	Difficulty in predicting the brightness of bulbs in series and parallel connections: battery is viewed as a constant source of current.
AC 3	Concept of resistance: there would be no resistance if there is no current
AC 4	Undifferentiated concepts (voltage and current): current and voltage should always appear together.
AC 5	Sequential reasoning : that the direction of current in the circuit and the order of connections of the bulbs determine the relative brightness of a bulb
AC 6	Consumer model : that current leaves the battery at a particular value and is modified thereafter depending on what it encounters in its path.
AC 7	Current is shared between components in series circuits
AC 8	Difficulty in predicting potential difference at different points in series and parallel connections: potential difference in series connections is the same (throughout the circuit)because current that passes through resistors connected in series is the same.
AC 9	Misunderstanding of causal relation between current and voltage : current is seen as the primary concept in the circuit, while potential difference is seen as the consequence of current flow and not as its cause.
AC 10	Difficulty in predicting potential difference of an open switch in series and open switch in parallel: there is a zero potential difference in an open circuit.
AC 11	Incorrect application of Ohm's law : when potential difference increases resistance also increases. Ohm's law is often expressed as $V = IR$.
AC 12	Difficulty in identifying series and parallel connections : when a single element is in series with two elements connected in parallel, that single element is in series with one of the elements in a parallel combination.

4.5 STATISTICAL COMPARISONS AND TESTING OF HYPOTHESES

The second part of this study was aimed at establishing whether or not the intervention led to any significant differences (a) between the pre-and post-tests for each group, and (b) between the post-test scores of the two groups. The results of these are presented below.

4.5.1 The effect of the OBE- based intervention on the students from the NCS

Figure 4.4 presents the effect of curriculum intervention based on OBE principle that redress the identified alternative conceptions on the students from the NCS

The figure below present the post-test results for NCS students.

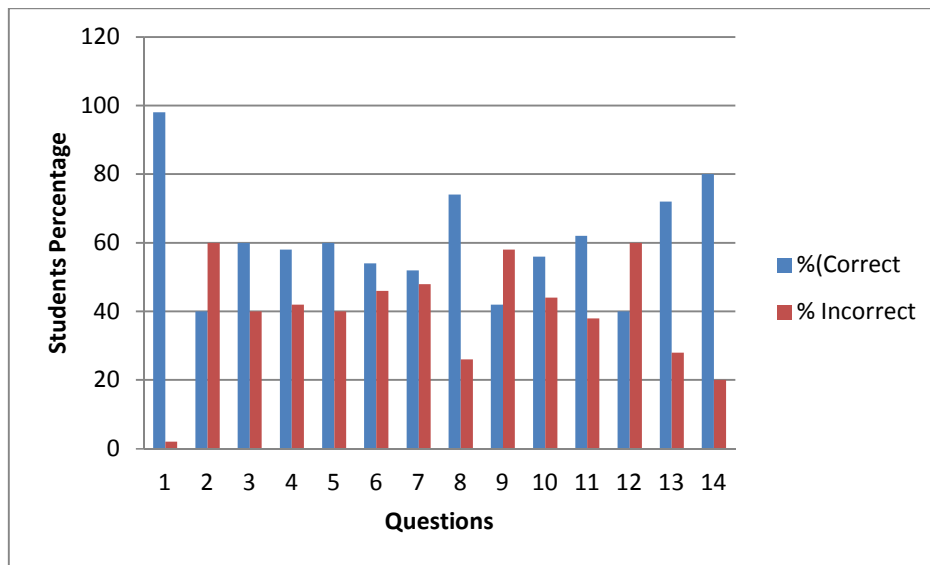


Figure 4.4: Post-test results for NCS students (n=50)

In Figure 4.4, it is indicated that the percentages of NCS students who answered the items right are higher compared to those who chose incorrect answers. This shows that there is an improvement in their results, compared to the results presented in Figure 4.1, where incorrect responses scored higher percentage in almost all cases. The NCS students scored less than 50% on questions 2, 9 and 12.

Figure 4.5 shows the graph presenting comparison of the pre and the post-test scores where the post-test is indicated in red and the pre-test is indicated in blue.

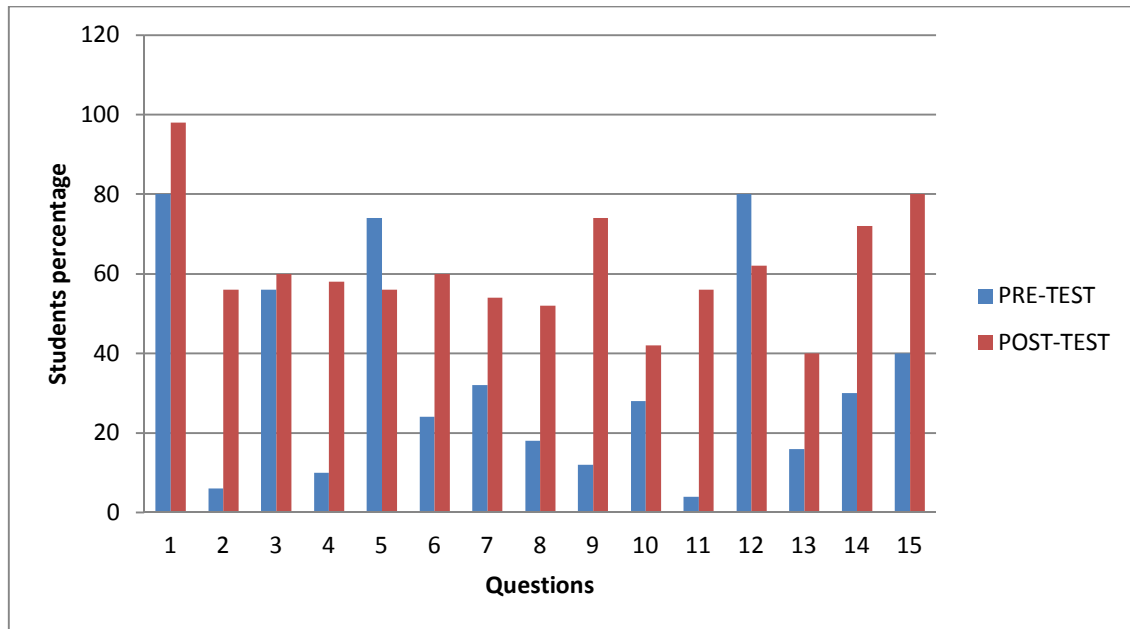


Figure 4.5: Comparison of learning gains of NCS students(n=50)

In Figure 4.5 the graph shows that the students performed better in the post-test, except for questions 5 and 12.

Comparisons between the pre- and post-test scores were carried out to test the effectiveness of the intervention on the NCS group. The results are presented in Table 33.

Table 33: Comparison of pre & post test results for NCS students

Group	Pre-test-mean score	Post-test-mean score	df	t_c	t_o	Result
NCS	31.7 sd = 24.5	60.6 sd = 16.2	13	1.76	-3.5	$p < 0,05$

The t-test yielded a statistically significant difference between the pre and post-test scores. The mean for the pre-test was 31.7 (sd = 24. 5) and the mean for the post-test was 60.6 (sd = 16.2); $p < 0, 05$. Therefore there was a statistically significant difference between the pre-test and the post-test for the NCS group. This demonstrated that the intervention was effective. Consequently, the directional hypothesis, as stated, is accepted. This means that an OBE-based intervention will significantly alleviate the alternative conceptions about electric circuits held by first year science education students, admitted from NCS high school curriculum. This is the result of Hypothesis 1.7.1.

4.5.1.1 Normalised gain scores for the NCS group

According to Hake (1998) and Meltzer (2002) $\langle g \rangle$ is a much better indicator of the extent to which a treatment is effective than either the gain or post-test score alone. For example, if the treatment yields $\langle g \rangle > 0.3$, then the course could be considered to fall

in the “interactive zone” Interactive engagement methods promote conceptual understanding through engagement of students in heads-on and hands-on activities which yield feedback through discussions with peers and /or teachers, all as judged by their literature description. Thus, as a way of cross-validating the above statistical comparisons normalised gain scores were calculated in order to ascertain how much the NCS group benefitted from the intervention. The results are summarised in Table 34.

Table 34: Average normalised gain scores for NCS students (n=50)

Pre-test Mean Scores	Post-test Mean Scores	Actual % gain	Average normalised Gain score	% Gain
31.7	60.6	28.9	0.41	41

The average score for the NCS group was 34% in the pre-test and this increased to 61.5% in the post-test, translating into 27% actual percentage gain, and an average normalised gain score of 0.4. This figure indicates the effectiveness of the intervention.

Actual percentage gain = post-test – pre-test

$$= 60.6 - 31.7$$

$$= 28.9\%$$

Maximum possible gain = Total possible- actual gain

$$= 100 - 28.9$$

$$= 71.1 \%$$

Average normalised gain = 28.9% / 71.1%

$$= 0.41$$

4.5.1.2 The effect of the OBE- based intervention on the students from the OSC

Figure 4.6 shows the post-test results for OSC students where the incorrect answers are indicated in red and the correct answers are indicated in blue.

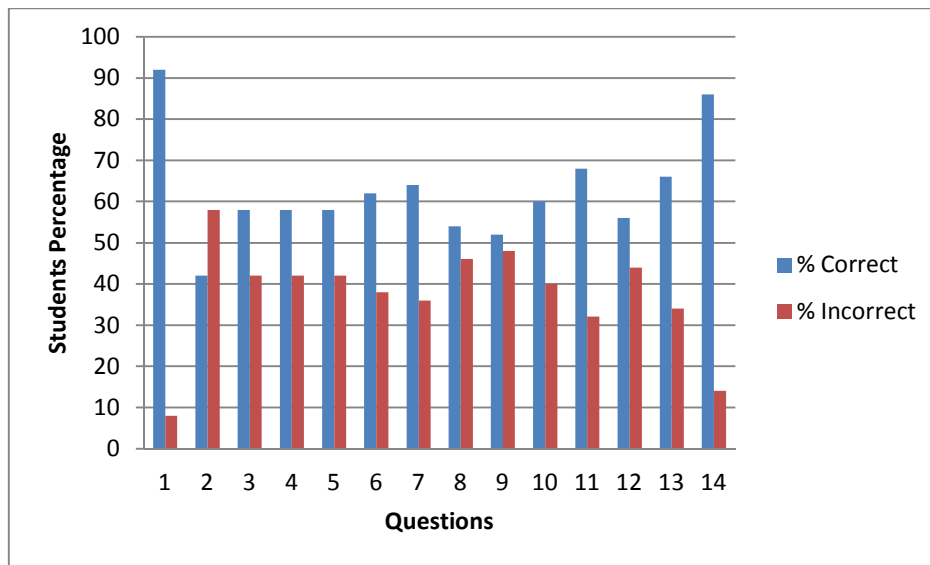


Figure 4.6: Post-test results for OSC students (n=50)

In Figure 4.6, it is indicated that the percentage of OSC students who answered the items right are higher compared to those who chose incorrect answers. This shows that there is

an improvement in their results compared to the results presented in Figure 4.2. where incorrect responses scored higher percentage in almost all cases.

Figure 4.7 shows a comparison between the pre and the post-test scores where the post-test scores are indicated in red and the pre-test in blue.

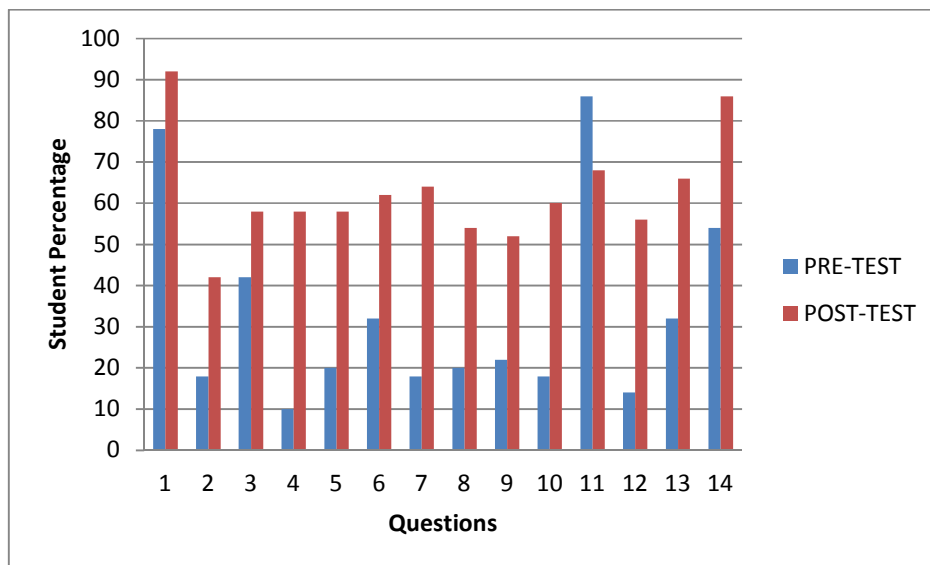


Figure 4.7: Comparison of learning gains of OSC students(n=50)

In Figure 4.7, it can be seen that the graph shows that the students performed better on the post-test, except for Question 11. This is likely due to the observation that most of the students have difficulty recognising the type of connections when several elements are connected.

4.5.2 Comparison of Pre & Post-test results of OSC students

The comparison was carried out to test the effectiveness of the OSC group intervention.

The results are presented in Table 35.

Table 35: The effect of an OBE-based intervention on students from the OSC curriculum

Group	Pre-test-Mean score	Post-test-Mean score	df	t_c	t_o	Result
OSC	33.1 sd = 23.8	62.6 sd = 12.9	13	1.76	-4.3	$p < 0,05$

The t-test yielded a statistically significant difference between the pre-test and post-test scores. The mean for the pre-test was 33.1 (sd = 23.8) and the mean for the post-test was 62.6 (sd = 12.9), $p < 0, 05$. Therefore, there was a statistically significant difference between the pre-test and the post-test for the OSC group, which implied that the intervention had been effective. Consequently, the directional hypothesis, as stated, is accepted. This means that an OBE-based intervention will significantly alleviate the alternative conceptions held by first year science education students admitted from OSC curriculum about electric circuits. This is the result of the hypothesis 1.7.2.

4.5.2.1 Average normalised gain scores

To quantify the success of the intervention that set out to remedy students' alternative conceptions and to compare the learning gains of NCS versus OSC students, the average normalised gains were calculated using Hake's (1998) formula. In Table 36 average the normalise gains of OSC and NCS students are shown.

Table 36: Average normalised gain scores for NCS students(n=50) and OSC students (n=50)

Curriculum	Pre-test Mean Scores	Post-test Mean Scores	Actual % gain	Average normalised Gain score	% Gain
NCS	31.7	60.6	28.9	0.41	41
OSC	33.1	62.6	29.5	0.42	42

The average pre-test score for the OSC was 33.1% and 31.7 for the NCS and increased to 62.6% in the post-test for the OSC and 60.6 for the NCS which translated to 29.5% actual gain for the OSC group and 28.9 % for the NCS group. The average normalised gain score for the OSC was 0.42 and for NCS it was 0.41, indicating the success of the intervention for both the groups.

The researcher then explored the effect of the intervention for the whole group (100) students, using the McNemar test. Table 37 indicates those questions where the gains between pre- and post-test scores were statistically significant.

Table 37: Comparison of pre and post test results of the two groups using the McNemar test

		Post wrong	Post right	McNemar p-value
Question 1	Pre wrong	3 (14.3%)	18 (85.7%)	P < 0.05
	Pre right	2 (2.5%)	77 (97.5%)	
	Total	5 (5%)	95 (95%)	
Question 2	Pre wrong	53 (62.4%)	32(37.6%)	P < 0.05
	Pre right	5(33.3%)	10 (66.7%)	
	Total	58(58%)	42 (42.0%)	
Question 3	Pre wrong	13 (30.2%)	30 (69.8%)	P > 0.05
	Pre right	28 (49.1%)	29 (50.9%)	
	Total	41 (41.0%)	59 (59.0%)	
Question 4	Pre wrong	39 (42.9%)	52 (57.1%)	P < 0.05
	Pre right	3 (33.33%)	6 (66.7%)	
	Total	42 (42.0%)	58 (58.0%)	
Question 5	Pre wrong	24 (30.8%)	54 (69.2%)	P < 0.05
	Pre right	17 (77.3%)	5 (22.7%)	
	Total	41 (41.0%)	59 (59.0%)	
Question 6	Pre wrong	30 (44.1%)	38 (55.9%)	P < 0.05
	Pre right	12 (37.5%)	20 (62.5%)	
	Total	42 (42.0%)	58 (58.0%)	
Question 7	Pre wrong	34 (41.5%)	48 (58.5%)	P < 0.05
	Pre right	8 (44.4%)	10 (55.6%)	
	Total	42 (42.0%)	58 (58.0%)	
Question 8	Pre wrong	29 (34.9%)	54 (65.1%)	P < 0.05
	Pre right	7 (41.2%)	10 (58.8%)	
	Total	36 (36.0%)	64 (64.0%)	
Question 9	Pre wrong	42 (56.0%)	33 (44.0%)	P < 0.05
	Pre right	11 (44.0%)	14 (56.0%)	
	Total	53 (53.0%)	47 (47.0%)	
Question 10	Pre wrong	37 (41.6%)	52 (58.4%)	P < 0.05
	Pre right	5 (45.5%)	6 (54.5%)	
	Total	42 (42.0%)	58 (58.0%)	
Question 11	Pre wrong	6 (35.3%)	11 (64.7%)	P < 0.05
	Pre right	29 (34.9%)	54 (65.1%)	
	Total	35 (35.0%)	65 (65.0%)	
Question 12	Pre wrong	45 (52.9%)	40 (47.1%)	P < 0.05
	Pre right	7 (46.7%)	8 (53.3%)	
	Total	52 (52.0%)	48 (48.0%)	
Question 13	Pre wrong	24 (34.8%)	45 (65.2%)	P < 0.05
	Pre right	7 (22.6%)	24 (77.4%)	
	Total	31 (31.0%)	69 (69.0%)	
Question 14	Pre wrong	9 (17.0%)	44 (83.0%)	P < 0.05
	Pre right	8 (17.0%)	39 (83.0%)	
	Total	17 (17.0%)	83 (83.0%)	

In Table 37, it is shown that most of the questions, in terms of both the pre- and post test results differed statistically significantly (i.e. $P < 0.05$, except for question 3 where $p > 0.05$) suggesting that the intervention was not successful on this question. A possible reason for this could be that some alternative conceptions are very difficult to change. The results for the test at least, however show that the intervention was successful because the pre and post test results differed statistically ($p < 0.05$).

4.5.3 Comparison of post-test results of NCS and OSC students

Figure 4.8 illustrates a comparison of the pre and the post-test performance of the students NCS and OSC students; the post-test results for NCS are indicated in blue and for OSC in red.

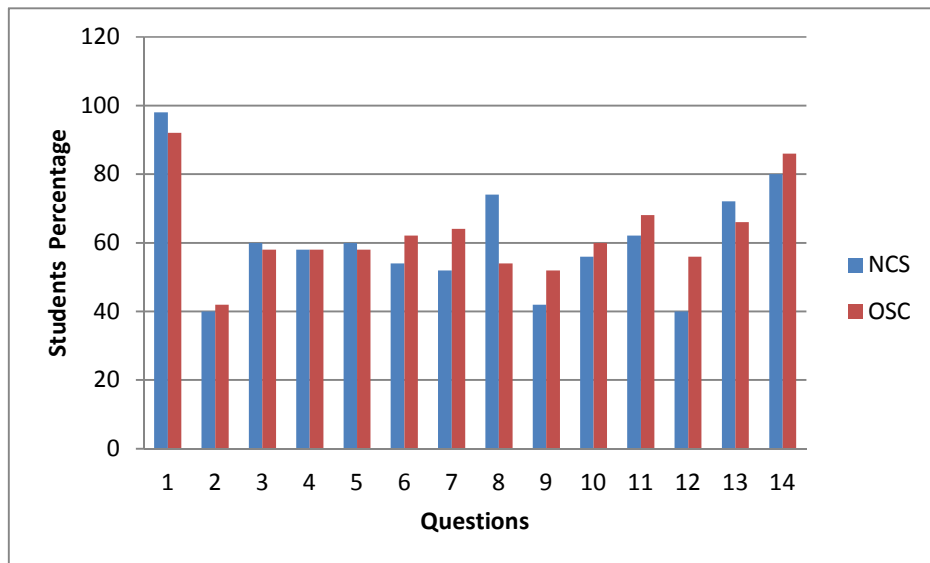


Figure 4.8: Comparison of the post-test for NCS and OSC students (n=50)

The percentage of the correct performances for both groups is higher than 50% on all the questions, except for questions 2 for both groups , 9 and 12 for NCS .The results of the two do not differ significantly on most of the questions.

The statistical comparison yielded a non –statistically significant difference between the post-test results of NCS and OSC students. The results are presented in Table 38.

Table 38:Comparison of post test results of NCS and OSC students

Group	Means	Sd	df	t_c	t_0	Results
NCS	60.6	16.2	26	2.04	-0.45	P > 0,05
OSC	62.6	12.9				

The test did not yield a statistically significant difference between the post-test scores of the two groups. The mean for the post-test for the NCS group was 60.6 as against 62.6 for the OSC students. Therefore, the hypothesis that students who studied under NCS would demonstrate significantly higher learning gains, as compared to those who matriculated from the OSC is rejected. This is the answer to hypothesis 1.7.3.

Question 1

The comparison of the post-test results for the NCS and the OSC students for question 1 is presented in Table 39

Table39: Comparison of question 1 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 1	NCS	1 (2%)	49 (98%)	0.169	-0.138
	OSC	4 (8%)	46 (92%)		
	Total	5 (5%)	95(95%)		

Only 2% NCS students answer question 1 wrong, against 98% NCS who got it right. This was close to the 8% OSC students who answered the question wrong and 92% who got it right. The Chi-square test yielded a probability greater than 0.05, thus indicating meaning that there was no significant difference between the two groups in terms of their performance on this question.

92% OSC students and 98% of NCS students respective chose option A, and the most common explanation given was :

“The bulb will glow because the circuit needs to be closed in order for it to work”.

The previously held alternative conception was successfully changed to a scientific conception.

Question 2

The comparison of the post-test results for the NCS and the OSC students for question 2 is presented in Table 40.

Table 40: Comparison of question 2 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 2	NCS	20 (40%)	30 (60%)	0.840	-0.020
	OSC	21 (42%)	29 (56%)		
	Total	41 (43%)	59 (59%)		

The Chi square test yielded a probability greater than 0.05, indicating that there was no significant difference between the two groups in their performance on this item.

60% of OSC students and 56% of NCS students chose the intended option, namely that the bulbs will remain the same the explanation given was that, *“Brightness will remain the same because the potential difference between the two bulbs connected in parallel is the same as the potential difference when it was only one bulb connected.”*

Some alternative conceptions are hard to change and some students still hold on to alternative conceptions this can be seen from the explanation given that, *“the same*

amount of flow has to light twice as many bulbs, and we have added more resistance to the current ”

The alternative conception was successfully changed to a scientific conception.

Question 3

The comparison of the post-test results for the NCS and the OSC students for question 3 is presented in Table 41

Table 41: Comparison of question 3 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 3	NCS	20 (40%)	30 (60%)	0.839	-0.020
	OSC	21 (42%)	29 (58%)		
	Total	41(82%)	59(59%)		

The table above shows that there was no significant difference between the two groups in their performance on this question. 58% of OSC students and 60% of NCS students chose the intended option which stated that when the switch is open, the resistance of the bulb will remain the same the explanation given was that ,*“resistance of a component depends only on its properties.”*

Mostb students tended to chose for the “*no current, no resistance*” alternative conception. The alternative conception previously held by the majority of students was succesfully changed into a scientific conception.

Question 4

Table 42 presents the results of the post test comparison between the NCS and OSC.

Table 42: Comparison of question 4 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 4	NCS	21 (22%)	29 (58%)	1.000	0.000
	OSC	21 (42%)	29 (58%)		
	Total	42 (42%)	58(58%)		

Only 22% of the NCS students answered question 4 wrong, against 58% NCS students who got it right;42% OSC students answered the question wrong and 58% got it right; $p > 0.05$ from the Chi-square test, meaning that there was no significant difference between the two groups in their performance on this question.

The percentage of OSC and NCS students who chose the intende option was 58% , and the most common explanation given was that, “*In series, with open switch potential difference across the gap is equal to the electromotive force (emf) and the potential*

difference across any resistor is zero because all energy is found across the open switch.”

The explanation given shows that the alternative conception previously held by the majority of students was successfully changed into a scientific conception.

Some students, however, still hold on to the alternative conception that, *“there is zero potential difference in an open switch and voltage is something that flows.”*

Question 5

Table 43 presents the results of the post test comparison between the NCS and OSC.

Table 43: Comparison of question 5 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 5	NCS	20 (40%)	30 (60%)	0.839	-0.020
	OSC	21 (42%)	29 (58%)		
	Total	41 (41%)	59(59%)		

The results of the Chi –square test indicated that the two groups performed the same on this question, $p > 0.05$: that is 58% OSC students and 60% of NCS students chose the intended option which correctly ranked the brightness in the following order, bulbs 1 and 4 are equally bright. Bulbs 2 and 3 are equally bright, and both are dimmer than bulbs 2 or 3. The most common explanation was that, *“bulb 1 and bulb 4 will be equally bright*

(dimmer) because they have high resistance and the current passing through them is the same, bulb 2 or bulb 3 will be equally brighter because they have lower resistance and the resistance in each branch is the same and the current flows through each bulb is the same. This causes identical bulbs in a parallel circuit to have the same brightness.”

The alternative conception previously held by the majority of students was change.

Question 6

Table 44 presents the results of the post test comparison between the NCS and OSC.

Table 44: Comparison of question 6 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 6	NCS	23 (92%)	27(54%)	0.418	0.081
	OSC	19 (84%)	31 (62%)		
	Total	42 (42%)	58(58%)		

On this item, 92% of NCS students answered question 6 wrong, against 54% NCS students who got it right. Similarly, 84% of OSC students answered the question wrong and 62% got it right; $p > 0.05$. Thus, in terms of the comparison of the performance of the two groups there was no significant difference between them could be found. Thus, 62% of OSC students and 54% of NCS students chose option D, which ranks the current flowing in the bulbs in the following order, the current through bulbs 1 and 4 is the same

and the current in bulb 2 is the same as bulb 3, and each is smaller than the current in bulbs 1 and 4. The explanation given, by the respondents can best be summarised as follows:

“Bulb 1 and bulb 4 are connected in series and the current passing through them is the same all the way round a series circuit and each charge will give up half its energy and they will become dimmer, such that bulbs 2 and 3 will be dimmer, while bulb 2 will be the same as bulb 3 because they will share the current equally because they have equal resistance and they are connected in parallel and they have low resistance. Potential difference is the same through them.”

Most of the students' alternative conceptions were successfully changed into a scientific conception this shows the success of the intervention between the two groups.

Question 7

The comparison of the post-test results for the NSC and the OSC students for question 7 is presented in Table 45.

Table 45 Comparison of question 8 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 7	NCS	24 (48%)	26 (52%)	0.224	0.122
	OSC	18(36%)	32 (64%)		
	Total	42 (42%)	58(58%)		

On this item, 52% of NCS students who answered the question right as compared to 64% OSC students; $p > 0.05$ from the Chi-square test. This suggests that there is no significant difference between the two groups in their performance on this item. 64% of OSC students and 52% of NCS students chose the intended option D, which ranks the potential difference across the bulbs in this order, potential difference across 1 is the same as 4. The most common reason given was that:

“The bulbs are connected in series and they have equal resistance. If the resistors were not the same the potential difference will not be the same, if the potential difference increases as resistance increases. Bulb 2 is the same as bulb 3, and both are smaller than bulb 1 or bulb 4. Bulbs 2 and 3 are connected in parallel and they have the same potential difference which is smaller than bulbs 1 and 4 because they have equal resistance and the resistance of the bulbs that are in series are twice the combination of the resistance of parallel bulbs. The potential difference of bulb 2 and bulb 3 is half the

potential difference of bulb 1 or bulb 4". This scientific explanation given by the students confirms the success of the intervention.

Question 8

The comparison of the post-test results for the NCS and the OSC students for question 8 is presented in Table 46.

Table 46: Comparison of question 8 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 8	NCS	13 (26%)	37 (74%)	0.037	-0.208
	OSC	23 (46%)	27(54%)		
	Total	36 (36%)	64(64%)		

The table shows that the two groups did not perform the same on this item, $p < 0.05$. 54% OSC students and 74% of NCS students chose the option stating that current in bulb 1 will decrease if the switch S is opened, because *"bulb 3 will be a dead end and bulbs 1, 2 and 4 will be in series which makes them to have high resistance. The current passing through the bulb 1 will decrease."*

The previously held alternative conception was successfully changed to a scientific conception.

Question 9

The comparison of the pos-test results for the NCS and the OSC students for question 9 is presented in Table 47.

Table 47: Comparison of question 9 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 9	NCS	29 (58%)	21(42%)	0.316	0.100
	OSC	24 (48%)	26(52%)		
	Total	53 (53%)	47(47%)		

In question 9, 58% of NCS students answered wrongly, against 42% of NCS students who got it right This was similar to the 48% OSC students who answered the question wrong and 52% who got it right; $p > 0.05$ from the Chi-square test. This means that there was no significant difference between the two groups in their performance on this question. A typical response was: *“Bulb 3 will be a dead end and bulb 2 will be in series with bulbs 1 and 4. The potential difference of bulb 2 will also increase.”*

Students had difficulty answeriong this question especially the NCS students whose performance dropped. This decline is ascribed to a topologically mistaken interpretation of the circuit, or the possibility that most of the students in the pre-test were guessing the answers.

Question 10

The comparison of the post-test results for the NSC and the OSC students for question 10 is presented in Table 48.

Table 48: Comparison of question 11 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 10	NCS	22 (44%)	28 (56%)	0.685	0.041
	OSC	20(40%)	30(60%)		
	Total	42 (42%)	58(58%)		

The table shows that the performance of the two groups is identical on this item, $p > 0.05$. Thus, 60% of OSC students and 62% of NCS chose the intended option the common explanation given was that, *“The bulbs have equal resistance. When the switch was closed, the current in bulb 2 was half the current in bulb 1 because bulbs 2 and 3 are connected in parallel and they share the half of the current from bulb 1, and the potential difference is smaller than that of bulbs 1 and bulb 4 (potential difference of bulbs 2 and 3 is half the potential difference of bulbs 1 and 4). When the switch is opened, the current in bulb 2 increases and also its potential difference increases because bulb 2 is now in series with bulbs 1 and 4 because there will be no current passing to bulb 3.”*

The students' alternative conception was successfully changed to a scientific conception.

Question 11

Table 49 presents the results of the post test comparison between the NCS and OSC.

Table 49: Comparison of question 11 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 11	NCS	19 (38%)	31(62%)	0.529	0.063
	OSC	16 (32%)	34 (68%)		
	Total	35 (88%)	65(65%)		

On this item 38% of NCS students answered question 11 wrong, against 62% NCS students who got it right. This was the same as 32% OSC students who answered the question wrong and 68% who got it right; $p>0.05$. This showed that there is no significant difference between the two groups in their performance on this item. The typical response from students who selected the intended response was:

“Current moves from positive to negative terminal of the battery and when it reaches a junction it branches and when current branches it means the resistors are in parallel.” In series circuit the different parts follow one after the other and there is just one path for the current flow.”

The alternative conception was successfully changed into a scientific conception.

Question 12

Table 50 presents the results of the post -test comparison between the NCS and OSC.

Table 50: Comparison of question 12 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 12	NCS	30(60%)	20 (40%)	0.109	0.160
	OSC	22 (44%)	28(56%)		
	Total	52 (52%)	48(48%)		

On this item 40% of NCS and 56% of OSC students answered this question correctly.

The typical explanation was as follows: “ *The current passing through a resistor must branch or it must be the same throughout the circuit.*”

The NCS students experienced some difficulty in answering this question because their performance has dropped. It seems as if the NCS students were guessing the answers in the pre-test. It remains a problem that students have difficulty identifying series and parallel connections.

Question 13

Table 51 presents the results of the post- test comparison between the NCS and OSC.

Table 51: Comparison of question 13 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 13	NCS	14 (28%)	36 (72%)	0.517	-0.065
	OSC	17 (34%)	33 (66%)		
	Total	31 (62%)	69(69%)		

Only 28% of NCS students answered question 13 wrong, against 72% who got it right. This was similar to the 34% OSC students who answered the question wrong and 66% who got it right; $p > 0.05$. The two groups performed the same on this item. Thus, 66% of OSC students and 72% of NCS students chose the intended option C, which stated that the current I_A

through R_A is $I_B = I_C$. The typical explanation given for choosing this answer was: “ R_A , R_B and R_C are connected in series and the current is the same throughout the circuit.”

The alternative conception was successfully changed to a scientific conception, thus showing the success of the intervention.

Question 14

Table 52 presents the results of the post test comparison between the NCS and OSC.

Table 52: Comparison of question 14 post-test results for NCS and OSC

		Wrong	Right	P	Phi
Question 14	NCS	10 (20%)	40 (80%)	0.424	0.080
	OSC	7 (14%)	43(86%)		
	Total	17 (17%)	83(83%)		

The table shows that the two groups performed identically on this question, $p > 0.05$.

Thus, 86% of OSC students and 80% of NCS students chose option C, which stated that: the relationship between I_B and I_C is $I_B = I_C$. The most common explanation given for the choice was that:

“Current that is passing through that resistors is the same because they are in series.”

The intervention was successful because the students’ alternative conceptions were successfully changed into scientific conceptions.

4.6 DISCUSSION OF FINDINGS

In discussion of the above findings set out above, starts with the presentation of identified alternative conceptions of first year science education students about electric circuits. This is followed by a discussion of the effectiveness of the curriculum intervention based on OBE principles with a view to redressing the identified alternative conceptions. Lastly, a discussion and interpretation of the “t” test and gain scores is presented.

4.6.1 Alternative conceptions identified

The first research objective concerned the identification of alternative conceptions held by first year university science education students. More specifically, the research objective reads as follows:

- Identify the alternative conceptions of first year university science education students about electric circuits

The alternative conceptions, as identified from the analysis of the pre-test questions were found to entail the following:

- 1) There is no need for a circuit to be closed in order for it to work
- 2) Students have difficulty predicting the brightness of bulbs in series and parallel connections: this is because they believe that a battery is a constant source of current.
- 3) Concept of resistance: there is a belief that there would be no resistance if there is no current.

- 4) Students harbour undifferentiated concepts (voltage and current): they feel that current and voltage should always appear together.
- 5) Sequential reasoning : this means the belief that the direction of current in the circuit and the order of connections of the bulbs determine the relative brightness.
- 6) Consumer model : this refers to a conception that current leaves the battery at a particular value and is modified thereafter depending what it encounters in its path.
- 7) Current is shared between components in series circuits.
- 8) Students find it difficult in predict potential difference at different points in series and parallel connections: they believe that potential difference in series connections is the same because current that passes through resistors connected in series is the same.
- 9) There is a misunderstanding of the causal relation between current and voltage : current is seen as the primary concept in the circuit, while potential difference is seen as the consequence of current flow and not as its cause.
- 10) Students have difficulty predicting potential difference on an open switch in series and open switch in parallel: there is a zero potential difference in an open circuit.
- 11) Incorrect application of Ohm's law: students believe that if potential difference increases resistance also increases. Ohm's law is often expressed as $V = IR$.

- 12) Students often find difficulty to identify series and parallel connections :when a single element is in series with two elements connected in parallel, that single element is in series with one of the elements in a parallel combination.

4.6.2 Curriculum intervention based on OBE principles with a view to redress the identified alternative conceptions

4.6.2.1 The effectiveness of the OBE-based intervention on NCS students

The percentage of NCS students who answered the items right are higher compared to those who chose incorrect answers. This shows that there was an improvement in their results compared to the pre-test results presented in Figure 4.1, where incorrect responses scored higher percentage in almost all cases. For example, the NCS students scored less than 50% on question 10 and 13. It also emerged in the literature that alternative conceptions are difficult to overcome and explicit instructional interventions aimed at addressing these conceptions are necessary. This study also found this to be the case.

4.6.2.2 The effectiveness of the OBE-based intervention on OSC students

The percentage of OSC students who answered the items right are higher compared to those who chose incorrect answers. This shows that there is an improvement in their results compared to the pre-test (results presented in Figure 4.2), where incorrect responses scored higher percentage in almost all cases. Making provision for different learning styles of the individual by applying a variety of instructional methods will help to promote effective learning. A tendency was identified by Novak (1998) that some students were most likely to favour rote learning approaches, and others were more

constructivist in their approach, which means that they tend to favour meaningful learning strategies. Therefore both extremes need careful consideration in education (Coetzee, 2008).

4.6.2.3 The effectiveness of the OBE-based intervention on NCS versus OSC students

The percentage of the correct answers by from both groups is higher than 50% for most of the questions. The statistical comparison yielded a non-statistically significant difference between the post-test results for the two groups. There was an improvement in the post-test results for both groups, thus clearly indicating the success of the intervention.

The intervention used in this study was the OBE approach. The theoretical justifications from the literature showed that the OBE approach was powerful and had a number of strengths. One noteworthy, from the constructivist point of view, peer learning interactive engagement methods is a can strongly recommended for effective learning. By incorporating student-centered methods specifically by using students' questions, comments, responses on tests and, and generally adhering to the constructivist approach, it is possible to build models of students' knowledge construction which may help towards identifying of students' alternative conception (Coetzee, 2008). Only when alternative conceptions have been identified and directly addressed, will student learning become effective. Geer and Rudge (2002) state that students learn by making sense of

phenomena as they experience them, as they evaluate their value and attempt to make sense of them within a socially acceptable context also in light of their prior knowledge.

OBE is a strategy within the constructivist theoretical framework, which does not impose a prohibition on any instructional method. Furthermore, OBE provides the opportunity for implementing a number of different classroom activities and reflection on these, which could facilitate changing alternative conceptions. According to Gray (1997) one of the benefits of OBE is to foster critical thinking and to create motivated independent learners, This can best be achieved in a situation where a constructivist teaching approach with features of a constructivist programme, a constructivist teacher and a constructivist classroom are all in place.

According to Millar (1989), the process of constructing new ideas takes place within the learner's own head. This occurs when any successful learning takes place and is independent of the instruction method. A consequence of the constructivist approach is however that science should be taught with a view to elicit the active involvement of learners, which in turn leads to reconstruction of meaning. Millar further suggests that a change to the constructivist approach is more likely to be found in terms of improving the sequence and pacing of the science curriculum, and less in terms of changing instructional methods.

4.6.3 Interpretation and discussion of the results of the gain scores

The average of the results from the pre-test to post-test increased dramatically for both NCS and OSC students. The average gain of both groups fall in the “interactive zone” (Hake,2002). The effectiveness of the strategies used in the intervention was, thus, comparable with contemporary interactive strategies and agrees with the hypothesis in paragraph 1.7.1.

The average normalised gains of both groups is slightly different and one of the reasons for this could be that many teachers are still teaching the new curriculum the same way as they were teaching in the old curriculum. The learning gain of the OSC students was 0.41 and for the NCS was 0.4, and consequently the null hypothesis was rejected which stated that students who studied under the NCS would demonstrate significantly higher learning gains after exposure to an OBE-based intervention, compared to those who matriculated from the old school curriculum.

4.7 CONCLUSION

The results of this study indicated the effectiveness of the intervention in ameliorating students’ alternative conceptions about electric circuits, regardless of which high school curriculum the participants came from. After students’ alternative conceptions have been confronted through activity-based instructional approaches they were guided to construct scientifically acceptable knowledge. The knowledge was consistent with their experimental observations. However, contrary to the researcher’s expectation that

students who came from the OBE-based curriculum (the NCS group) would perform better than the group from OSC, the results of this study showed that the gains of the two groups were identical.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

A large number of researchers have reported the prevalence of alternative conceptions concerning many concepts and principles in science especially regarding electric circuits. It is by now well established that students do not come to the classroom as empty vessels; it follows that knowledge should not simply be transferred from the lecturer to them, because they develop beliefs about things that happen in their surroundings from the very earliest days of their lives. Indeed, students come to science classrooms with a number of unscientific ideas, which may differ in salient ways from the scientific understanding and theories the lecturer may wish to develop in them.

The origin of alternative conceptions could be any previous experience or observation by the student; these conceptions do not necessarily arise out of formal training, but can be based on any life experience. The important point in this regard is that alternative conceptions, once formed, have a bearing on students' observations and the sense they make of further learning. These alternative conceptions are resistant to change, and thus

a considerable number of learners hold on to certain intuitive notions despite the science teaching they receive in school (Driver, 1983).

Many of the sources of confusion in science classes are not identified in the classroom as teaching occurs. Students may be aware of some conceptual blockages, especially those that stop learning completely, but they may remain unaware of other blockages, because knowledge construction continues, but in a wrong direction, thus leading to a number of alternative conceptions. In order to develop such models that can address this situation, interactions among students and lecturers have to occur openly (Coetzee, 2008).

5.2 SUMMARY OF STUDY

The aim of the study was to investigate students' alternative conceptions about electric circuits and the effect of an activity-based instructional approach in ameliorating the alternative conceptions.

OBE is a teaching strategy within the constructivist theoretical framework, and provides for using a number of different classroom activities and attendant reflections, which could in turn facilitate change from alternative conceptions into scientific ways of knowing and understanding. According to the DoE (2003), one of the benefits of OBE is that it fosters critical thinking and creates motivated and independent learners.

Lemmer and Lemmer (2010:7) propose a conceptual refinement model as a teaching learning model according to which learners' productive intuitive resources are gradually

refined towards the accepted scientific concepts. Aspects of learners' initial knowledge that contains elements of the physics concept (i.e. productive conceptual resources) are identified and refined (Hammer, 2000). Learners are then guided to generalise a conceptual understanding from the similarities and differences in a variety of selected everyday and classroom experiences. In this way, physics knowledge is constructed onto the learners' experiential knowledge as they systematically develop coherent conceptual knowledge. In the conceptual refinement model, conceptual knowledge refers to conceptual understanding of physics that can be expressed in relations between concepts, and can be used to explain different situations, i.e. a conceptual explanatory model. Thus, learners' conceptual knowledge that has been formed from a combination of their experiential (everyday) and experimental (physics) knowledge becomes the resource for the abstraction of their formal physics knowledge that includes advanced reasoning and problem-solving skills, operational definitions, generalised laws, mathematical relations between concepts and multiple representations these. The conceptual refinement model requires an adequately refined conceptual understanding before formalisation can take place.

One major task of the educator is to alleviate any alternative conceptions which are not in line with the intended learning of the scientific concepts. From the literature, it was noted that most conventional physics instruction does not pay attention to learners' intuitive conceptions and explanations.

OBE is a strategy within the constructivist theoretical framework. Furthermore, OBE gives the opportunity for a number of different classroom activities and reflection. According to Coetzee (2008:273), quoting Gray (1997) one of the benefits of OBE is to foster critical thinking and create motivated independent learners, when a constructivist teaching approach with features of a constructivist programme, a constructivist teacher and a constructivist classroom are all in place.

According to Millar (1989) the process of construction of new ideas takes place within the learner's own head. This occurs when any successful learning takes place and is independent of the instruction method. A consequence of the constructivist approach is however that science should be taught to engage the active involvement of learners, which leads to reconstruction of meaning. Millar further suggests that a change to the constructivist approach is more in terms of improving the sequence and pacing of the science curriculum, and less in terms of changing instructional methods.

The interventions used in this study were activity-based instructional approaches within the pedagogic aegis of OBE, using activity-theory as a theoretical framework. The attendant theoretical justifications from the literature showed that the OBE approach had a number of strengths that could be harnessed with a view to promote conceptual change. In the present study, it was observed that students were made to be active participants. The "t" score showed that there was a significant difference between the pre and post-test scores of the participants meaning that the OBE intervention was successful in changing alternative conceptions to scientific conceptions.

One finding that raises concern is that the OBE- based curricula at schools seems not to be effective. The intervention used by the researcher based on the same principle was effective. The researcher has identified and assessed the alternative conceptions held by students and referred to everyday life experiences, using visualisation, analogies and so forth. The researcher demonstrated and discussed activities with students but he did not give students the correct' answers. The other contributing factor to the success of the intervention was that students worked in a hands-on manner. Educators are complaining about lack of resources and proper training, but most of them still use the transfer of knowledge approach in their schools.

The first objectives of the empirical study was to identify the alternative conceptions of first year university science education students about electric circuits This objective was accomplished by means of a test (Appendix A). The test established the selected students' alternative conceptions about electric circuits. On the basis of these results an instructional sequence (Appendix B) made up of activity-based lessons in electric circuits was developed and implemented. This sequence was, based on OBE principles, and set out to redress the alternative conceptions that have been identified (Objective 2). The instructional sequence progressed from contextual to conceptual to formal learning. The effectiveness of the intervention was determined by means of "t" test and McNemar tests. The average normalised gains were calculated with a view to compare the learning gain of NCS students against those from the OSC.

An activity-based instructional approaches was used in the intervention because it

- (a) Is in line with the requirements of the National Curriculum Statements (Department of Education, 2003 a and b);
- (b) Is constructivist in nature, since it provides opportunities for learners to express their pre-knowledge that can then be remedied by the facilitator (Tarabanet *al*, 2007);
- (c) Is learner-centered, since it encourages active learner involvement (Ramsden, 1994, Tarabanetal, 2007);
- (d) Motivated and enhances learning (Ramsden, 1994);
- (e) Benefits disadvantaged learners especially (Donnellan& Roberts, 1985).

The results showed that most of the students, both from the NCS and OSC groups have common alternative conceptions about electric circuits before instruction. Other conceptual problems included that the learners did not understand scientific concepts such as emf and confused the concepts of voltage and current.

The high normalised learning gain of 0.41for NCS students and 0.42for OSC students achieved by the intervention indicates the effectiveness of the activity-based instructional sequence in changing the students' alternative conceptions into a scientifically accepted understanding of the concept of electric circuits. There was no significant difference between the NCS and OSC students in terms of the learning gains.

Since the purpose of the study concerned students' alternative conceptions about electric circuits and the effect of activity-based instructional approach, the instructional strategy that was followed is summarized below. The intervention implemented activity-based instructional approaches in accordance with the constructivist learning theory.

Students worked in groups so that co-operative learning could take place. In these groups they discussed the solutions to a variety of problems and performed enquiry-based experiments. The order of activities followed the contextual didactical approach. In this way, the students were guided to change their alternative conceptions to scientific accepted ideas. The intervention was consequently based on OBE using activity-theory as a theoretical framework.

When students were given familiar contexts (e.g. the bicycle), they were eager to express their own views. Through verbalisation they revealed their alternative conceptions as well as their anchoring conceptions. For example, in the variety of contexts given in Appendix B, students may say the bicycle chain moves slowly but the energy is instantly available and that energy is only transferred from source (pedal) when the links moved. This type of understanding can be used as anchoring ideas to explain law of conservation of energy. Following from this and by means of analogous explanations, the students were able to predict the brightness of the bulbs in the experiments correctly.

Current, resistance and potential difference also formed the anchoring idea in the conceptual problem demonstrated in an enquiry experiment (Appendix B). Learners' everyday knowledge and analogous explanations were used to explain the brightness of the bulb. Formalisation of the concepts was followed after the students have grasped the concepts that are used to explain the working of electric circuits.

Similarly, the concepts of power, internal resistance and emf were introduced by way of a formal problem (Appendix B). Before solving a problem, the explanation of the concepts was given.

The high normalised gain was consequently accomplished by way of an effective teaching sequence based on the constructivist learning theory.

5.3 CONCLUSION

Most researchers (Chin & Brewer; 1998:104) contend that the quality of prior knowledge is perceived to have powerful effects on the teaching and learning process in science. If educators can probe the nature of learners' prior knowledge, they can identify learners' alternative conceptions; this will set the scene for the need to learn and teach according to what learners already know. Consequently, teaching strategies should be guided by the activity-based instructional approaches in order to accomplish conceptual change effectively. A combination of different teaching strategies should be utilized in order to make different cognitive demands on learners and to accommodate individual differences.

The high percentage of occurrence of learners' alternative conceptions about electric circuits and students' deficiencies in understanding certain scientific concepts, as revealed by the pre-test, are disturbing. These first year university students have been exposed to the concept of electricity from grades 10 to 12 in the physics module *Electricity and Magnetism*. However, it appears that during these years of instruction

their alternative conceptions and learning difficulties were not sufficiently addressed at all (Edwards, 2007). It also seems that scientific terminology such as potential difference; emf, charge, and energy were not dealt with effectively.

The activity-based instructional approaches used in this study, which progressed from contextual to conceptual to formal understanding proved to be effective with an average normalised learning gain of 0.41 for NCS and 0.42 OSC students. According to Hake (2002a), a treatment (e.g. an intervention) that yields a gain larger than 30% can be considered to be in the "interactive engagement zone".

This high gain illustrates the success of the intervention in effecting conceptual change towards the correct scientific conceptions. The sequence of activities successfully enhanced the development of scientific conceptions. The results stress that it is necessary to implement the constructivist principle that students' initial understanding should be engaged and their conceptual understanding appropriately developed on the basis of their prior knowledge and understanding.

This study was conducted against the reported resilience of students' pre-concepts to extinction. The results of this investigation showed that an OBE-based activity-based instructional approach led to significant changes in alleviating students' pre-conceptions that is not consistent with espoused scientific thinking. To this end, this study has succeeded in achieving its objectives, thereby making a significant contribution to both theory and practice.

Overall, therefore, this study has been significant and, certainly, rewarding to the researcher.

5.4 RECOMMENDATIONS

This study involved a sample of 100 students. The high learning gain obtained illustrated the effectiveness of the intervention. It is therefore justified to infer that the activity-based instructional approaches followed in this study made a significant improvement in students' understanding of the science concepts that were studied.

The poor pre-test results showed that the students' alternative conceptions and learning difficulties related to electric circuits were not efficiently addressed in lower grades. This could be ascribed to a number of different factors, such as ineffective teaching, inappropriate textbooks, lack of facilities for practical work, and others.

On the basis of this and other studies (Redish, 2003 & Trumper, 1990:353) it can be recommended that the following steps are followed when teaching and implementing interventions of this nature:

- ✓ Start with what learners already know.
- ✓ Treat learners' alternative conceptions with the urgency they require so that learners do not carry them to the subsequent years of study.
- ✓ Use constructivist teaching-learning approaches (e.g. enquiry teaching-learning strategies) to promote conceptual change and understanding.

- ✓ Create a list of terms with definitions in order to foster learners' understanding of requisite scientific terminology.
- ✓ Relate the scientific knowledge that is being taught to its application in real life situations.

Teachers may also apply ideas from this study to research their own practices as well as to design learning and teaching experiences and materials for effective and meaningful learning and teaching (DoE, 2003:5). The value of researching one's practices as a teacher is the ability to be kept abreast with the dynamic nature of the teaching and learning environment.

An understanding of the alternative conceptions which students bring to the tertiary education sector will serve as a very important input into curricula of university programmes. These alternative conceptions and teaching strategies, which may lead to the required conceptual changes, must be studied in science education modules by prospective science educators.

Educators and curriculum advisors need to be informed that it is crucial to understand both the prevalence and nature of alternative conceptions in order to effectively design and implement programmes that bring about the required conceptual changes to the teaching and learning practices of the science classroom.

REFERENCES

Anderson, J. R., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y. (2004). An Integrated Theory of the Mind. *Psychological Review*, 111(4), 1036–1050.

Applebee, A.N., Langer, J.A., Nystrand, M & Gamoran, A. (2003). Discussion-Based Approaches to Developing Understanding: Classroom Instruction and Student Performance in Middle and High School English. *American Educational Research Journal*, 40,(3): 685-730.

Arons, A.B. (1997). *Teaching introductory physics*. New York: John Willey and sons.

Ausbel, D. (1968). *Educational psychology; A cognitive view*. New York: Holt, Rinehart and Winston.

Banchi, H. & Bell, R. (2008). The Many Levels of Inquiry. *Science and Children*, 46(2), 26-29, October.

Bartlett, D. (2004). *Analogies between electricity and gravity*. *Metrologia* 41:S115-S124.

Baser M & Geban Ö, (2007). Effect of instruction based on conceptual change activities on students' understanding of static electricity concepts. *Research in Science & Technological Education*, 25(2), 243-267

Bødker, S. (1989). A human activity approach to user interfaces. *Human-Computer Interaction* 4:171– 195.

Bransford, J.D., Brown, A.L. & Cocking, R.R. (2000). How people learn: Brain, mind, experience & school. Washington, D.C: National Academy Press.

Brown, D. E. (1992) Using examples and analogies to remediate misconceptions in physics: Factors influencing conceptual change. *Journal of research in science teaching*, 29: 17-34.

Brown, D.E. & Clement, J. (1989). Overcoming misconceptions by analogical reasoning abstract transfer versus explanatory model construction. *Instructional Science*, 18:237-261. Kluwer Academic Publishers, Netherlands.

Brown, H.J. (1977). Perception. Theory and commitment-the new philosophy of science. Chicago: Precedent.

Bunge, S. A., Wendelken, C., Badre, D., & Wagner, A. D. (2005). Analogical reasoning and the prefrontal cortex: Evidence for separable retrieval and integration mechanisms. *Cerebral Cortex*, 3: 239-249.

Cajori, F (1914). A history of Physics. London: Macmillan

Calliot, M. & Xuan, A.N. (1993). Adults' misconceptions in electricity: The proceeding of the third international seminar on misconceptions and educational strategies in Science and Mathematics (Ithaco, N, Y Misconception Trust).

Carey, S. (1985) *Conceptual change in childhood* .Cambridge, MA, MIT Press).

Carivita, S. (2001).A re-framed conceptual change theory?*Learning and Instruction*, 11, 421–429.

Carl, J. (2008). Dealing more effectively with alternative conceptions in science.*Journal of Physics Teacher Education*.5(1).

Cashion, M & Karen, G. (2006). Exploring problem-based learning in the context of high school science: *Design & implementation*. 106(7):280-294.

Chi, M.T.H (2005). Commonsense Conceptions of Emergent processes: Why some misconceptions are robust. *The journal of the learning sciences*. 14 (2).161-199.

Chi, M.T.H., Slotta, J.D. & Deleuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and instruction*, 4:21-A3.

Chinn, C.A & Brewer, W.F (1998). An empirical test of taxonomy of responses to analogous data in science. *Journal of research in science education* 35:623-654.

Chisholm, L .(2005). The making of South Africa's National Curriculum Statement. *Journal of Curriculum Studies*, 37:193-208.

Clement, J & Steinberg M. S. (2002). Step-Wise Evolution of Mental Models of Electric Circuits: A “Learning-Aloud” Case Study. *The Journal of the Learning Sciences*, 11(4):.389-452.

Clement, J & Rea-Ramirez, M.A (2008). Model based learning and instruction science, 11-22

Clement, J. (1982).Students' preconceptions in introductory mechanics. *American Journal of physics* 50:66-71.

Clement, J. (1983).Use of analogies and spatial transformations by experts in solving mathematics problems.{In Bergeron, J. &Herscovics, N. eds. Proceedings of the fifth annual conference of the international group for the psychology of mathematics education, Montreal, 1:101-111.)

Clement, J. (1987).Overcoming students misconceptions in physics: The role of anchoring intuitions and analogical validity. Proceedings of the second international seminar.Misconceptions and Educational strategies in Science and Mathematics, p84-97.

Clement, J., Brown, D., &Zietsman, A. (1989). Not all preconceptions are misconceptions: Finding anchoring conceptions for grounding instruction on students' intuitions. *International Journal of Science Education*,11:554-565.

Coetzee, A (2008). Alternative conceptions concerning interference and diffraction of light. Department Of Mathematics, Science and Technology Education. M.Ed. dissertation, Tshwane University Of Technology, Pretoria.

Cohen, R., Eylon, B. & Ganiel, U. (1983). Potential difference and current in simple electric circuits: A case study of students' concepts. *American journal of Physics*, 51, 407-412.

Collins, A. (2002). How students learn and how teachers teach. (In: Bybee, R.W. (Ed). *Learning science and the science of learning*, Arlington, Virginia: NSTA press.) p3-11

Cosgrove, M. & Osborne, R. (1985). Lesson frameworks for changing children's ideas. *Learning in science*. Heinemann.

Crespo, M.A.G. (2004). Relationship between everyday knowledge and scientific knowledge: Understanding how changes matter. *International journal of science education*, 26(11), 1325-1343.

Cutnell, J. D. & Johnson, K. W. (1998). *Physics*. 4th ed. New York: John Wiley & sons.

Dada, S., Granlund, M & Alant E. (2006). A discussion of individual variability, in activity-based interventions, using the niche concept. *Child: Care, Health and Development*, 33(4), 424-431.

Dekkers, P.J.J.M., & Thijs, G.D. (1998). Making productive use of learners' initial conceptions in developing the concept of force. *Science Education*, 82, 31-51.

Dell, R & Rand, D (2001), *Understanding Batteries*, Royal Society of Chemistry, pp. 2-4, [ISBN0854046054](#)

Department of Education (2011). *Curriculum and assessment Policy Statement* Grades 10-12. Physical sciences. Pretoria: Government Printing Works.

Department of Basic Education (2010). *National Examinations and Assessment Report on the National Senior Certificate Examination Results Part 2 2009*. Pretoria:

Department of Education (2008a). *Abridged Report: 2008 National Senior Certificate Examination Results*. Pretoria: Department of Education.

Department Of Education.(2003a). National Curriculum Statement for GET (Natural Science). Pretoria, Tirisano.

Department Of Education. (2007). Learning programme Guideline. Pretoria:Government Printer.

Department Of Education.(2003). National Curriculum Statements for Grade10-12(General) physical science. Pretoria: Government Printer..

Dewey, J. (1944). Democracy and education. New York: Free press.

Dolmans, D.H.J.M., De Grave, W., Wolfhagenm I.H.A.P &Van der Vleuten, C.P.M. (2005). Problem-based learning: future challenges for educational practice and research. *Medical Education*, 39,732–741.

Donnellan, K.M & Roberts, G.J. (1985). What research says? Science & Children. January; 119-121.

Driver, R. (1983). *The pupil as scientist*. Milton Keynes: Open University Press.

Driver, R. (1989). Students conceptions and learning of science. *International journal of science education*. 11: 481-490.

Driver, R. (1983). *The pupil as scientist?* Buckingham: Open University press. 113 p.

Driver, R., Guesne, E. & Tiberghien, A. (1985). *Children's ideas in science*. Buckingham: Open University Press.

Duffin, W.J. (1980). *Electricity and Magnetism 3rd edition*. McGraw-Hill.

Duit, R. & Treagust, D. F. (1995). Students conceptions and constructivists teaching approaches. In B.J. Fraser & H.J. Walberg (eds). *Improving science education* (Illinois: The National Society for Study of Education, 46-47).

Duit, R. (1981). Students' notions about the energy concept - before and after physics instructions. Paper presented at workshop on problems concerning students' representation of physics and chemistry knowledge at the Pädagogische Hochschule Ludwigsberg, September.

Duit, R., & Treagust, D.F. (2003). Conceptual change: a powerful framework for improving science teaching and learning. *International journal of science education*, 25(6), 671–688.

Dufresne, R.J., Gerace, W.J. & Leonard, W.J. (1997). Solving physics problems with multiple representations. *The Physics Teacher*, 35:270-275, May.

Dykstra, D. (1992) Studying conceptual change, in: R. Duit, F. Goldberg & H. Niedderer (Eds) *Research in physics learning: theoretical issues and empirical studies* (Kiel, Institute for Science Education at the University of Kiel. pp. 40–58).

Edens, K.M. (2000). Preparing Problem Solvers for the 21st Century through Problem-Based Learning, *College Teaching*, 48(2), 55-60

Edwards, J.M. (2007). Evaluering van natuurwetenskaphandboeke vir die onderrig van warmte in Graad 7. Potchefstroom: NWU. (Dissertation M.Ed.).

Edwards, N. (2010). An analysis of the alignment of the grade 12 physical sciences examination and the core curriculum in South Africa. *South African Journal of education*. 30 (4). Pretoria

Ellse, M. & Honeywill, C. (2001) Fields, forces and synthesis. Available online at: http://www.nelsonthornes.com/secondary/science/nas_new/html/sample_pdfs/fields_20_29.pdf
. Retrieved: 15/02/2011

Engel, C, E. (1992). Problem-based learning, *British Journal of Hospital Medicine*, 46:325-329.

Engelhardt, P.V & Beicher, R.J, (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics*, 72(1): 98-115.

Enger, S. & Yager, R. (2001). *Assessing Student Understanding in Science*. Thousand Oaks, CA: Corwin Press.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultit Oy.

Engeström, Y. & Middleton, D. (1996). *Cognition and communication at work*. Boston, MA: Cambridge University Press.

Eylon, B.S & Ganiel, U. (1990). Macro-micro relationships: the missing between electrostatic and electrodynamics in students' reasoning. *International journal of science education*, 12, 79-94.

Feldman, A. & Minstrell, J. (2000). Action research as a research methodology for the study of the teaching and learning of science. (In A.E. Kelly, and R. Lesh (Eds.) *Handbook of research design in mathematics and science education*. Mahwah, N J: Erlbaum.).

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

Fredette, N. & Lockheed, J. (1980). Students conception of simple circuits. *The physics teacher*, 18, 194-198.

Geer, A.C & Rudge, D.W. (2002). A review of research on constructivist based strategies for large lecture science classes. *Electronic Journal of Science Education*, 7(2).

Gilbert J.K., Osborne, R.J &Fensham, P.J. (1986).Children: Science and its consequences for teaching. In J.Brown, A. Cooper, I. Hurton, F.Juates and D.Zeldin (eds) .Exploring the curriculum: Science in schools (Milton Keynes: Open University press), 302-331.

Gilbert, J.K. & Watts, O.M. (1983) Concepts, Misconceptions and alternative conceptions: changing perspectives in science education. *Studies in science education* 10:61-98.

Gilbert, S. (1989) .An evaluation of the use of analogy, simile, and metaphor in science texts.

Glatthorn, A. (1999). Curriculum alignment revisited. *Journal of Curriculum and Supervision*, 15:26-34.

Gray, A. (1997). Constructivist teaching and learning, SSTA Research Centre Report #97-07, University of Saskatchewan, Canada.[Online]. Available at: <http://www.ssta.sk.ca/research/instruction/97-07.htm>. Retrieved: 5/01/2011

Gregory, B. (1988). *Inventing reality: Physics as language*. New York, N.Y.: Wiley.

Grow, G. O. (1996). "Serving the Strategic Reader: Reader Response Theory and Its Implications for the Teaching of Writing," an expanded version of a paper presented to the Qualitative Division of the Association for Educators in Journalism and Mass Communication. Atlanta, August, 1994. Available on-line at: <<http://www.longleaf.net/ggrow>>. Original paper available as Eric Documentation Reproduction Service No.ED 406 644.

Gunter, A. M; Estes, T. H. &Schawb, J. (1991). *Instruction.A model approach*. Allyn and Bacon.

Hake, R.R. (1998). Interactive - engagement vs. traditional methods: a six -thousand student survey of mechanics test data for introductory physics courses. *American Journal of physics education research*. 66(1):64-74

Hake, R.R. (2002a).Lesson from physics education reform.*Conservation Ecology* 52:8; online at <[http:// www.consecol.org/vol5/iss2/art28](http://www.consecol.org/vol5/iss2/art28)>. Retrieved: 13/05/2011

Hake, R.R. (2002b). Assessment of student learning in introductory science courses, PKAL Roundtable on the future: Assessment in the service of student learning, Duke University, March 1-3; an updated version of 1 June 2002.

Halloun, I & Hestenes, D. (1985). The initial state of college physics students. *American Journal of Physics*, 53, 1043–1055.

Halloun, I (1996). Schematic modeling for meaningful learning of physics. *Journal of research in science teaching*, 33(9):1009-1041

Hammer, D. (2000). Learner resources for learning introductory physics. *American Journal of Physics*, 68(7), S52–S59.

Harpaz, Y. & Lefstein, A. (2000). Communities of thinking. *Educational Leadership*, 58(3), 54 - 57.

Harrison, A. G. & Treagust, D. F. (1994) Analogies, *The Science Teacher*, 61, 41–43.

Hewson, P. W., & Hewson, M. G. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science*, 13, 1–13.

Hewson, P.W & Thorley, N.R. (1989).The condition of conceptual change in the classroom.*International journal of science education*, 119(Special issues), 541-553.

Hmelo-Silver, C. E. & Barrows, H. S. (2006).Goals and strategies of a problem-based learning facilitator. *Interdisciplinary Journal of Problem- based Learning Misconceptions and Educational strategies in Science and Mathematics*, p84-97-*based Learning*, 1, 21-39.

Hobden, P (2005). What did you do in science today? Two case of Physical studies of 912 Physical Science classrooms. *South African journal of science*, 101,308-302.

Iding, M. K. (1997) How analogies foster learning from science text, *Instructional Science*, 25.

Imenda, S.N. (2005b). Zambian high school students' alternative conceptions and spiritual / cultural beliefs about the environment.*Proceedings of the International Conference on Education, Singapore, 2005*. World Scientific Publishing Company: 328-333.

Imenda, S.N. & Muyangwa, M.M (2006). *Introduction to research in education and behavioral sciences*. Pretoria: Tshwane University of Technology,

Johnstone, A. H. & Mughol, A.R. (1978). The concept of electrical resistance. *Physics Education*, 13(1):47-49, Jan.

Jonassen, D. H. & Rohrer-Murphy, L. (1999). Activity theory as a framework for designing constructivist learning environments. *Educational Technology Research & Development*, 47(1)61-79.

Jones, E. R. & Childers, L. R. (1992) *Contemporary college physics* (2nd edn) (p. 474) (New York).

Joshua, S, (1984). Students' interpretation of simple electrical diagrams. *European journal of science education*, 271-275.

Jung, W, (1994). Towards preparing students for change: a critical discussion of the contribution of the history of physics in physics teaching. *Science and education*, 3(2):99-130

Kabapinar, F. (2004). The design and evaluation of teaching –learning sequence addressing solubility concepts with Turkish secondary school students. *International journal of science education*, 26(5), 635-652.

Kaska, K & Rannikmae M (2006). Estonian teachers' readiness to promote inquiry skills among students. *Journal of science education*. Keynes: Open University Press.

Klassen, S. (2006). Contextual assessment in science education: Background, issues, and policy. *Science education*, 90:820-851.

Koumaras, P., Kariotogou, P & Psillos, D. (1997). Causal structure and counter intuitive experiments in electricity. *International journal of science education*, 9, 617-630.

Kruckenber, R. (2006). A Deweyan perspective on science education: Constructivism, experience and why we learn science. *Science Education*, 15, 1–30.

Kuutti, K. (1991). Activity theory and its applications to information systems research and development. In H.-E Nissen, ed., *Information Systems Research* (pp. 529–549). Amsterdam: Elsevier Science Publishers.

Lawson, A.E. (1993). The importance of analogy: A prelude to the special issue. *Journal of research in science teaching*, 30(10):1213-1214.

Leedy, P.D. &Ormrod, J.E.(2001). Practical research: planning and design. 7th Ed. New Jersey: Prentice - Hall.

Lemmer, M. (1999).First year university students' conceptions of time and space in physics. Potchefstroom: PU for CHE. (Thesis - PhD.).

Lemmer, M. &Lemmer, T.N. (2005).Contextualization as a didactical approach to physics education. (In: Grayson,D.J (Eds). What physics should we teach? Proceedings of the international Physics Education Conference, Durban,5-8 July 2004,p212-218

Lemmer, M., &Lemmer, T.N. (2010).A hypothesis on the learning process as a basis for science curriculum development. In: Constantinou, C.P. &Papadouris, N. (Eds) *Selected papers of the GIREPconference, Nicosia, Cyprus, 18 – 22 August 2008*. pp. 22–38.

Lemmer, M. (2011). Analysis of South African Grade 10 learners' conceptual resources regarding the concept of energy in physics. *African Journal of Research in MST education*, vol 15 (1). pp.4-17.

Leont'ev, A. N. (1981). The problem of activity in psychology. In J. V. Wertsch (Ed.), *Activity in soviet psychology* (pp. 37–71). M. E. New York: Sharpe, Inc.

Liégeois, L. & Mullet, E. (2002). High school students' understanding of resistance in simple series electric circuits. *International journal of science education*, vol 24 no 6, 551-564.

Leonard, W.J, Durfresne, R.J & Mastre, J.P (1996). Using qualitative problem solving strategies to highlight the role of conceptual knowledge in solving problems. *American Journal OF Physics*, 64(12):1495-1503, Dec.

Liu, X; Zhang; B; Liang L; Fulmer G; Kim B & Yuan H.(2009). Alignment between the Physics content standard and the standardized test: A comparison among the United States-New York State, Singapore, and China-Jiangsu. *Science Education*, 93:777-797.

Lord, T. R. (1999). Are we cultivating couch potatoes in our college science lectures?. *Journal for College Science Teachers* 29:159–62.

Mackenzie, N., Eraut, M. & Jones, H. C. (1970). *Teaching and learning: An introduction to new methods and resources in higher education*. Belgium: Unesco.

Maloney, D.P., O’kuma, T.L. & Hieggelke, C.J. (2001). Surveying students’ conceptual knowledge of electricity and magnetism. *American journal of physics*, 69, 512-523.

Marbach, A.D & Solokove, P.G. (2000). Can undergraduate biology students learn to ask higher level questions? *Journal of research in science teaching*, 37, 854-870.

McBride, J & Muhammad, I (2004). Using an inquiry approach to teach science to secondary school science teachers. *Physics education journal*, 39(5)

McDermott, L. C & Shaffer, P.S. (1992). Research as a Guide for Curriculum Development: An Example from Introductory Electricity. Part I: Investigation of Student Understanding. *American journal of physics*, 60: 994-1002.

McDermott, L.C (1991). What we teach and what is learned-closing the gap. *American Journal of Physics*, 59(4):301-315, April.

McLaren, P. G. (1984), *Elementary Electric Power and Machines*, Ellis Horwood.

mechanics test data for introductory physics courses. *American Journal of Physics*, 66:64–74.

Meltzer, D.E.(2002a). The relationship between mathematics preparation and conceptual learning gains in physics: a possible 'hidden variable' in diagnostic pre-test scores). *American journal of physics*, 70(12): 1259-1268.

Meltzer, D.E. (2002b). Normalized gain: A key measure of student learning. Addendum to Meltzer 200a ;<<http://www.physics.iastate.edu/per/articles/index.html>>. Retrieved: 13/03/2011

Meltzer D (1996). Promoting interactivity in Physics lecture classes, *Physics teaching*.34, 72.

Mendenhall, C.E., Eve, A.S., Keys, D.A. & Sutton, R.M. (1956).College Physics.Boston.Heath.

Mestre, J.P. & Cocking, R.R (2002). Applying the science of learning to the education of prospective science teaching. (In: Bybee, R.W. (Ed) Learning science and the science of learning, Arlington : NSTA press micro computer-based laboratories, American journal of physics, 65(1):45-54, Jan.

Millar, R. (1989). What is scientific method and can it be taught? (In Wellington, J. ed. *Skills and processes in science education*. New York: Routledge. p. 47 - 62).

Moore, T.A (1998), *Six ideas that shape physics*. McGraw-Hill.

Morris, S C. (2003), *Life's Solution: Inevitable Humans in a Lonely Universe*, Cambridge University Press, pp. 182–185,

Mwanza, D. (2001b). Changing tools, changing attitudes: effects of introducing a CSCL system to promote learning at work. *Proceedings of the Euro-CSCL 2001: 1st European Conference on Computer-Supported Collaborative Learning* (pp. 470–477), Maastricht, The Netherlands.

Nada, C.A., Iman, O. &Waisim, Z. (2009). Students' alternative conception about electricity and effects on inquiry based teaching strategies. *International journal of science and mathematics education*, 7:103-132.

Nardi, B. A. (1996). *Context and consciousness: activity theory and human-computer interaction*. Cambridge, MA: MIT Press.

Novak, J.D. (2004). Reflections on a half-century of thinking in science education and research: Implications from a twelve - year longitudinal study of children's learning. *Canadian journal of science, mathematics and technology*, 4 (1): 23-41.

Novak, J.D. (2002). Meaningful learning: the essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners, *science education*, 86, 548-571.

Novak, J.D. (1998). The pursuit of a dream: education can be improved. In:Mintzes JJ, Wandersee JH & Novak J, (eds.).1998. *Teaching science for understanding: a human constructivist view*.Chapter 1. San Diego: Academic Press.

Novak, G.M., Patterson, E.T. Gavrin, A.D, & W. Christian. (1999). *Just-In-Time Teaching: Blending Active Learning with Web Technology*. Prentice Hall.

Nussbaum, J. & Norvick, S. (1982). A study of conceptual change in the classroom. Paper presented at the annual meeting of the National Associations for research in Science teaching, Lalle Geneva, and Chicago.

Oliva, J.M (2003). The structural coherence of students' conceptions in mechanics and conceptual change. *International Journal of Science Education*, 25 (5): 539-561.

Olivier, C. (2002). Let's educate, train and learn outcomes-based: a 3D experience in creativity, NQF based. Ifafi: OBET pro. 73 p.

Organisation for Economic Co-Operation and Development (2008). *Reviews of National Policies for Education: South Africa*. OECD, Paris.

Osborne, (1983). Toward modifying children's idea about electric current. *Research in science and technological Education*, 1:73-82

Osborne, R. (1981). Children's ideas about electric current. *New Zealand. Science teacher*, 29:12-19.

Pardhan, H. & Yasmeeen, B. (2001). Science teachers' alternate conceptions about direct conception about direct currents. *International journal of science education*, 23(3): 301-318.

Patterson, W. C. (1999), *Transforming Electricity: The Coming Generation of Change*, Earthscan, pp. 44–48, ISBN 185383341X

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

Perry, W.F (1970). *Forms of intellectual and Ethical Development in the college years*. Holt, Rinehart & Wilson.

Piaget, J. (1950) *The psychology of intelligence* (New York, Harcourt Brace).

Posner, C.J., Strikes, K.A., Hewson, P.W. & Gertzog, W.A., (1982). Accommodation of a scientific conception: Towards a theory of conceptual change, *Science education*, 66(2):211-227.

Ramsden, J. (1994). Context and activity-based science in action. *School science review*. 275(75): 7-14.

Rapule, S.D. (2005). Assessing the impact science centers have on the holistic development of science learners. M.Ed dissertation, North-West University.

Redish, E.F., Saal, J.M. & Steinberg, R.N. (1997). On the effectiveness of active-engagement Microcomputer-based laboratories. *American journal of physics*, 65:45-54

Reif, F (1991). Cognition in scientific and everyday domains: Comparison and learning implications. *Journal of research in science teaching* 28:733-760

ReVelle, C (1992), *The Global Environment: Securing a Sustainable Future*, Jones & Bartlett,

Richland, L. E., Morrison, R. G., & Holyoak, K. J. (2006). Children's development of analogical reasoning: Insights from scene analogy problems. *Journal of Experimental Child Psychology*, 9: 249-273.

Roberts, D. (2000). Strategies for assisting students overcoming their misconception in high school physics. Memorial University of Newfoundland. Education 6390.

Rogan, J.M (2007). How much curriculum change is appropriate? Defining a zone of feasible innovation. *Science Education*, 91:439-460.

Roschelle, J. (1992). Learning by Collaborating: Convergent Conceptual Change. *The Journal of the Learning Sciences*, 3:265-283,

Sanger, M. J. & Greenbowe, T. J. (1999) .An analysis of college of chemistry textbooks as sources of misconception and errors in electrochemistry, *Journal of Chemistry Education*, 76(6), 853–860.

Schwab, J.J. (1962). The teaching of science as inquiry Cambridge, MA: Harvard University Press.).

Scott, P.H., Asoko, H.M. & Driver, R.H. (1992). Teaching conceptual change: A review of strategies (In: R. Duit, T. Gorberg, H.Nieder (Eds): Research in physics learning: Theoretical issues and empirical studies proceedings of an international workshop. (March 1991) <http://www.physics-union-state.edu/~jovem/ICPE/5html>. Accessed: 14/04/2011.

Serway, R. A. (2006). *Serway's College Physics*, Thomson Brooks,

Shipstone, D. (1988). Pupils' understanding of simple electricity circuits: some implication for instruction. *Physics education*, 23:92-96.

Shipstone, D. M. (1984) A study of children's understanding of electricity in simple DC circuits, *European Journal of Science Education*, 6, 185–198.

Shuell, T.J. (1987) Cognitive psychology and conceptual change: Implications for teaching science. *Science education* 5(1): 49-59.

Smit, J.J & Nel, S.J (1997). Perception of models of electrical current held by physical science teachers in South Africa. *South African Journal of Science*, 93(5):202-206, May

Sokoloff, D, (1992).Teaching Electric Circuit Concepts Using Microcomputer-Based Current/Voltage Probes. Proceedings of the NATO Advanced Research Workshop on Microcomputer-Based Laboratories. Amsterdam, November 9-13, 1992

Revised 1/22/93.

Solymar, L. (1984), *Lectures on electromagnetic theory*, Oxford University Press

Soviet psychology (pp. 37–71). M. E. New York: Sharpe, Inc.

Spady, W. & Marshall, K. (1991) Beyond traditional Outcomes-based education. *Educational Leadership*, 49(2): 67-72.

Spady, W. (2008a). It's time to end the decade of confusion about OBE in South Africa. Unpublished article which led to newspaper article.

Sprod,T. (1998). I Can Change Your Opinion on That: Social Constructivist Whole Class Discussions and Their Effect on Scientific Reasoning. *Research in Science Education*. Vol. 28 (4), pp. 463-480,

Stavy, R. (1991). Using analogy to overcome misconceptions about conservation of matter. *Journal of research in science teaching*, 28(4):305-313.

Stavy, R. & Berkvits, B. (1980). Cognitive conflict as a basis for teaching quantitative aspects of the concept of temperature. *Science education* 64:679-692.

Stocklmayers, M & Treagust, D. F (1996). Images of electricity. How do novices and experts model electric current? *International Journal of Science Education*, 18, 163-178.

Taraban, R., Box, C., Myers, R.M., Pollard, R. & Bowen, C.W. (2007). Effects of active learning experiences on achievements, attitudes and behaviours in high school biology. *Journal of research in science teaching*, 44 (7):960-979.

Thagard, P. (1992). *Conceptual revolution*. Princeton: Princeton university press. 285 p.,
P. 1992. *Conceptual revolution*. Princeton: Princeton university press. 285 p.
the concept of force. *Science Education*, 82, 31-51.

Thijs, G.D & Van Der Berg, E. (1995). Cultural factors in the origin and remediation of alternative conceptions in physics. *Science and education*, 4(4):317-347, Oct.

Thomas, J.M. (1991). Michael Faraday and the Royal institute. New York :Wiley.

Trowbridge, L. W., Bybee, R. W. & Powell, J. C. (2004). Teaching secondary school science: strategies for developing scientific literacy. 4th ed. New Jersey: Merrill Prentice Hall. 433 p.

Trowbridge, L. W.; Bybee, R. W. & Powell, J.C. (2000).Teaching Secondary School Science. Strategies for developing scientific literacy. (7th edition).Merrill, An imprint of Prentice Hall. Upper Saddle River. NJ. Columbus, Ohio.USA.

Trumper, R (1990).Being constructive: An alternative approach to the teaching of energy concept. *International journal of science education* 12:343-354

Trumper, R.O. (1991).Being Constructive. An alternative approach to the teaching of energy concept. Part two. *International journal of Science Education*, 13: 1-10.

Uden, L (2007). Activity theory for designing mobile learning. *International Journal of mobile learning and organization*, 1(1):81-102

Umalusi (2009). *From NATED 550 to the new National Curriculum: maintaining standards in 2008. Part 2: Curriculum Evaluation*. Pretoria:

Van der Linde, H.J, Vander Wal, R.E.W & Wilkinson, A (1994). Practical work in science teaching in developing communities. *South African Journal of Education*, 14(1):48-51, Feb.

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

Vosniadou, S. (2007). The cognitive-situative divide and the problem of conceptual change. *Educational Psychologist*, 42(1), 55-66.

Vreken, N. J. (1980). 'n Ondersoek na die huidige praktyk in die onderrig van fisika aan voorgraadse studente. Potchefstroom: PU vir CHO (Thesis -Ph.D.).

Vygotsky, L. (1978). *Mind in society: the development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wald, M (1990). "Growing Use of Electricity Raises Questions on Supply", *New York Times*, <http://query.nytimes.com/gst/fullpage.html?res=9C0CE6DD1F3AF932A15750C0A966958260>, Accessed: 12/06/2011.

Watson (2003). *Understanding Physics and Chemistry*

Ward, R. (1960), *Introduction to Electrical Engineering*, Prentice-Hall, p. 18.

Weld, J. (2002). Learner-centered teaching. (In: Bybee, R.W. (Ed). *Learning science and the science of learning*, Arlington, Virginia: NSTA press.)p 77-83.

Wesi, R.P. (2001). Higher Diploma In *Education for Physical Science teachers*.
Workbook for Subject for didactics. Northwest University.

Wesi, R.P. (1997). Conceptualization of core concepts in electricity by physical science teachers. M.Ed. dissertation, Potchefstroom University for Christian Higher Education.

Western Cape Education Department (2008a). *Physical Sciences -Paper 1*.

Available at <http://wced.wcape.gov.za/documents/2008-exam-> .Accessed :26

February 2010.

Western Cape Education Department (2008b). *Physical Sciences -Paper 2*.

Available at [http://wced.wcape.gov.za/dOSCuments/2008-exam_reports/reports/ physical science/](http://wced.wcape.gov.za/dOSCuments/2008-exam_reports/reports/physical%20science/) Accessed 26 February 2010.

White, R. T. & Gunstone, R. (1992). *Probing understanding*. New York: Falmer. 196 p.

White, R.T. (1988). *Learning Science*. Oxford: Blackwell. 227 p.

White, R.T. (1992). Implications of recent research on learning for curriculum and assessment, *Journal of curriculum studies*, 24,153-164.

Wiggins, G.P. & Mctighe, J. (1998). *Understanding by design*. Alexandria, VA: Association for supervision and curriculum development.

APPENDIX A

TEST ON THE ELECTRIC CIRCUIT CONCEPTUAL EVALUATION

Instructions

This test consists of two sections. In section A, you are required to fill in your personal information and section B, you are required to circle the correct alphabet and you must justify your answer.

SECTION A: Biographical and Background Information

Name :

Name of School :

Province :

Year Completed Grade 12 :

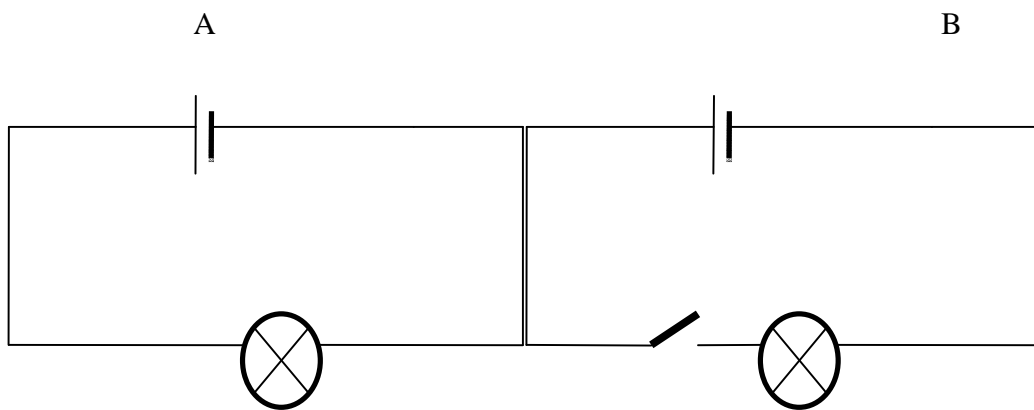
Gender :

NCS/Old Curriculum :

SECTION B

NB: On this test, all batteries are ideal (they have no internal resistance), and connecting wires have no resistance.

Q1 Which bulb will glow in the following scenario? Diagram A or B (1)



Justify your answer (3)

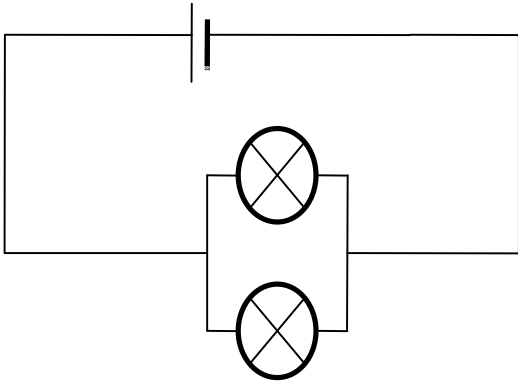
Q2 What happens to the brightness of the bulb as an identical bulb is added in parallel?

Does it (1)

(a) become brighter,

(b) dimmer, or

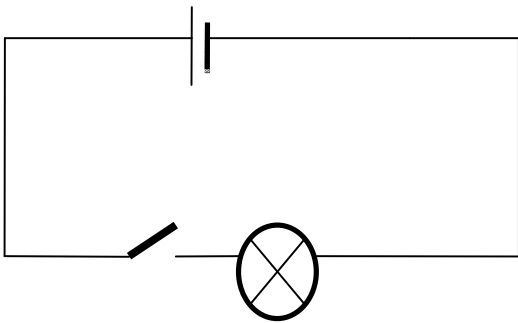
(c) remain the same?



Justify your answer

(3)

Q3 If the switch is open, what happens to the resistance of the bulb (resistor)? (1)



(a) The resistance increases

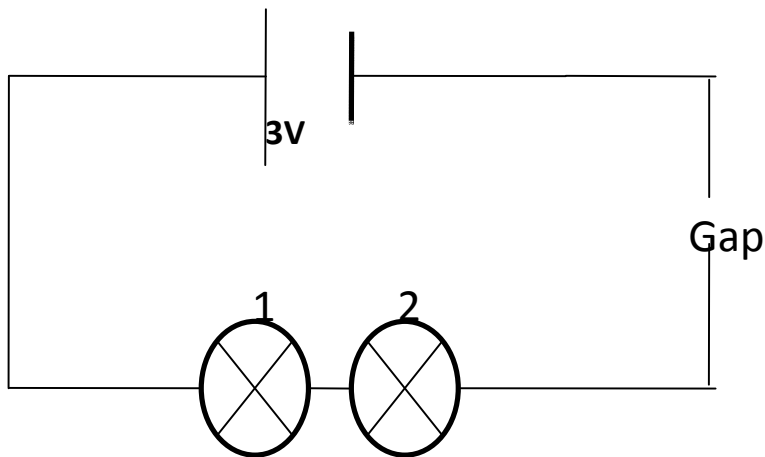
(b) The resistance decreases

- (c) The resistance becomes zero
- (d) The resistance stays the same

Justify your answer

(3)

Q4



Bulbs 1 and 2 are identical. Then:

(1)

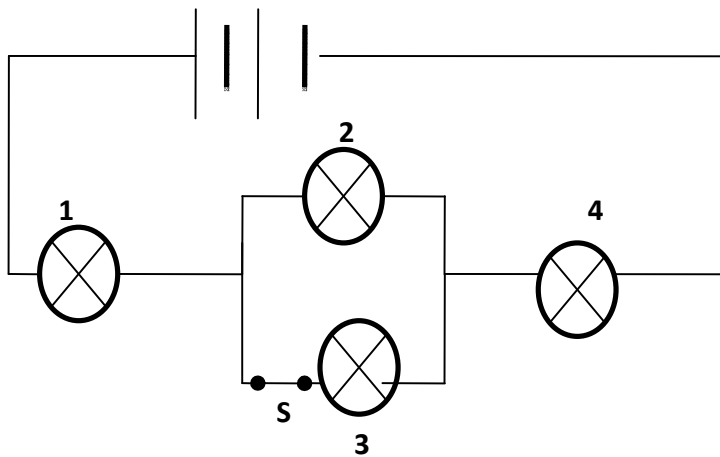
- a) $V_{\text{gap}}=V_1=V_2=1\text{V}$
- b) $V_{\text{gap}}=V_1=V_2=0\text{V}$
- c) $V_{\text{gap}}=V_1=V_2=3\text{V}$
- d) $V_{\text{gap}}=3\text{V}, V_1=V_2=0\text{V}$

Justify your answer

(3)

Q5-12

Refer to the circuit below in which four identical bulbs are connected to a battery. (The switch S, is initially closed as shown in the diagram)



Q5 Which of the following correctly ranks the bulbs in brightness? (1)

- A. All bulbs are equally bright
- B. Bulb 1 is brightest; bulb 2 next brightest, bulb 3 next brightest and bulb 4 dimmest
- C. Bulb 1 is brightest; bulbs 2 and 3 are equally bright, and each is dimmer than bulb 1; bulb 4 is dimmest
- D. Bulbs 1 and 4 are equally bright; bulbs 2 and 3 are equally bright, and each is dimmer than bulb 1 or 4

- E. Bulbs 2 and 3 are equally bright; bulbs 1 and 4 are equally bright, and each is dimmer than bulb 2 or 3
- F. Bulb 1 is brightest, bulb 4 is next brightest; bulbs 2 and 3 are equally bright, and each is dimmer than 4
- G. None of these is correct

Justify your answer

(3)

Q6 Which of the following correctly ranks the current flowing through the bulbs? (1)

- A. All bulbs have the same current flowing through them
- B. The current through bulb 1 is largest, bulb 2 next largest, bulb 3 next largest and bulb 4 smallest.
- C. The current through bulb 1 is largest; bulb 2 is the same as bulb 3, and each is smaller than bulb 1. bulb 4 is smallest.
- D. The current through bulbs 1 and 4 is the same; bulb 2 is the same as bulb 3, and each is smaller than bulb 1 or 4
- E. The current through bulb 2 and bulb 3 is the same; bulb 1 is the same as bulb 4, and each is smaller than bulb 2 or 3.
- F. The current through bulb 1 is largest, bulb 4 is next largest; bulb 2 is the same as bulb 3, and each is smaller than bulb 4.

G. None of these is correct

Justify your answer

(3)

Q7 Which of the following correctly ranks the potential differences across the bulbs? (1)

- A) All bulbs have the same potential difference across them
- B) The potential difference across bulb 1 is largest, bulb 2 next largest, bulb 3 next largest and bulb 4 smallest
- C) The potential difference across bulb 1 is largest. Bulb 2 is the same as bulb 3, and each is smaller than bulb 1. bulb 4 is smallest
- D) The potential difference across bulb 1 is the same as bulb 4; bulb 2 is the same as bulb 3, and each is smaller than bulb 1 and bulb 4.
- E) The potential difference across bulb 2 is the same as bulb 3; bulb 1 is the same as bulb 4, and each is smaller than bulb 2 and bulb 3.
- F) The potential difference across bulb 1 is largest, bulb 4 is next largest; bulb 2 is the same as bulb 3, and each is smaller than 4
- G) None of these is correct.

Justify your answer

(3)

Q8 What happens to the current through bulb 1 if the switch, S, is opened? (1)

- A) It increases
- B) It remains the same
- C) It decreases
- D) Not enough information is given

Justify your answer (3)

Q9 What happens to the current through bulb 2 if the switch, is opened? (1)

- A) It increases
- B) It remains the same
- C) It decreases
- D) Not enough information is given

Justify your answer (3)

Q10 Based on your answers to questions (8) and (9) compare the current through bulb 2 with the switch, S, opened to the current through bulb 1 before the switch was opened (1)

- A) The current through bulb 2 equaled the current through bulb 1 before S was opened.
- B) The current through bulb 2 was more than half the current through bulb 1 before S was opened.
- C) The current through bulb 2 was half the current through bulb 1 before S was opened.
- D) The current through bulb 2 was less than half the current through bulb 1 before S was opened.
- E) Not enough information is given.
- F) None of these is correct.

Justify your answer (3)

Q11 Bulbs 2 and 3 are connected: (1)

- A) In series
- B) In parallel
- C) In series and parallel
- D) Neither in series nor parallel

Justify your answer

(3)

Q12 Bulbs 1 and 3 are connected

(1)

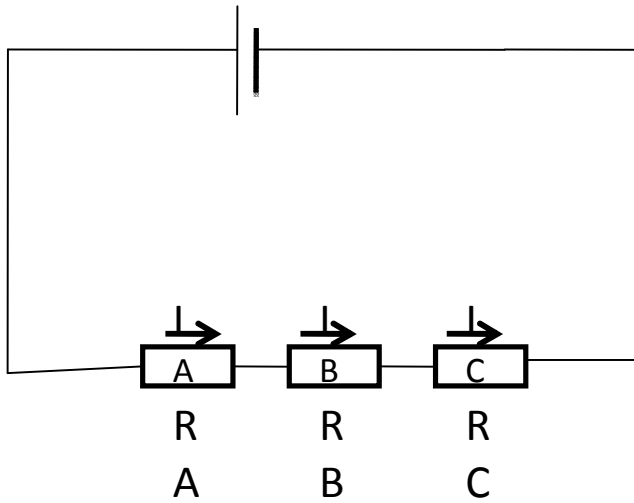
- A) In series
- B) In parallel
- C) In series and parallel
- D) Neither in series nor parallel

Justify your answer

(3)

Questions 13 and 14 refer to the figure below in which three resistors are identical: $R_A = R_B = R_C$.

Q13 What can you say about the current I_A through R_A ? (1)



A = I_B , only

B = I_C , only

C = $I_B = I_C$

D = $I_B + I_C$

E = $I_B - I_C$

F. None of these is correct

Justify your answer

(3)

Q14 What is the relationship between I_B and I_C ?

(1)

A. $I_B = \frac{1}{3} I_C$

B. $I_B = \frac{1}{2} I_C$

C. $I_B = I_C$

D. $I_B = 2 I_C$

E. $I_B = 3 I_C$

F. None of these is correct.

Justify your answer

(3)

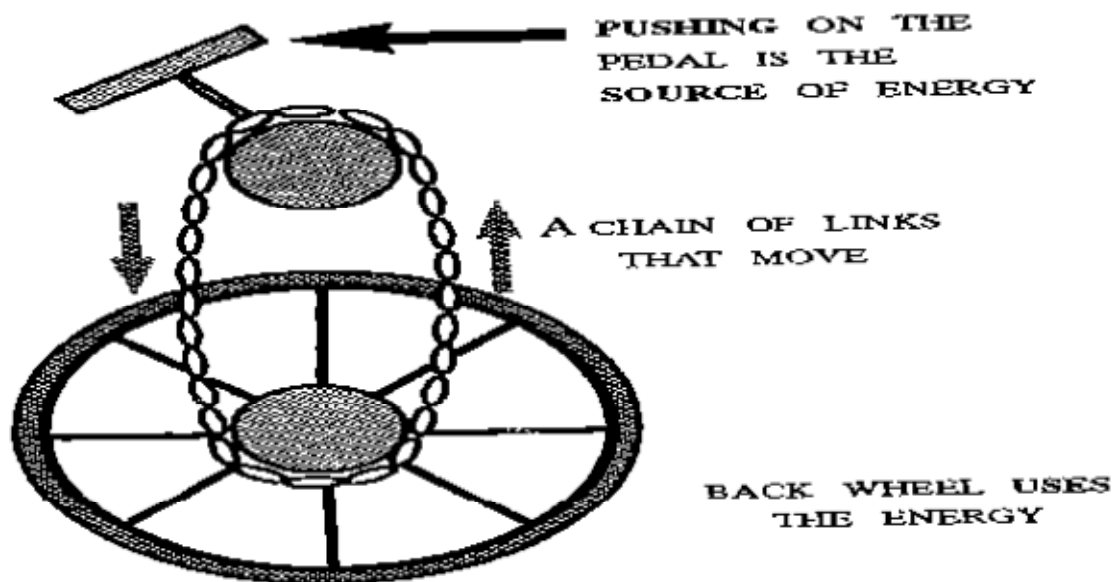
ACTIVITY-BASED INTERVENTION

APPENDIX B

CONTEXTUAL PROBLEM

Bicycle Analogy

Chain links are like electric charges



(Adopted from Watson, 2003)

1. Explain how energy is transferred when a bicycle is pedaled
2. What is the function of the chain?
3. What will happen if the chain breaks?
4. How does this model resemble an electric circuit?

CONCEPTUAL PROBLEM

Experiment 1

Apparatus; 3 cells, connecting wires and a bulb.

Instructions:

1. Connect a bulb to a single cell and observe the brightness of the bulb.
2. Repeat the above step with two and three cells connected in series (make sure you do not overload your circuit).
3. Record your observation on the table below.

Number of Cells	Brightness
One	
Two	
Three	

- 1 How does the number of cells connected in series affect the brightness of the bulb?

- 2 What relationship can be deduced between the number of cells connected in series and the energy delivered to the bulb?

- 3 What will happen to the filament of the bulb if more and more cells are connected in series?

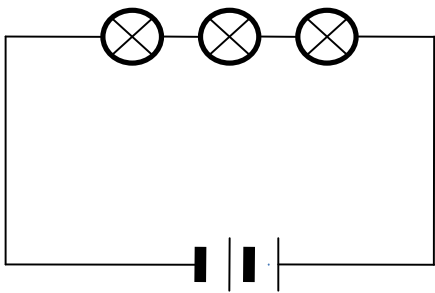
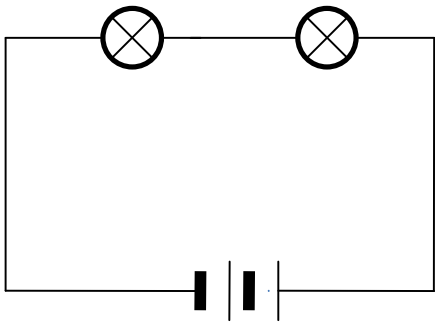
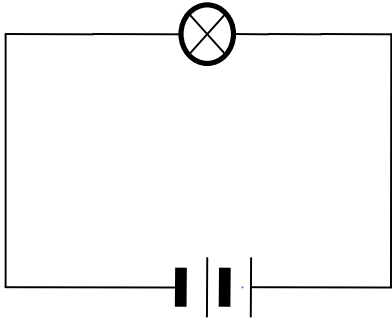
Experiment 2

PART I

Apparatus: two cells; three bulbs and connecting wires

Instructions:

- 1 Connect one bulb to a battery of two cells and observe its brightness
- 2 Repeat the above with two and with three bulbs connected in series



3 Record your observation in the table below

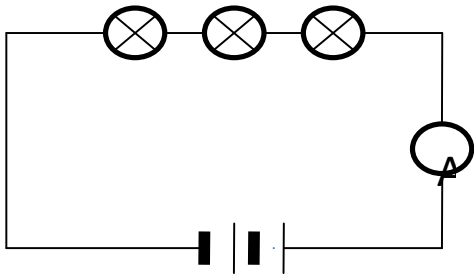
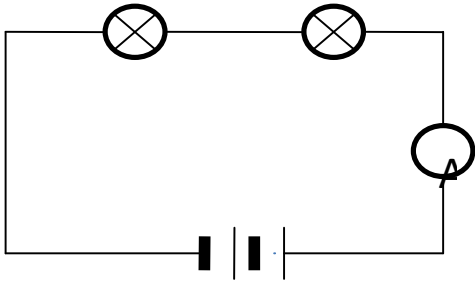
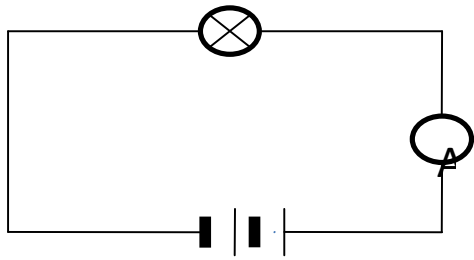
Number of bulbs	Brightness
One	
Two	
Three	

1 How does the brightness of two cells compare in all three cases?

2 Explain why the brightness of the bulbs decreases as more bulbs are connected in series.

PART II

1. Connect one bulb to a battery of two cells , and measure the current using the ammeter
2. Connect a voltmeter across the circuits elements
3. Repeat the above the above step with two and with three bulbs connected in series



Number of bulbs	Current strength	Potential Difference
One		
Two		
Three		

1. What happens to the ammeter reading every time a bulb is added?

2. Give an explanation for your answer.

3. What can you say about potential difference of resistors in series?

4. What can you say about the resistance of the resistors in series?

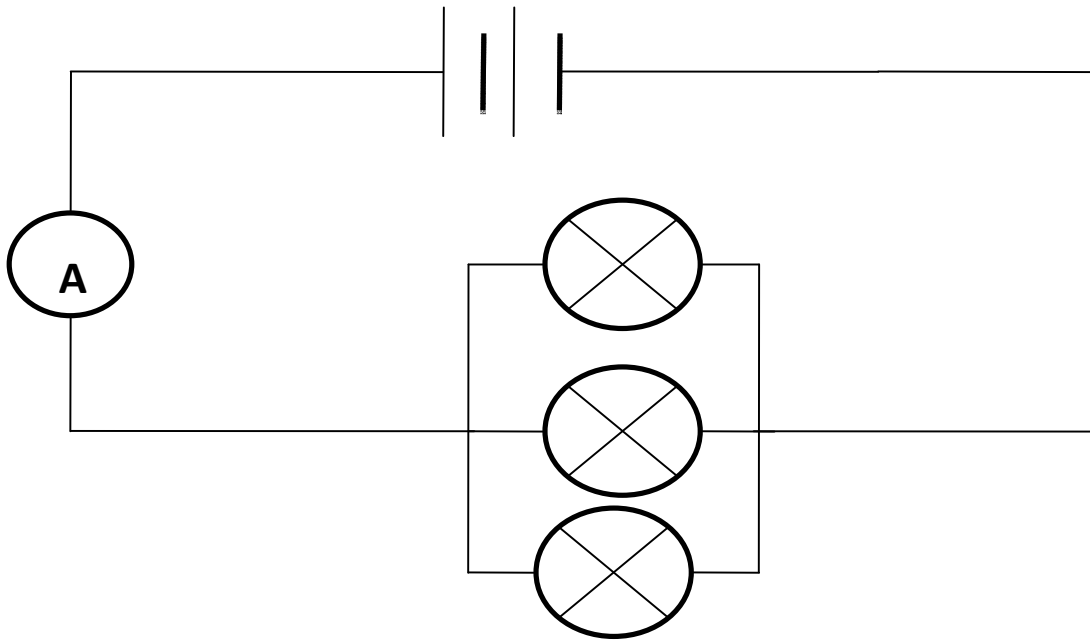
Experiment 3

Apparatus: 3 bulbs, 2 cells, connecting wires and ammeter

Instructions:

1. Connect a battery of two cells to three bulbs in series, and observe the brightness of the bulbs.

2. Use an ammeter to measure the current in the circuit.
3. Disconnect the circuit and connect the three bulbs in parallel to a battery of two cells. Observe the brightness of the bulbs.
4. Use an ammeter to measure the current in the circuit.



	Brightness	Current
Series circuit		
Parallel Circuit		

1. How does the current strength in a series connection (bulbs) compare to that in parallel connection?

2. Give reason for your answer.

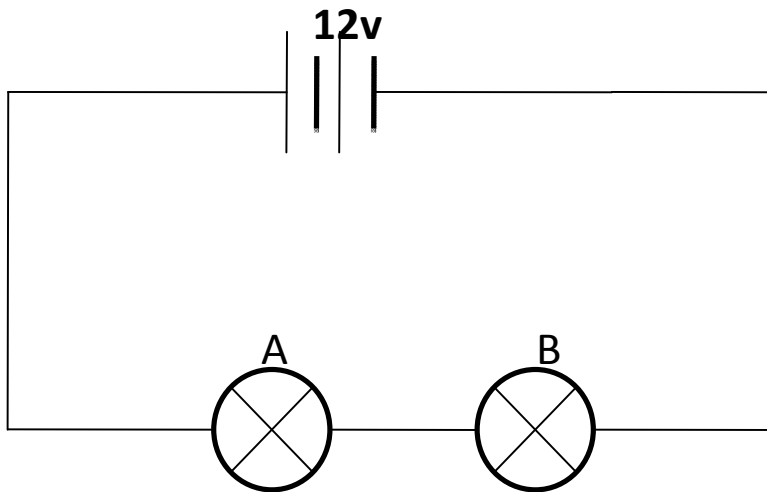
3. When light bulbs are connected in parallel such that the current branches will equal current flow through the bulb?

4. What can you say about the potential difference of the resistors in parallel?

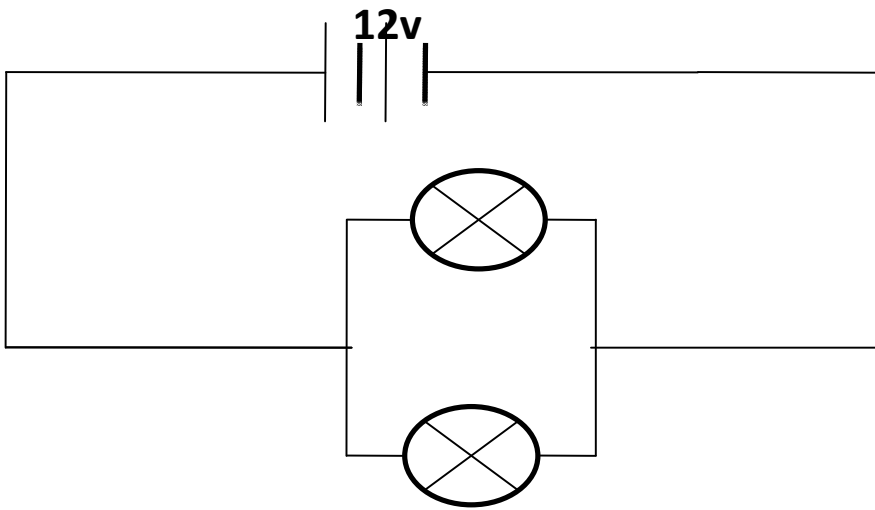
5. What can you conclude about the resistance of resistors connected in parallel?

FORMAL PROBLEM

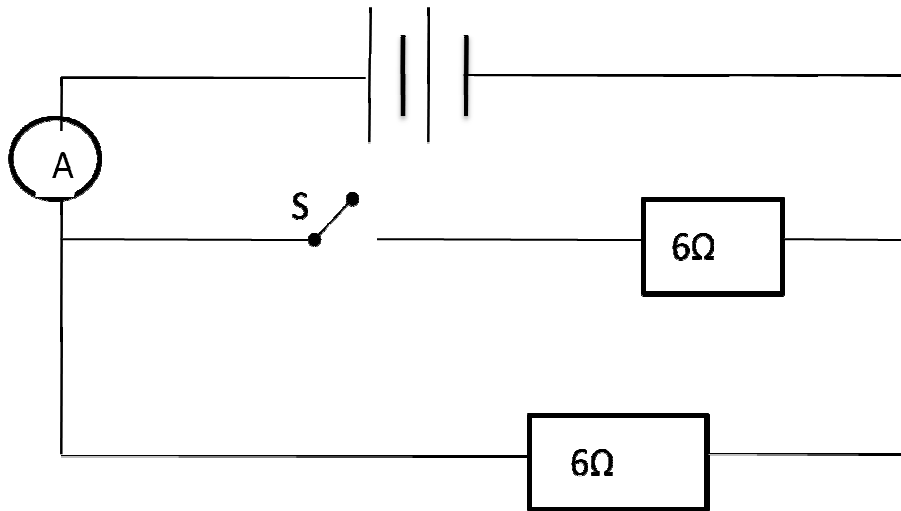
1) Bulb A glows brighter than B when both are connected to a 12v source as indicated in the diagram below.



The same bulbs now are connected to the same 12 V source as indicated in diagram Y. By referring to potential difference, currents, explain how the brightness of the two bulbs now compare.



2) In the circuit below, the ammeter reads 2A when the switch S is open and 3A when it is closed. Each resistance has a value of 6Ω

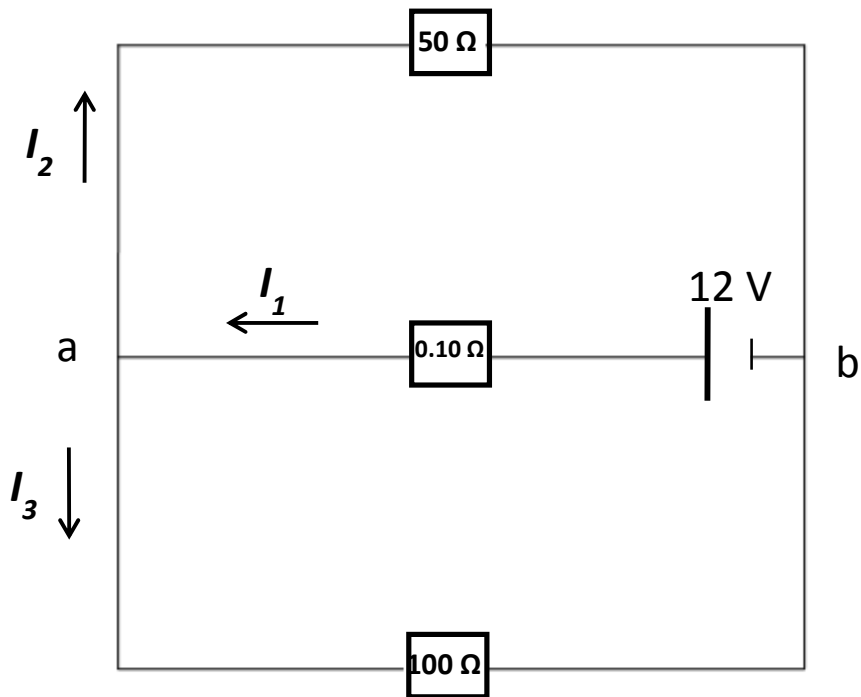


Calculate

- i) the internal resistance(r) of the battery.

ii) the emf of the battery.

3) Consider the circuit below. Here a battery with emf of 12 V has an internal resistance of 0.10Ω . If the two light bulbs whose resistances when hot are 50Ω and 100Ω , respectively, as shown in the figure, what are the currents in the three branches of the circuit?



APPENDIX C

Formal Problem 2

The historical development of emf, potential difference and internal resistance was used to ameliorate the students' alternative conceptions in this formal problem by discussing them as below.

Emf and potential difference

Cells supply energy to charges that move through it in an electric circuit. The amount of energy that a cell can supply to one coulomb of charge passing through it (from the negative terminal to the positive terminal) is called the emf of the battery. Emf is measured in volts just like potential difference. Potential difference is however associated with the energy drop experienced by each coulomb of charge when passing through a component in a circuit, while emf is associated with the total energy gained by each coulomb of charge passing through the cell (Cutnell&Johnson,1998).

Historically it was believed that a certain kind of force is responsible for pushing charge through the cell or battery. This force was referred to as the electromotive force (emf). It was later found that the concept of the electromotive force is not descriptive of the actual situation and was discarded. However the used of the term emf was retained, and is used to refer to the total amount of energy supplied to one coulomb of charge passing through the cell. Potential difference refers to the energy one coulomb of charge, when passing through a current element (appliance) can transfer to that element. The concept of emf

and potential difference are defined to enable a quantitative description of energy transfer in a circuit.

Internal resistance

Batteries or cells also offer resistance to the flow of current through them. When a cell supplies current, charges flow in the whole circuit simultaneously, i.e. also in the cell itself. It is therefore logical that the charge carriers will also experience resistance inside the cell due to collision. This resistance is called internal resistance of the cell. Energy is therefore also used in the cell to move the charge in the cell. Not all the energy of a cell is therefore available for conversion in the external circuit.

To ameliorate students' alternative conceptions on this problem you need to remind students that the emf and internal resistance are always constant and you need to put r as a separate resistor in series with the battery.

i) For open switch

$$\text{Emf} = I(r + R)$$

$$\text{Emf} = 2(r + 6)$$

$$= 2r + 12 \dots\dots\dots (1)$$

For close switch

Current is increasing because of low resistance. The two resistors are in parallel

$$\frac{1}{R} \text{ Parallel} = \frac{1}{R1} + \frac{1}{R2}$$

$$= \frac{1}{6} + \frac{1}{6}$$

$$= \frac{2+2}{12}$$

$$= \frac{4}{12}$$

$$= \frac{12}{4} \text{reciprocal inverse}$$

$$= 3\Omega$$

$$\text{Emf} = I(R + r)$$

$$= 3(3 + r)$$

$$= 3r + 9 \dots\dots\dots (2)$$

Equate the two equations

$$2r + 12 = 3r + 9$$

$$r = 3\Omega$$

The internal resistance of the battery (r) = 3Ω

ii) The emf of the battery

$$\text{Emf} = I(r + R)$$

$$= 2r + 12$$

$$= 2(3) + 12$$

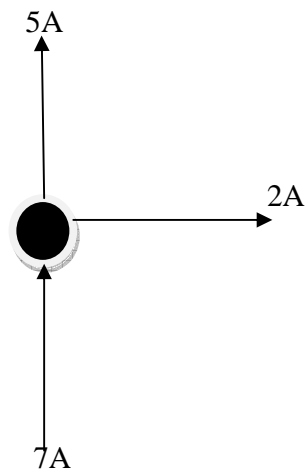
$$= 18\text{V}$$

Formal problem 3

To arouse students interest the lecturer introduced the history of Gustav Robert Kirchhoff (1824-1887) whose first contribution to physics was the analysis of electrical networks while he was still a university student at the age of 21. Kirchhoff was confined to wheel chair or crutches for many years as a result of an accident. One day his banker, unimpressed by Kirchhoff's ability to locate elements in the sun with spectroscope, asked him, "Of what use is gold in the sun if I cannot bring it down to the earth?" Some years later when Great Britain presented Kirchhoff with a gold sovereign for his research, Kirchhoff handed it over to the same banker, with the sly remark "Here is your gold from the sun". This was done to introduce philosophical element into physics teaching.

The first step is to draw the current, which we have chosen to be clockwise around the circuit. This is arbitrary, and if it is incorrect, I will turn negative

The junction is a point in a circuit where a number of wires are connected.



To help students on the difficulty of applying the junction rule the above example was given. In other words the junction rule states that the total current directed into a junction must equal the total current out of the junction, or $7A = 5A + 2A$.

Now we apply the junction rule at point a

I_1 moves into the junction and $I_2 + I_3$ moves out of the junction in other words :

$I_1 = I_2 + I_3$ from the junction rule.

The difficulty on applying the loop rule was corrected by following the steps

- To apply the loop rule first step is to draw the current, which we have chosen to be clockwise around the circuit. This is arbitrary, and if it is incorrect, I will turn negative.
- The second step is to mark the resistors with plus and minus signs, which serve as an aid in identifying the potential drops and rises for Kirchoff's loop rule. Remember that, outside a battery, conventional current is always directed from a higher potential (+) toward a lower potential (-). Thus, we must mark the resistors to be consistent with the clockwise direction chosen for the current. The loop rule states that around any closed circuit loop; the sum of the potential drops equals the sum of the potential rises.
- The other thing which is important is that a potential drop is from positive to negative (+ to -), and potential rise is from negative to positive (- to +).
- Potential drop is equal to potential rises

From the loop rule, on going around the loops in a clockwise direction. Let us consider the upper loop. The other thing which is important is that a potential drop is from positive to negative (+ to -), and potential rise is from negative to positive (- to +).

For the upper loop:

In a clockwise direction

(0.10Ω) potential drop (+ to -) of $IR = (0.10\Omega)I_1$

(50Ω) potential drop (+ to -) $=50\Omega I_2$

$(12V)$ potential rise (- to +) of $12V$ across the $12V$ battery

Potential rise = potential drop

$$12v = (0.10\Omega)I_1 + (50\Omega)I_2$$

$$12V - (0.10\Omega)I_1 - (50\Omega)I_2 = 0 \quad \text{equation 1}$$

For the lower loop:

0.10Ω potential rise of $IR = (0.10\Omega)I_1$ Remember that, outside a battery, conventional current is always directed from a higher potential (+) toward a lower potential (-).

100Ω potential rise of $IR = (100\Omega)I_3$

$12V$ potential drops $12V$ across the $12V$ battery

Potential rise = potential drop

$$(0.10\Omega)I_1 + (100\Omega)I_3 = 12V$$

$$-12V + (0.10\Omega)I_1 + (100\Omega)I_3 = 0 \quad \text{equation 2}$$

On adding these two equations, we obtain

$$100 I_3 = 50I_2 \text{ or } I_2 = 2I_3$$

$$\text{Hence } I_1 = I_2 + I_3 = 2I_3 + I_3 = 3I_3$$

On substituting this in our second loop equation we have $-12V + (0.10\Omega)I_1 + (50\Omega)I_3 = 0$

$$I_3 = 12V / 100.3\Omega = 0.12 A$$

Hence $I_2 = 2I_3 = 2(0.12\text{A}) = 0.24\text{ A}$

$I_1 = 3I_3 = 3(0.12\text{A}) = 0.36\text{ A}$

APPENDIX D

Information & Consent Form

Date:

Title of Project: The effect of activity-based instructional approaches in ameliorating students' alternative conceptions about electricity

Supervisor: Prof. SN Imenda

Researcher: Mr MP Rankhumise

Study Overview

I am a Doctoral student in the Department of Mathematics, Science and Technology Education at the University of Zululand conducting research under the supervision of Prof. SN Imenda. You are invited to participate in a study investigating the effect of activity-based instructional approaches in ameliorating students' alternative conceptions about electric circuits.

What You Will Be Asked to Do

As a participant in this study, you will be asked to participate fully in the study, by first completing a questionnaire and take part in three activity-based lessons and after the lessons then you will complete a questionnaire.

Personal Benefits of the Study

The study forms part of your syllabus.

Confidentiality

All information you provide is considered completely confidential; indeed, your name will not be included or in any other way associated, with the data collected in the study. Furthermore, because the interest of this study is in the average responses of the entire group of participants, you will not be identified individually in any way in any written reports of this research.

Thank you for your interest in our research and for your assistance with this project.

Consent of Participant

I have read the information presented in the information letter about a study being conducted by Mr Rankhumise M.P under the supervision of Prof. S.N.Imenda, Faculty of Education at the University of Zululand. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional

details I wanted. I am aware that I may withdraw from the study at any time by advising the researcher of this decision.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

Print Name

Signature of Participant

Date

Witness