

THE USE OF PRACTICAL ACTIVITIES TO ADDRESS GRADE 11 LEARNERS'  
CONCEPTUAL DIFFICULTIES IN ELECTRICITY AND MAGNETISM

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## **Declaration**

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Date: 25 November 2013

## **ABSTRACT**

This research study investigated the use of a practical activities-based approach to Physical Sciences teaching using TRAC equipment to address learner conceptual difficulties in Electricity and Magnetism (E&M). TRAC uses practical activities based on the school curriculum to complement the theory through the utilisation of data logging equipment linked to a computer. The participants in this study were a group of black Grade 11 learners (n=47) from a township school in the province of the Western Cape, South Africa. Their ages range from 16 to 21, with isiXhosa the home language of most of them.

A mixed methods approach was utilized to gather the research data. Quantitative data was collected, using pre- and post-testing of learners to determine their conceptual difficulties in E&M, as well as to measure the effect of the practical activities-based approach in addressing learner conceptual difficulties in E&M. Null hypotheses were formulated for the six concepts and t-tests were used to find any statistically significant difference between the pre- and post-test. Qualitative data was obtained from the learner transcripts, as well as from the questionnaires and observation schedules. The results indicated significant improvements in learner understanding of the concepts in five out of the six tests as well as reducing commonly held misconceptions in E&M. It is recommended that careful scaffolding should be done during a practical activity in order for learners to make the connection between the domains of observables and ideas. .

## OPSOMMING

Hierdie navorsingstudie het die gebruik van 'n praktiese aktiwiteitsgebaseerde benadering tot Fisiese Wetenskappe onderrig met behulp van TRAC apparaat ondersoek. Die doel was om leerders se konseptuele haakplekke in Elektrisiteit en Magnitisme (E&M) aan te spreek. TRAC maak gebruik van 'data logging' apparaat om die teorie deur middel van praktiese aktiwiteite wat op die skoolkurriulum gebaseer is, te komplementeer. Die deelnemers in die studie was 'n groep swart Graad-11 leerders (n=47) uit 'n swart woongebied in die Westelike Provinsie, Suid Afrika. Hulle ouderdomme strek van 16 tot 21 met isiXhosa as die huistaal vir die meerderheid van hulle.

'n Gemengde metode benadering was gebruik om die navorsingsdata te versamel. Kwantitatiewe data was deur 'n voor- en natoets van die leerders versamel om hulle konseptuele haakplekke in E&M te bepaal. Die effek van die praktiese aktiwiteitsgebaseerde benadering om die leerders se konseptuele haakplekke in E&M aan te spreek was ook gemeet. Nul hipotese was vir die ses konsepte geformuleer en t-toetse was gebruik om statisties-beduidende verskille tussen die voor- en natoets te bepaal. Kwalitatiewe data was van die leerders se oorgeskryfde onderhoude sowel as vraelyste en observasieskedules verkry. Die resultate toon 'n beduidende verbetering in leerders se begrip van die konsepte in vyf van die ses toetse sowel as 'n afname in algemene wanbegrippe in E&M. Dit word aanbeveel dat versigtige opbouing gedurende die praktiese aktiwiteit gedoen moet word sodat die leerders 'n verband tussen die domein van waarneembare en idees kan maak.

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**CONTENTS**

chapter 1: Introduction .....	1
1.1.    INTRODUCTION .....	1
1.2.    BACKGROUND OF THE PROBLEM .....	1
1.3.    PROBLEM STATEMENT .....	6
1.4.    PURPOSE OF THE STUDY .....	8
1.5.    SIGNIFICANCE OF THE STUDY .....	9
1.6.    PRIMARY RESEARCH QUESTIONS .....	10
1.7.    HYPOTHESIS .....	11
1.8.    RESEARCH DESIGN .....	11
1.9.    ASSUMPTIONS, LIMITATIONS AND SCOPE .....	13
1.10.   DEFINITION OF TERMS .....	14
1.11.   ACRONYMS .....	14
Chapter 2: Literature Review .....	16
2.1.    INTRODUCTION .....	16
2.2.    PHYSICAL SCIENCE EDUCATION IN SOUTH AFRICA .....	16
2.2.1. <i>Physical Science Performance Internationally And Locally</i> .....	16
2.2.2. <i>Suggested Remedies To Sa Learners' Poor Science Performance</i> .....	18
2.3.    ACTUAL LEARNER DIFFICULTIES IN SCIENCE .....	20
2.3.1. <i>Abstractness And Cognitive Demand Of Physical Science</i> .....	21
2.3.2. <i>Confusion Of Terms</i> .....	21
2.3.3. <i>Scientific Literacy</i> .....	22
2.3.4. <i>Issues Of Language</i> .....	23
2.3.5. <i>Content, Available Time And Textbooks</i> .....	24
2.3.6. <i>Mathematical Skills</i> .....	25
2.3.7. <i>The Teaching Approach</i> .....	25
2.3.8. <i>Cutting Back On Hands-On Approaches</i> .....	26
2.4.    SUGGESTED REMEDIES .....	26
2.4.1. <i>Language, Experience, Modelling And Analogies</i> .....	26
2.4.2. <i>Packaging And Delivery Of Content</i> .....	29
2.4.3. <i>Hands-On Science</i> .....	29
2.4.4. <i>Information Technology And Computer Simulations In Science</i> .....	30
2.4.5. <i>Micro-Chemistry Kits</i> .....	32
2.5.    CONCEPTUAL DIFFICULTIES AND MISCONCEPTIONS IN CURRENT ELECTRICITY AND MAGNETISM. ....	33
2.5.1. <i>Introduction</i> .....	33
2.5.2. <i>Misconceptions</i> .....	33
2.5.3. <i>The Role Of Teachers</i> .....	35
2.5.4. <i>Confusion Of Terms: Current, Potential Difference, Power, Resistance</i> .....	36
2.5.5. <i>Inadequate Understanding Of Electric Current</i> .....	37
2.5.6. <i>Failure To Distinguish Between Potential Difference And Current</i> .....	37

2.5.7.	<i>Inadequate Understanding Of Resistance</i> .....	38
2.5.8.	<i>Interpretation Of Circuit Diagrammatic Representations</i> .....	39
2.5.9.	<i>Inability To Reason Qualitatively About Electric Circuits</i> .....	39
2.6.	STRATEGIES TO REMEDY THE DIFFICULTIES.....	40
2.6.1.	<i>Physics By Inquiry</i> .....	40
2.6.2.	<i>Tutorials</i> .....	40
2.6.3.	<i>Concept Substitution</i> .....	41
2.7.	ELECTROMAGNETISM DIFFICULTIES AND MISCONCEPTIONS.....	42
2.7.1.	<i>Introduction</i> .....	42
2.7.2.	<i>Reliance On Other Domains And Issues Of Language</i> .....	43
2.7.3.	<i>Abstractness Of Terms And Mathematical Skills</i> .....	43
2.7.4.	<i>Fuzzy Encoding</i> .....	45
2.8.	REMEDIES.....	45
2.8.1.	<i>Restructuring Of E&amp;M Courses</i> .....	45
2.8.2.	<i>Tutorials</i> .....	46
2.8.3.	<i>Concept Maps</i> .....	46
2.8.4.	<i>Peer Instruction</i> .....	47
2.8.5.	<i>Teal Project</i> .....	48
2.9.	THE USE OF PRACTICAL ACTIVITIES IN SCIENCE.....	49
2.9.1.	<i>Introduction And Definition Of Terms</i> .....	49
2.9.2.	<i>Practical Work And Science Curriculum</i> .....	50
2.9.3.	<i>Scientific Inquiry Vs. Practical Activities</i> .....	51
2.9.4.	<i>Practical Work And Scientific Knowledge</i> .....	53
2.9.5.	<i>Effectiveness Of Practical Work</i> .....	56
2.9.6.	<i>Advantages Of Practical Work</i> .....	61
2.9.7.	<i>Criticism And Limitations Of Practical Work</i> .....	62
2.10.	THE TRAC APPROACH – INCLUSION OF COMPUTERS IN PRACTICAL ACTIVITIES.....	64
2.11.	SUMMARY AND CONCLUSION.....	67
Chapter 3: Research Design And Methodology.....		69
3.1.	INTRODUCTION.....	69
3.2.	RESEARCH DESIGN.....	70
3.2.1.	<i>Mixed-Methods And Mixed-Model</i> .....	70
3.2.2.	<i>Mixed Methods Research Process</i> .....	75
3.2.3.	<i>Rationale For Mixed Methods In This Study</i> .....	77
3.3.	RESEARCH INSTRUMENTS (DATA COLLECTION TOOLS).....	77
3.3.1.	<i>Pre And Post-Tests</i> .....	78
3.3.2.	<i>Questionnaires</i> .....	79
3.3.3.	<i>Observations</i> .....	82
3.3.4.	<i>Validation Of The Research Instruments</i> .....	83
3.4.	DATA.....	84
3.4.1.	<i>The Research Sample</i> .....	84

3.4.2. Data Collection.....	86
3.5. DATA ANALYSIS.....	87
3.5.1. Data Analysis Stages Utilized.....	87
3.5.1.1. Data Reduction.....	88
3.5.1.2. Data Display.....	88
3.5.1.3. Data Transformation.....	89
3.5.1.4. Data Integrations.....	90
3.5.2. Interpretation Of Data.....	90
3.5.2.1. Quantitative Data Interpretation.....	90
3.5.2.2. Qualitative Data Interpretation.....	93
3.5.3. Legitimation (Validity) Of The Data.....	94
3.5.3.1. Mixed Research Legitimation Types.....	95
3.5.3.2. Qualitative Validity.....	96
3.6. LIMITATIONS AND POTENTIAL PROBLEMS.....	98
3.7. ETHICAL CONSIDERATIONS.....	100
3.8. CONCLUSION.....	101
Chapter 4: Data Collection And Analysis.....	102
4.1. INTRODUCTION.....	102
4.2. SUMMARY OF FINDINGS.....	102
4.2.1. Summary Of All The Test Results.....	102
4.2.2. Analysis Of Learners Test Scores.....	103
4.3. BASICS OF CURRENT ELECTRICITY.....	104
4.3.1. Pre And Post-Test 1 Scores.....	104
4.3.2. Learner Difficulties Detected From The Pre-Test 1.....	106
4.3.3. Practical Activities Based Intervention 1.....	108
4.3.4. Post-Test 1 Analysis.....	109
4.3.5. Sub-Conclusion Based On Pre And Post-Test 1.....	110
4.4. RESISTANCE AND OHM'S LAW.....	112
4.4.1. Pre And Post-Test 2 Results.....	112
4.4.2. Learner Difficulties Detected From The Pre-Test 2.....	113
4.4.3. Practical Activities Based Intervention: Ohm's Law.....	114
4.4.4. Post-Test 2 Analysis.....	115
4.4.5. Sub-Conclusions.....	116
4.5. EMF AND INTERNAL RESISTANCE.....	117
4.5.1. Pre And Post-Test 3 Results.....	117
4.5.2. Learner Difficulties Detected From The Pre-Test 3.....	118
4.5.3. Learner Difficulties Detected From The Pre-Test 3.....	119
4.5.4. Practical Activities Based Intervention: Emf And Internal Resistance.....	120
4.5.5. Post-Test 3 Analysis.....	121
4.5.6. Sub-Conclusions.....	122
4.6. SERIES AND PARALLEL CIRCUITS.....	122
4.6.1. Pre And Post-Test 4 Results.....	123

4.6.2. Learner Difficulties Detected From The Pre-Test 4 .....	124
4.6.3. Practical Activities Based Intervention: Series And Parallel Circuits .....	125
4.6.4. Post-Test Analysis .....	127
4.6.5. Sub-Conclusions .....	128
4.7. MAGNETIC FIELD ASSOCIATED WITH CURRENT .....	129
4.7.1. Pre And Post-Test 5 Results.....	129
4.7.2. Learner Difficulties Detected In Pre-Test 5.....	130
4.7.3. Practical Activities Based Intervention: Magnetic Field Associated With Current .....	131
4.7.4. Post-Test 5 Analysis .....	132
4.7.5. Sub-Conclusions .....	132
4.8. CURRENT ASSOCIATED WITH MAGNETIC FIELD .....	133
4.8.1. Pre And Post-Test 6 Results.....	134
4.8.2. Learner Difficulties As Detected In The Pre-Test 6 .....	135
4.8.3. Practical Activities Based Intervention: Magnetic Field Associated With Current .....	135
4.8.4. Post-Test 6 Analysis .....	137
4.8.5. Sub-Conclusions .....	137
4.9. LEARNER MISCONCEPTIONS AND PRACTICAL WORK .....	138
4.10. HOW THE PRACTICAL ACTIVITIES-BASED APPROACH ENHANCES LEARNING .....	141
4.11. SUMMARY .....	142
4.12. CONCLUSION .....	143
Chapter 5: Conclusion .....	144
5.1. INTRODUCTION .....	144
5.2. SUMMARY OF FINDINGS.....	145
5.2. DISCUSSION OF FINDINGS .....	146
5.2.1. <i>Researcher's Reflection &amp; Relationship With Previous Studies</i> .....	146
5.2.2. <i>Explanations Of Unanticipated Findings</i> .....	146
5.3. RECOMMENDATIONS ON THE USE OF PRACTICAL WORK – FROM LITERATURE AND THIS STUDY ....	147
5.4. LIMITATIONS OF THIS RESEARCH STUDY .....	149
5.5. CONTRIBUTIONS OF THIS RESEARCH .....	150
5.6. QUESTIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH .....	150
5.7. FINAL CONCLUSION .....	152
Appendix A: Test 1 Scores .....	162
Appendix B: Test 2 Scores .....	163
Appendix C: Test 3 Scores .....	164
Appendix D: Test 4 Scores .....	165
Appendix E: Test 5 Scores .....	166
Appendix F: Test 6 Scores .....	167
Appendix G: Test Scores 1 – 6 Participants In All.....	168

Appendix H: Pre- And Post-Test 1 .....	164
Appendix I: Pre- And Post-Test 2 .....	169
Appendix J: Pre- And Post-Test 3 .....	177
Appendix K: Pre- And Post-Test 4.....	181
Appendix L: Pre- And Post-Test 5.....	189
Appendix M: Pre- Post-Test 6 .....	195
Appendix N: Activity 1 - Basic Of Current Electricity .....	201
Appendix O: Activity 2: Ohm's Law (Em1).....	203
Appendix P: Activity 3 - Series And Parallel Connections Practical.....	216
Appendix P: Activity 4 – Series And Parallel Circuits (Em2) .....	218
Appendix Q: Activity 5: Resistance.....	231
Appendix R: Activity 6 – Em3 .....	232
Appendix S: Activity 7 – Em5 .....	242
Appendix T: Pre- And Post-Intervention Questionnaires.....	255
Appendix U: Observation Schedules.....	268
Appendix V: Letter Of Permission – Doe.....	271
Appendix W: Letter Of Permission By Parents : English Version .....	272
Appendix X: Letter Of Permission By Parents (Isixhosa Version).....	273
Appendix Z: Minor Consent .....	277

## LIST OF FIGURES

FIG 3.1. MIXED MODEL DESIGNS (AND MONOMETHODS).....	71
FIG 3.2. MIXED-METHODS DESIGN MATRIX WITH MIXED METHOD RESEARCH DESIGNS SHOWN IN FOUR CELLS (JOHNSON & ONWUEGBUZIE, 2004:22).....	72
FIG 4.1: PRE AND POST-TEST AVERAGES - ALL TESTS .....	103
FIG 4.2: PRE- AND POST-TEST 1 SCORES – BASICS OF CURRENT ELECTRICITY.....	105
FIG 4.3: PRACTICAL ACTIVITY 1 BASIC CIRCUIT .....	109
FIG 4.4: PRE AND POST TEST 2 SCORES – OHM’S LAW.....	112
FIG 4.5: OHM’S LAW EXPERIMENT SET-UP .....	114
FIG 4.6: FIG 4.6: PRE AND POST TEST 3 SCORES – EMF AND INTERNAL RESISTANCE .....	117
FIG 4.7: EXPERIMENTAL SET-UP – EMF AND INTERNAL RESISTANCE .....	121
FIG 4.8: PRE AND POST TEST 4 SCORES – SERIES AND PARALLEL CIRCUITS .....	123
FIG 4.9: PRE AND POST TEST 5 SCORES – MAGNETIC FIELD ASSOCIATED WITH CURRENT.....	129
FIG 4.10: EXPERIMENTAL SET-UP – MAGNETIC FIELD ASSOCIATED WITH CURRENT .....	132
FIG 4.11: PRE AND POST TEST 6 SCORES – CURRENT ASSOCIATED WITH MAGNETIC FIELD.....	134
FIG 4.12: EXPERIMENTAL SET-UP – ELECTROMAGNETIC INDUCTION.....	136
FIG 4.13: MUTUAL INDUCTION SET-UP.....	137

## LIST OF TABLES

TABLE 1.1: PHYSICAL SCIENCE PASS RATE FROM 2008 - 2011.....	2
TABLE 1.2: PERCENTAGE OF LEARNERS WHO ACHIEVED 40% AND ABOVE.....	3
TABLE 2.1: ABRAHAMS AND MILLAR'S (2008:1949) ANALYTICAL FRAMEWORK OF THE EFFECTIVENESS OF A PRACTICAL TASK.....	60
TABLE 3.1: PERFORMANCE LEVELS INDICATOR.....	88
TABLE 3.2: T-TEST FOR EXAMPLE: PRE- AND POST-TEST 1.....	91
TABLE 3.3: NULL HYPOTHESIS ANALYSIS .....	91
TABLE 3.4: PEARSON'S CORRELATION INTERPRETATION .....	93
TABLE 3.5: AN EXAMPLE OF QUANTITIZED QUALITATIVE DATA .....	94
TABLE 3.6: PARTICIPANTS ATTENDANCE.....	99
TABLE 4.1: PERFORMANCE LEVELS INDICATORS .....	104
TABLE 4.2: OHM'S LAW DATA .....	115
TABLE 4.3: SERIES CIRCUIT TYPICAL DATA TABLE .....	126
TABLE 4.4: PARALLEL CIRCUIT TYPICAL DATA TABLE .....	127
TABLE 4.5: TYPICAL DATA TABLE FOR ELECTROMAGNETIC INDUCTION .....	136

## **CHAPTER 1: INTRODUCTION**

### **1.1. INTRODUCTION**

The teaching and learning of Physical Sciences, in high schools in particular has been a topic of research for a number of years and it continues to be as this subject is a requirement for careers in Science, Engineering and Technology (SET). Physical Sciences as a subject continues to challenge many a student as evidenced by many research studies that report concept difficulties and misconceptions in various science topics at secondary and university levels (Bahar & Polat, 2007:1114). Fensham (2008: 21) at the United Nations Educational, Scientific and Cultural Organization (UNESCO) added that science learning, for both successful and unsuccessful students, is seen to be more difficult than a number of other subjects. According to Bahar and Polat (2007: 1114), researchers and innovators keep producing various techniques to make the teaching and learning of this subject easier.

Some of these techniques have included the use of models; the introduction of technology; use of computers and simulations; curriculum developments; practical work; and scientific investigations, amongst others. However, in spite of all these innovations and techniques all over the world, many research studies report concept difficulties and misconceptions in Science topics in secondary and university levels (Bahar & Polat, 2007:1114). Further research is therefore still needed in the teaching and learning of Physical Science.

This study, done in a South African context, evaluates one of the abovementioned techniques as a means to address the difficulties in science topics, i.e. the use of practical activities to address learner difficulties in Physical Science topics. What this study hopes to accomplish is the diagnosis of the difficulties experienced by learners in Physical Science, more specifically in the module Electricity and Magnetism. This study aims to investigate the use of practical work as a possible remedy for these difficulties.

### **1.2. BACKGROUND OF THE PROBLEM**

One of the biggest challenges facing South Africa (SA) at present is the provision of high-quality education for all its children (Howie, 1999:199). The Bill of Rights in the South African Constitution (1996:1257) clearly stipulates that “everyone has the right to basic education, which the State, through reasonable measures, must make progressively

available and accessible” and that “significant progress has been made towards the realisation of this right to basic education”. While this is true, the quality of education received by the learners in the classroom, in particular the previously disadvantaged schools, still needs significant improvement.

Evidence of this continued need for significant improvement can be seen, amongst others, in the performance of these learners in subjects like Physical Science and Mathematics. These are the subjects needed for learners to enter into the *scarce skills* careers of Science, Engineering and Technology (SET), which are critical for any country’s economic development. Currently, South Africa is facing the highest shortage of engineering capacity and scarce skills crises in years (du Toit & Roodt, 2008:3). These authors attribute this shortage to, amongst other things, the shortage of matriculants who meet the criteria to gain entrance to engineering degree programs.

In acknowledgement of this need of scarce skills professionals, goal number six of the South African Department of Education’s Action Plan 2014 (DBE, 2010:2) is to increase the number of Grade 12 learners who pass Physical Science. They propose to do this by providing additional resources and training to all schools. This solution has however not been fully implemented, and therefore the fruits thereof remains to be seen.

The one tool used to measure success in South African education is the matriculation results. Although the overall pass rate of 70.2 % (DBE, 2011:5) for 2011 in the National Senior Certificate (NSC) indicates an improvement, the state of Physical Science education in SA is still cause for concern.

The statistics (DBE, 2011:57) below, although showing a steady rise from 2009, still indicate that the number of grade 12 learners who pass Physical Science remains very low compared to other subjects.

**Table 1.1: Physical Science pass rate from 2008 - 2011**

	2008	2009	2010	2011
<b>Physical Science Pass Rate (30% or more)</b>	54.9	36.8	47.8	53.4

While the aforementioned numbers might seem reasonable, depending on the perspective of the viewer, 46.6% of the learners failed Physical Science in 2011. In other words, 46.6% of the learners could not obtain a mere 30%, which is the required pass percentage. In addition, when one looks at table 2 below (which illustrates the percentage of learners who achieved at 40% and above in the Science NSC over the years), the numbers are disconcerting as it speaks to the quality of the passes in the examination.

**Table 1.2: Percentage of Learners Who Achieved 40% and above**

	2008	2009	2010	2011
% Achieved at 40% and above	28.8	20.6	29.7	33.8

Within this small percentage (for example 33.8% in 2011), the number of learners who obtained above 60% is found. The 60% is the minimum required for the learners to qualify to apply for a degree or diploma in most of the SET careers. This result is far from satisfactory, especially for a country faced with a huge scarce skills shortage.

Furthermore, the performance of South African learners in Mathematics and Physical science is very poor compared to international standards, as evidenced for example by the Trends in Mathematics and Science Study (TIMSS) results (Howie, 1999: 11). According to Howie, South African learners' performance in these subjects was lower than every other country. In fact, "of the 38 and 50 countries that participated in the Trends in Mathematics and Science Study (TIMSS) in 2001 and 2003, respectively, some of which are developing countries, South African learners came last in Mathematics and Science" (Kriek & Grayson, 2009:185). This trend seems to be continuing as reflected in the 2011 TIMSS study, where learners from the former African administered schools (which include South Africa) still achieved the lowest scores, in spite of demonstrating greatest improvement between 2002 and 2011, for both science and mathematics (Human Sciences Research Council, 2011: 5).

When commenting on the 2003 TIMSS, Reddy (2006: 46) also raised his concerns about the low number of learners scoring high in these subjects. She concluded that without achieving high scores at Grade 8 level, it was unlikely that learners would go on to attain high scores at grade 12, thus restricting their opportunity to pursue tertiary level studies in science and / or engineering.

Many reasons have been given for this poor performance, by teachers, learners themselves and even the Department of Education (DoE). The participants in this study cited shortage of science teachers; inadequately or under-qualified teachers; teaching and learning of science in English for learners whose mother tongue is not English; lack of adequate educator training on the curriculum; large teacher-learner ratios in most previously disadvantaged schools; insufficient time to adequately cover the curriculum; lack of textbooks in some schools; insufficient educator support by the relevant subject advisors. The shortage of fully equipped Physical Science laboratories, was one of the reasons given, and for this reason little or no experiments are done.

In a South African study by Mji and Makgatho (2006: 259) on learners' and educators' views on factors that contribute to poor performance in Mathematics and Physical Science, working with seven schools from poor performing schools in District 3 of Tshwane North (South Africa), the factors that were identified to have a direct influence included content knowledge, motivation and interest, laboratory use and non-completion of the syllabus in a year.

On laboratory use, these authors stressed the importance of laboratory sessions in learning Physical Science because practical work in a way "brings to life" what teachers explain using textbooks. They added that when learners either conducted the experiments themselves or at least observed educators demonstrating, the learners supplemented what was in textbooks and as a result, learning would be enhanced. An advantage of laboratory usage, in their view, was that it improves learners' higher order learning skills such as analysis, problem solving, and evaluating (Mji & Makgato, 2006:260).

Practical work and its impact on Physical Science education is a topic well documented before 1990. However, there is very little recent research on the topic at a time where all possible avenues pertaining to the teaching and learning of Physical Science should be receiving much more attention.

The introduction of scientific investigations in secondary schools was also through the National Curriculum Statement (NCS) Learning Outcome one (LO1) - Practical Scientific Inquiry and Problem-solving Skills. This outcome states that:

The learner is able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts, (DoE, 2003:13).

Teachers' attempts at the implementation of LO1 have been hampered by the requirements from the Department of Basic Education dictating a need to have one practical investigation per quarter for continuous assessment (CASS) purposes. These requirements resulted in "the whole thing being a haze of cramming and rushing" (Dockrell & Doherty, 2011) to finish these tasks and generally being under pressure to do so. The result is that instead of learning and having a real interest in the subject, learners end up being more focused on impending deadlines (Dockrell & Doherty, 2011). This has led to a group of learners that can produce well-written laboratory reports and can list the steps involved in a scientific investigation but have very little knowledge of the concept they were 'investigating'. This is because the focus of the investigation tends to be more on the investigative process and the lab report rather than on the learning needed to take place through and during the investigation.. This might result little learning taking place, in spite of high CASS marks.

The learners in our research group reported to have done only one practical activity per quarter. This has meant that students hardly ever do practical activities that are not 'for marks', i.e. practical activities as part of the science lesson they are being taught. The reasons given for not doing the experiments or practical work include: lack of equipment and the cost attached; lack of time; concerns about learner and equipment safety; large class numbers and possible discipline problems during practical sessions as well as teachers' inability to conduct experiments and manage practical sessions.

While the above reasons may be valid, they also illustrate a lack of willingness to innovate and find means of doing practical work, thereby depriving the learners of great benefits like "making abstract concepts more understandable, developing practical skills, illustrating the method of science and making science more real and interesting" (Bradley, Durbach, Bell, and Mungarulire, 1998:1406).

Research in this field is replete with conflicting arguments for and against practical work. Most of these arguments are however, not against practical work as such but the methods involved, and therefore research of practical work as a teaching tool continues to be essential. For example, according to Hofstein and Lunetta (1982:203), some of the arguments raised against extensive student laboratory activities included: lack of teacher competency in effective practical work; too much emphasis on laboratory activity leading to a narrow conception of science; too many trivial experiments performed in secondary

schools and laboratory work in schools often being remote from, and unrelated to, the capabilities and interests of the children.

On the other hand, Millar (2004:6) advocated that the teaching of scientific knowledge was essentially an act of communicating scientific concepts to the learners and that practical work supplements communication forms like verbal, graphical, pictorial and symbolic, that teachers might use. He further added that practical experience is important for understanding the world around us. Furthermore, he argued, given that the material world is the subject matter of science, learning science will obviously involve seeing, handling and manipulating real objects and materials. Teaching science would therefore involve acts of 'showing' as well as of 'telling'. He concluded then that the practical experience of observing and more importantly intervening in the world is essential for understanding in science.

The use of practical activities as a teaching tool and investigating the extent to which it remedies learner difficulties is therefore the focus of this study, but this research is limited to only one module in the current Physical Sciences curriculum – Electricity and Magnetism (E&M). This is one of the modules in which learners experience a lot of conceptual difficulties in Physics (Gunstone, Mulhall & McKittrick, 2009: 521).

### **1.3. PROBLEM STATEMENT**

The E&M module consists mainly of current electricity, electrostatics, electromagnetism and electromagnetic induction. The difficulty with E&M is that, as with most scientific concepts, it is not a directly observable phenomenon; only its effects are observable. This makes it abstract and therefore more difficult for learners to comprehend, more so if taught theoretically rather than practically. Because of the abstract nature of these concepts, learners tend to either memorize what they can, because they cannot visualize and simply struggle with the rest. In addition, the mathematical relationships involved contribute to the difficulties experienced by the learners.

The analysis of the National Senior Certificate illustrated just some of these difficulties. The analysis showed that the grade 12 learners of 2011 performed poorly in the questions on E&M in the 2011 NSC Physical Science examinations. Some of these difficulties, as mentioned by the examiner, included the following (DBE, 2011:130):

- learners' inability to use the equation  $V = IR$ ;
- inability to differentiate between external resistance,  $R$  and internal resistance,  $r$ . He added that internal resistance was poorly understood and that the manipulation of the formula  $\text{emf} = I(R + r)$  was also poorly done. Assuming that all the light bulbs were identical, and simply splitting the current into their respective ratios was one of the errors identified. Learners' use of the term 'magnetic force' instead of 'magnetic field' in their explanations was another common error.

Physics education research on these difficulties has focused mostly on students' understanding of DC (direct current) circuits and the electric field and there have been few studies that have documented and analysed student difficulties in E&M (Planinic, 2006:1143). Even in this case, little research focuses on how practical work remedies the difficulties in DC circuits and electric fields. The closest research work done has been on practical work in general, very little specifically relating to Electricity *and* Magnetism, especially pertaining to secondary school learners.

In terms of what has been done to address the problem above in the broader South African context, government – among other role players – has implemented interventions like the Dinaledi Schools Project. Established in 2001 to increase the number of matriculants with university-entrance Mathematics and Physical science passes, this strategy involves selecting certain secondary schools for Dinaledi status (schools that have demonstrated potential for increasing learner participation and performance in Mathematics and Physical Science), and providing learners with the resources like scientific equipment and support to improve the teaching and learning of these subjects (DoE, 2009:6).

The shortfall of this intervention, from the point of view of this research, is that it is very broad and places no special focus on any module. The way in which it operates is such that in order for schools to maintain the Dinaledi status, they need to keep showing an improvement in their pass rates, especially in Mathematics and Physical Science. If a school does not perform, it is simply removed from the program – no research is done to diagnose and possibly solve the possible problems that led to the failure.

Conversely, various other interventions by NGO's (non-governmental organisations) targeting certain groups of children (mainly top performers) have taken place, but have

also focused more time on the theoretical content. Most interventions tend to focus on a small group of learners and the teaching approach, often referred to as “exam preparation” tends to focus on getting the students ready for examinations. For this reason and due to time constraints, content that is not examinable at the end of Grade 12 is left out. Some of the foundational concepts of E&M have fallen by the wayside due to this omission.

With specific reference to E&M, the research done around the world on teaching and learning strategies focuses mainly on Current Electricity only or certain aspects of the module. Some of this research identified the difficulties experienced by learners and suggested various strategies to remediate this problem. Some of these strategies include modelling and simulations, but practical work finds no prominence in the suggested strategies.

Whilst the strategies and interventions mentioned above certainly contribute, they are not enough to deal with and solve the problem of poor performance in this module. In terms of the actual difficulties in Current Electricity and Magnetism as well as to what extent a practical activities based approach addresses those difficulties, there is still a gap in the knowledge in the current body of literature.

#### **1.4. PURPOSE OF THE STUDY**

There are two main objectives to this study. The first objective is to determine the conceptual difficulties experienced by learners in the module E&M. Learners perceive the E&M module as the most abstract in the Physics curriculum as the explanations to the observed phenomena are generally not concepts that they come across in everyday life. This means that in order for learners to master this module, they need help in linking the observed phenomena and the terminology and concepts involved.

In addition to the determination of these difficulties, a brief review of the research on some of the common misconceptions experienced by learners in this module will be conducted using the available literature. The learners' pre and post-tests will then be analysed for the presence of these misconceptions in order to determine whether the practical activities based approach contributed in reducing or clearing these misconceptions or even the possibility that it might have increased them.

Secondly, the study investigates the implementation of a practical activities based approach in teaching these concepts and observing to what extent the practical approach addresses these difficulties and then document how this approach enhances learning. The meaning of the phrase 'practical activities' in this case is that the learners will actually perform hands-on practical activities on the particular topic identified as posing difficulties. These practical activities are not specifically designed to improve learner understanding on these difficult concepts, but are utilised to see to what extent they actually do. If this approach is successful in remediating the difficulties discovered, an in-depth study on how practical activities actually enhance learning will also be conducted.

### **1.5. SIGNIFICANCE OF THE STUDY**

The scarce skills shortage that South Africa is dealing with is aggravated by poor performance in Mathematics and Physical Science. One of the contributing factors to the poor performance in Physical Science at least, is the fact that educators teach this already abstract subject only theoretically, neglecting the practical activities-based approach to the teaching of Physical Science.

Although much research has been done globally on practical work itself, this study is still necessary as not much research has been done, especially in the South African context, to determine the difficulties experienced by learners in E&M and on how these can be addressed using a practical activities-based approach. Therefore, the answers to the research questions could help the South African Department of Basic Education (subject advisors, school principals, educators) in their design and implementation of their lessons.

Knowledge gained from this research will go a long way in assisting learners to prevent some of these difficulties in this module but as well as those that are generic to other modules in the Physical Science curriculum.

Researchers in the field of science education could also benefit from some of the results, observations and recommendations made in this study.

In addition, "many groups and organisations, from NGOs to businesses to provincial education officials to student volunteers, have tried to improve the state of school Science through a variety of interventions" (Kriek and Grayson, 2009:186). These intervention

program facilitators could also be in a position to know the possible challenges their learners might experience in this module. This information would be very useful in the design and implementation of their programs.

One such intervention program is TRAC South Africa (Technology Research Activity Centres), whose mission is to encourage and enable South African school leavers to go into SET careers. TRAC SA believed that anecdotal evidence existed to suggest that one of the reasons for learner conceptual difficulties in Physical Science is the teaching and learning of this subject only theoretically rather than by making use of practical activities. This belief led them to a realization that

it had become imperative that an instrument had to be de-signed and implemented to test the impact of the TRAC methodology in a situation where external factors have little to no relevance. This pilot impact testing process was implemented and has proven that the practical hands-on approach of TRAC is successful” (TRAC SA, 2013:6).

TRAC thus concluded that a practical activities based intervention, has a significant role in increasing learner knowledge in Physical Science (TRAC SA, 2013:26).

This study will also be of a significant benefit to TRAC as they are proponents of this approach. In fact, TRAC SA intervenes by providing schools with a suitably qualified facilitator who brings a mobile laboratory to the school to perform Physical Science experiments in partnership with the teacher. They have, however, never researched the exact difficulties in E&M and how the practical activities based-approach addresses these difficulties. Although this research deals with one of six modules, it should provide TRAC SA with a decent foundation for future research in other modules and ultimately the whole curriculum.

## **1.6. PRIMARY RESEARCH QUESTIONS**

The following questions emanate from the problem statement:

1. What are the conceptual difficulties experienced by learners in the module E&M?

2. How does the use of practical activities address these conceptual difficulties?
3. Do the learners exhibit some of the commonly known misconceptions experienced by learners in the module E&M and has the practical activities based approach addressed them?
4. If the practical activities based approach does have an effect, how does it enhance the learning of E&M?

## **1.7. HYPOTHESIS**

Students experience serious misconceptions and difficulties in learning the module E&M and a practical activities based approach can develop learners' conceptual knowledge of this module. This reduces the number of misconceptions and eases the level of difficulty compared to a theory based approach to the learning of E&M.

In the data analysis, for the various sub-sections of work, null hypotheses have been provided.

## **1.8. RESEARCH DESIGN**

In order to gain insight as well as an extensive understanding of the problem as stated in the problem statement, a mixed method research design has been employed. This design incorporates both quantitative and qualitative research tools to better understand and be able to explain the use of practical activities in addressing learner difficulties in E&M. The main data is quantitative, in the form of the test scores, and the pre- and post-intervention questionnaires as well as the actual learner transcripts will provide the qualitative data.

A quantitative approach involving pre- and post-testing of learners to determine their conceptual difficulties in E&M, as well as measuring the effect of the practical activities based approach in addressing learner difficulties in E&M, was employed. This was done with the assistance of a group of grade 11 learners from a Western Cape school who had already received instruction from their educator on this module.

The research variables in this case were: difference in learner performance (i.e. difference in test scores); practical activities; other interventions; teacher; as well as computer skills, with learner performance as the dependant variable and practical activities the

independent variable. The variable 'other interventions' was kept constant in that the learners indicated no other interventions other than this one. The teacher and computer skills, however, could not be fixed, as it was part of the schools set-up that, for ethical reasons, the researcher had to include both Grade 11 classes who had two different teachers. Furthermore, the one Grade 11 group was also doing Computer Applications Technology (CAT) as a subject and the other did not. These are discussed in detail in the limitations section 5.5.

To augment the quantitative data, a qualitative research was conducted, making use of questionnaires-, learners' actual tests- (transcripts) and observations of learner behaviour. This was done to: diagnose possible misconceptions; obtain the exact detail of concepts posing difficulty; explore the learners' experiences of the practical activities, and to discover areas of improvement for the practical activities based approach.

The main instruments of data collection were pre- and post-tests, six in total, spanning over the module. In order to gain more insight and detail of the problem, the contents of the pre- and post-tests also provided much in the way of qualitative data by detailing the difficulties as well as the misconceptions., In addition, the tests were supplemented with pre- and post-intervention questionnaires together with observation schedules providing details of what took place during the intervention.

The procedure followed started with the pre-intervention questionnaire, followed immediately by the first pre-test. The practical intervention followed within a day or two after the pre-test. After that followed the post-test, also within a day or two after the practical intervention. The pre-testing, then practical intervention, then post-test process, was repeated six times to cover the concepts in the module. The observation schedules were utilized during the actual practical interventions and the post-intervention questionnaire was administered after the last post-test was written.

Participants in this study are a group of black Grade 11 learners from a township school in the province of the Western Cape, South Africa. Their ages range from 16 to 21 with isiXhosa the home language of most of them. This group is all the Grade 11 Physical Science learners at the school, i.e. they were all given an opportunity to participate in the study, although not all of learners participated. This was a combination of two different

classes taught by two different teachers and in addition, part of the group was doing CAT as a subject while the other did not.

All the Grade 11 learners doing Physical science at this school were given the option to participate in the study, and they agreed. The collection of all the data (questionnaires, pre- and post-tests, practical activities) took place at the school, most times during the school's study session. The study sessions were cancelled on occasion, which meant that the participating learners remained after school for the research sessions, while the rest of the school was dismissed.

### **1.9. ASSUMPTIONS, LIMITATIONS AND SCOPE**

The following assumptions were made:

- Learners were taught the content on E&M prior to the research sessions.
- Learners answered the pre- and post-tests to the best of their knowledge and individual abilities.
- Learners responded truthfully and accurately to the interview questions based on their personal experience.
- Learners possessed the mathematical abilities required for clearer understanding in the module covered.

The researcher was sometimes restricted in terms of available time and the number of learners attending the sessions because at times the study sessions would be cancelled without notice. At these times, most learners would choose to go home instead of staying for the sessions; therefore, the researcher is not responsible for the fluctuations in numbers i.e. the varying samples. The time available for the entire project also depended heavily on the school, and was affected by the above-mentioned as well as the approaching examination season. Although the collection started in the third term, it had to continue onto the fourth term. This included the time between the various stages of the research, i.e. time between pre-test, practical intervention and post-test.

The researcher is also not responsible for the observed culture of learning and teaching that existed where learners barely asked when something was unclear to them. There were also language limitations also presented, where learners lacked full understanding of

the questions asked, thereby also expressing themselves in the tests. Other limitations related to the actual experiments and the inability of the equipment used to provide 100% accuracy.

In terms of scope, the number of participants varied from 23 on the last session to 47 on the first session. These are participants who attended all the phases of the sessions, i.e. pre-intervention questionnaire; pre-tests, practical activities; post-tests and post-intervention questionnaires. The data applicable to this study as well as the outcomes thereof can also be applicable to any of the modules in the Physical Science curriculum in any grade, as well as applicable to any school with the necessary equipment.

This research *does not* intend to

- suggest that a practical activities-based approach is the only approach to the teaching and learning of science;
- suggest a new method to the teaching of this subject;
- provide assessment tools with regards to the experiments done;

#### **1.10. DEFINITION OF TERMS**

- Practical activities – refers to practical hands-on experimental activities used to strengthen the concepts being taught and to verify established theories.
- Scientific investigations – an activity where learners learn a concept using the scientific process and steps involved. The steps include investigative question; hypothesis; variables; apparatus, method; results and discussion and conclusion.
- Learners – participants in this study are also referred to as learners or students.
- Teachers or educators refer to the same people.
- E&M – electricity and magnetism (excluding electrostatics)
- DBE and DoE – same department, the name changed from DoE to DBE after the department was divided into basic and higher education.

#### **1.11. ACRONYMS**

- DoE – Department of Education
- DBE – Department of Basic education
- E&M – Electricity and Magnetism
- TRAC – Technology Research Activity Centre
- CASS – Continuous Assessment
- CAPS - Curriculum and Assessment Policy Statement
- NCS – National Curriculum Statement
- LO – Learning Outcome
- TIMSS – Trends in International Mathematics and Science Study
- SET – Science, Engineering and Technology
- SA – South Africa
- SAIRR – South African Institute for Race Relations
- STEM - Science, Technology, Engineering and Mathematics
- DC – Direct Current
- AC – Alternating Current
- CSEM - Conceptual Survey of Electricity and Magnetism
- PI – Peer Instruction
- TEAL - Technology-Enabled Active Learning
- POE - Predict-Observe-Explain
- SCORE – Science Community Representing Education

## CHAPTER 2: LITERATURE REVIEW

### 2.1. INTRODUCTION

This literature review and critique is limited to learner difficulties in the Physical Sciences module Electricity and Magnetism (E&M). Firstly, in order to provide a proper context for this study, it highlights the poor performance of South African (SA) learners in Physical Science (often referred to as “science”) as a subject, as well as suggested strategies to remedy this poor performance. Secondly, it analyses the difficulties experienced by learners with science in general and how these may be remedied.

Thirdly, this review provides a detailed look at the conceptual difficulties and misconceptions (mainly the current electricity part) experienced by learners in E&M as well as some of the strategies suggested by researchers to address these difficulties. Finally, the theoretical framework of this study is laid out by discussing the use of practical activities in addressing the learner conceptual difficulties previously stated. Various forms of practical work as well as its advantages, limitations and recommendations for its effective use are also outlined.

This analysis is anchored around the main objectives of this study, which are:

1. to determine the conceptual difficulties experienced by learners in the module E&M;
2. to provide a brief review of the research on some of the common misconceptions experienced by learners in this module;
3. to investigate the implementation of a practical activities-based approach in teaching these concepts by:
  - a) observing to what extent the practical approach addresses these difficulties,
  - b) and document how this approach enhances learning.

### 2.2. PHYSICAL SCIENCE EDUCATION IN SOUTH AFRICA

#### 2.2.1. Physical Science Performance Internationally and Locally

The one program that provides useful data in comparing the Physical Science performance of South African learners with their counterparts in other countries is the TIMSS (**Trends in International Mathematics and Science Study**) program. TIMSS is an international assessment of science and mathematics knowledge which started in

1995. The participating countries use TIMSS in various ways to “explore educational issues, including: monitoring system-level achievement trends in a global context, establishing achievement goals and standards for educational improvement, stimulating curriculum reform, improving teaching and learning through research and analysis of the data, conducting related studies (e.g. monitoring equity or assessing students in additional grades), and training researchers and teachers in assessment and evaluation”.

The teaching and learning of Physical Science in the South African context is experiencing many challenges. This is evidenced by the consistently poor performance in this subject compared to other subjects, as reflected for example, in the Reports in the National Senior Certificate Examinations (DBE, 2010:55; 2011:116). The Department of Basic Education (2011:116), however, celebrated what they called “a consistent improvement since 2009 in the percentage of learners passing at the 30% and above level and at the 40% and above level in Physical science”. Indeed the results indicated a steady increase of learners passing at the 30% and above level from 36.8% in 2009 to 53.5% in 2011 (DBE, 2011:116).

A concern, however, emerges when one interrogates the actual quality of this “improvement”. According to the DBE (2011:116), there was also an increase in the number of learners passing by 40% and above, from 20.6% in 2009 to 33.8% in 2011. The percentages of learners obtaining higher than 50% from 2009 to 2011, also showed a steady increase from 10.1% in 2009, 18.4% in 2010 and 19.5% in 2011 (DBE, 2012:5). This percentage is still low in the light of South Africa and its scarce skills situation. It is unclear from this report the number of learners who passed at higher than 60% for the period 2009 to 2011.

The 60% mark is important because it is the requirement by universities and universities of technology in order for learners to register for careers in Science, Engineering and Technology (SET). As “promising” as this improvement might seem, it indicates an insufficiently small number of matriculants who have the necessary grades and subjects to access programs like engineering, medicine and accounting (Erasmus & Breier, 2009:1), certainly at university or university of technology level. This small number is a contributing factor to the scarce skills crisis in South Africa.

On an international level, when comparing South African learners to other learners in Mathematics and Science, they actually come last. This was done through the Trends in International Mathematics and Science Study (TIMSS), conducted with learners from 50 countries, where South Africa participated in 1995, 1999 and 2003 but opted out in 2007. Of the 50 participating countries in 2003, South Africa had the lowest average performance in Mathematics and science (Reddy, 2006: 34). In fact, according to Reddy (2006:112), South Africa performed even lower than the accepted international low benchmark in science and Mathematics. Reddy (2006:20) further illustrated that when compared to other African countries, with economic conditions worse than those of South Africa, SA learners still scored lowest on average in Mathematics and in science. This, Reddy proposed, implies that the economic conditions alone were not enough to ensure success.

While the TIMSS results did not suggest that learners from the higher performing countries like Singapore, the Korean Republic, Hong Kong (Reddy, 2006:17) and others experienced no difficulties at all, it did suggest that it is possible for learners to succeed in this subject. The above assertions made it very clear that South African learners are experiencing serious difficulties in Physical Science.

### **2.2.2. Suggested Remedies to SA Learners' Poor Science Performance**

In order to remedy this situation, the World Bank, through authors Ottevanger, van den Akker and de Feiter on their Secondary Education in Africa Study (SEIA) in Sub-Saharan Africa, made a few suggestions on science, mathematics and ICT resources (Ottevanger, Akker & Feiter, 2007:xv). These authors suggested that schools needed to reassess the provision of resources to schools in order to promote something they called "good science".

For example, they advocated for the use of simple equipment like micro-science kits. They also strongly recommended the optimization of the use of teaching and learning resources, in particular practical work and ICT. They made examples of science resource centres or special science schools as implemented in countries like Senegal and Nigeria. Ottevanger *et al.* (2007:xi) also observed that textbooks, equipment and consumables for practical work were often available in limited supply. Education policy emphasised learner-centred education, but actual classroom practices were still largely dominated by teachers, with students silently copying notes from the blackboard.

Kriek and Grayson (2009:185) brought another dimension to this matter, stating that the concerning state of Mathematics and science education in South Africa could also be attributed to many Mathematics and science teachers' limited content knowledge, ineffective teaching approaches and unprofessional attitudes. As a means to address these three problem areas, they suggested a "holistic professional development model" for the development of teachers in these subjects. In order to do this Kriek and Grayson (2009:190) worked with 75 teachers through distance education over a period of four years. The model which they found to be successful, made use of "a study guide which integrated the development of the teachers' content knowledge, pedagogical content knowledge, cognitive skills and experimental skills; reflective journals; assignments; workshops; peer support and science kits" (Kriek & Grayson, 2009:185).

Kriek and Grayson (2009:200) found this model to be successful in "improving the teachers' content knowledge and increasing their confidence". They, however, provided no evidence of how this improved knowledge and confidence translated to learner performance, which would be the real measure of success. In other words, the authors stopped their research a step too early by omitting to measure its impact on the performance of the learners being taught.

The South African Department of Education concurred with most of the challenges mentioned. In fact, in the department's 2010/11 annual report (DBE, 2011:53), detailing their plan to improve enrolment and performance in mathematics and science, they had the following activities as planned:

- train maths and science teachers in Dinaledi schools and others;
- monitor 200 Dinaledi schools and provide teaching and learning resources;
- register the Dinaledi Schools learners in maths and science Olympiads;
- evaluate the maths and science strategy to establish correlation progress as mentioned by the World Bank standards (DBE, 2011:53).

The shortcoming of the above DBE activities is that most tended to focus on the Dinaledi schools whose learners made a very small percentage (between 17 and 20% (DBE, 2012:5)) of the total number of Physical Science learners in South African Schools. The Dinaledi Schools Project was established, as part of the DoE's National Mathematics and Science and Technology (MSTE) strategy to address and improve performance in

Mathematics and Physical Science outputs (DBE, 2012:1). This project, according to the DBE (2012:1), was established to give targeted support to raising the performance of black learners in these subjects. This was done through allocation of funds to achieve the following:

- address textbook shortages;
- provide mobile laboratories; Mathematics kits, ICT laboratories and computers; educational software
- install televisions to receive educational broadcasts;
- training and support for participation in Olympiads
- teacher training; and
- capacity building of the school principals (DBE, 2012:7).

The extent to which the department has succeeded in achieving the above, has not yet been established.

Although the Dinaledi strategy has yielded some results, these results seem insignificant when compared to the national picture. For example, the percentage of Dinaledi learners passing Physical Science by 50% or more, as a percentage of the national totals, has changed from 2.3% in 2009, 6.4% in 2010 and 5% in 2011 (DBE, 2012:5). The fact still remains: South African learners still perform significantly poorly in Physical Science. It is therefore necessary to examine the actual difficulties experienced by learners in science in order to assist the relevant stakeholders in designing solutions to remediate these problems. The next sub-section reviews literature on the actual learner difficulties in Physical Science and some of the researched and suggested remedies for these difficulties.

### **2.3. ACTUAL LEARNER DIFFICULTIES IN SCIENCE**

In order to tease out some of the causes of difficulties in science, Tobias (1993:297) conducted a research study that asked the question “what makes science hard?”, in particular for otherwise intelligent students. Tobias, “neither a scientist nor a science teacher”, used an interesting group as the research sample – “college professors and graduates not in science who are indisputably not dumb or lazy” (1993:298) – and studied their experience of science learning.

In summary, Tobias listed nine issues that his “students” found as causes for difficulties in science. These issues, some of which will be discussed in this section, included: course structure, examinations content, amount of work required, class time, the rigid and hierarchical nature of science instruction, type of textbook, foreignness of the language of science and the tyranny of technique (Tobias, 1993:298). In addition to this list, other contributing factors will be discussed.

### **2.3.1. Abstractness and Cognitive Demand of Physical Science**

Science is generally known to deal with abstract and cognitively demanding concepts (Dori & Belcher, 2005:244; Bahar & Polat, 2007:1121). Simply put, these are concepts that are generally not part of the learners’ everyday experiences. Because of this and many other challenges, students tend to experience difficulties with this subject in general. Research is awash with discussions of these difficulties as well as the various strategies suggested to assist learners with these difficulties.

On the topic of electromagnetism, Bagno and Eylon (1997:726) assert that electromagnetism courses focus on the acquisition and application of abstract concepts and that these courses usually involve “a mathematical treatment of central relationships and sophisticated problem solving tasks”. The same can be said for the entire Physical science curriculum, especially the Physics component thereof. In fact, Bahar and Polat (2007:1123) emphasized that students were better able to understand scientific concepts if they were related to everyday life. The difficulty arises with scientific concepts that have no connection to everyday life.

### **2.3.2. Confusion of Terms**

The tendency to confuse related but distinct Physics concepts was another difficulty that was experienced by science students and this tends to give rise to alternate conceptions (Grayson, 2004:1127). Grayson illustrated this assertion, by an example where students used the word “electricity”, which to learners had elements of current, voltage, energy and power all mixed up together. In order to help students disentangle these related concepts and assign the correct meaning to these terms, Grayson (2004:1127) suggested a teaching strategy used to build on the correct intuitions of the students while remediating incorrect reasoning or conceptual difficulties.

Grayson called this strategy “concept substitution”, where the students’ “correct intuitions were turned into useful building blocks to construct scientifically acceptable concepts” (2004:1127). This strategy, which made use of practical activities and demonstrations, was elucidated using current electricity as a context. For this reason, it will be discussed and analysed in more detail in the E&M difficulties and misconceptions section 2.5.

### **2.3.3. Scientific Literacy**

Another challenge with science education as highlighted by Webb (2010:449) is the increasing decline in scientific literacy. Scientific literacy is measured by one’s proficiency in scientific discourse, which includes reading, writing and talking science (Webb, 2010:448). In order to achieve this, the Webb suggested that students needed assistance “crossing the borders” between the informal languages spoken at home and the academic language used at school, particularly the science language which the authors view as specialized.

In order to promote science literacy therefore, Webb (2010:448) cited various language-based strategies from research (Romance & Vitale, 1992, 2006; Cervetti, Pearson, Bravo and Barber, 2006; Hand, 2008). Some of these strategies included science content reading programs; science writing; reading to learn science and science writing heuristic. The common thread in all these strategies, which the authors found to be successful, was the integration of language and science instruction in order to promote scientific literacy.

In the South African science education context, Webb (2010:449) suggested that in order to achieve scientific literacy, attention must be paid to the cognitive development in both the language of instruction and the students’ home languages. One such strategy, he contended, was the use of “code-switching” by teachers. In other words, the teachers needed to allow children to first make sense of what is expected of learners in their home language and to translate what they understood into the official language of teaching and learning.

The strategies suggested by the above researchers in promoting scientific literacy are commendable in as far as increasing the involvement of students in their learning is concerned. In addition, the issue of the use of home language and or code switching in the

teaching and learning of science is a noble concept. However, the latter (use of language and code switching) has fewer chances of success in the current South African context. This is because in most of the official languages, there is very little science vocabulary to assist teachers, for example in code switching. This assertion therefore leads the discussion to the issues of languages in science.

#### **2.3.4. Issues of Language**

There is anecdotal evidence that the only language group in SA for which the approach suggested by Webb (2010) would and is currently succeeding, is the Afrikaans speaking group. The Afrikaans language is already highly developed and has all the necessary scientific vocabulary. What would typically happen then, in the case of the other South African official languages, is that the teachers and learners end up only code switching the linguistic rather than the scientific concepts and therefore end up with sentences that are a mixture of the two.

In addition, the differing meanings of the same word in the different languages compared to its meaning in science might exacerbate the problem. This, instead of helping, sometimes brings confusion and misrepresentation of the science ideas (Mji & Makgato, 2006:261). For example, the word “speed” in English means an object is moving fast while in science it means the rate of change of distance, which might be rate of increase or decrease of distance.

Plainly speaking, the language and terminology used in the classroom and in the textbooks is unknown and unfamiliar to most students (Mji & Makgato, 2006:263; Tobias, 1993:298, Maloney, O’Kuma, Hieggelke & van Heuvelen, 2001:19). This is especially true for those concepts that stem from the Latin language, for example. This is what Chapman (2000:98) referred to as “lexicon - a jargon replete with acronyms”. The language deficiencies resulted in students lacking the knowledge of the precise meaning of concepts, as well as confusing the words that looked and sounded alike.

Chapman (2000) also offered more clarity on how to remedy the language issues, first by acknowledging that each branch of science has its own jargon, which students must learn. They learn it much better and easily by ‘doing science’. According to Chapman (2000:98), English is the language that suits and serves science well and therefore if students (who

have English as a medium of instruction) are to learn science, they must develop good English language skills. This could be done through student science debates and discussions i.e. allowing students to articulate scientific observations and ideas to their peers and to themselves, thus developing clear and precise thinking required in science (Chapman, 2000:98).

Another alternative suggestion to this issue of language would either be the development of the scientific vocabulary in the other official languages or increased development of the current language of instruction. In other words, language does have an important connection to science learning but currently, in the majority of learners, English is the language used and therefore that is the language whose skills must be developed in learners (Tobias, 1993:301). This, argued Tobias, could be done by, among other things, getting students to discuss and debate scientific ideas – in English – thereby internalizing and taking ownership of these ideas while developing their language skills.

Wellington (1994:168) was also of the opinion that “science, although a practical subject, its teaching occurs extensively through the medium of language, both spoken and written’. He proceeded to divide the words of science into four categories: naming words, process words, concept words and mathematical words and symbols. Each category, according to Wellington (1994:169) acquired meaning in a different way and this complexity, the science teachers need to be aware of and address in their teaching of the subject.

### **2.3.5. Content, Available Time and Textbooks**

In addition to the issue of languages and scientific literacy as some of the difficulties in science, Bahar & Polat (2007:1121) asserted that science content, available time and the use of textbooks also contribute to these difficulties experienced by teachers and/or students in science. They contended that the science curriculum covers too much content, resulting in the learners having to learn a lot of principles, concepts, theories and formulas in an inadequate amount of time.

The authors insisted that the allocated amount of time was simply not enough to digest and meaningfully understand the topics. Tobias (1993:303) succinctly expressed the excessiveness of the pace of new material in science, saying “they shovel it in, rather than

nailing it down". In other words, the amount of available teaching and learning time made it difficult to consolidate and assimilate the concepts.

The prescribed textbooks also contributed to learner difficulties in science instead of assisting to eradicate them. This was a view of teachers in Bahar & Polat's (2007) research. They argued that the textbooks also had misconceptions and/or sometimes present the content in a manner that caused misconceptions (2007:1124).

In addition to all of the above, the perceived incorrect order of the concepts in the curriculum (Tobias, 1993:299) made it difficult for educators to effectively build on concepts and foster proper understanding.

### **2.3.6. Mathematical Skills**

Physical Science content contains many mathematical concepts embedded within the science. This means that a certain mastery of mathematics (expressions and formulae) is required in order for learners to fully understand some scientific concepts. Mathematical expressions and formulae therefore make science difficult for the students (Chabay & Sherwood, 2006:329; Dori & Belcher, 2005:244; Bahar & Polat, 2007:1121), especially for those students that are not good at Mathematics.

Students tend to confuse the formulae and the symbols, especially those symbols that can be used interchangeably for two or more concepts. Such an example would be the use of the symbol " $v$ " which in science could mean "velocity" or "volume" or "potential difference", depending on whether it is used as small or capital letters. Tobias (1993:304) agreed that mathematical skills were highly useful in terms of problem solving in science, and asserted however that the manner in which you treat a Physics problem was different to a maths problem. This is because in Physics the scope of solutions to the same problem is much wider.

### **2.3.7. The Teaching Approach**

The teachers' approach to science was another factor that research also showed to contribute to learner difficulties. For example, science classes where the teacher-centred teaching approach was dominant resulted in uninterested, bored and passive learners who

ended up perceiving the subject as boring and uninteresting (Tobias, 1993:301). Because of this, among other reasons, the learners ended up having negative attitude towards science and therefore performed badly in the subject. This creates a vicious cycle because the bad performance also leads to bad attitudes, which again lead to poor performance.

### **2.3.8. Cutting Back on Hands-On Approaches**

In a United States of America (USA) study on challenges facing science education, Thornburg (2009:2-9) mentioned shortage of qualified teachers; the treatment of science as abstract topics devoid of human passion; cutting back on hands-on science; moving away from science as a process of inquiry and real projects as well as connecting science with other subjects.

Advocating for hands-on science, not only in class but outside the classroom as well, Thornburg (2009:4) argued that “hands-on science seems to be in short supply” in the US schools and that in classes where science is taught, it seemed to be more textbook-based lectures. Thornburg (2009) therefore acknowledged that cutting back on hands-on science also contributed to science difficulties. This was similar to what Bahar and Polat (2007:1121) referred to as inactive participation of learners in class.

## **2.4. SUGGESTED REMEDIES**

This section contains some of the researched strategies that have been offered to remedy difficulties with science in general, as discussed in section 2.3 and other difficulties not necessarily discussed in detail above. Research has shown that strategies like modelling, the correct packaging of the content, computer simulations and others, can be utilized with a certain measure of success to address these difficulties. These strategies and more will be discussed below.

### **2.4.1. Language, Experience, Modelling and Analogies**

To address the difficulties in science and finding the causes, Bahar & Polat (2007:1126) offered the following remedies:

- language and terminology needed more care

- In order to for science to be actively learnt, language, mathematical and modelling skills were required.
- Science curriculum content needed to be lessened and teaching time increased.

Bahar and Polat (2007) did a sterling job in describing the difficulties found in the teaching and learning of science. Their study was done with primary school learners, and although some of the difficulties might not be specific only to science, the difficulties listed are applicable to high school learners as well.

The one query is on the fact that the study was presented as aiming to diagnose the perceived difficulties, find the reasons behind the difficulties and suggested some remedies. The suggestions on remedies have, however not been given enough attention in comparison to the difficulties. The suggested remedies themselves have not been given in detail to suggest the method of implementation. For example, “language and terminology needs more care” (Bahar & Polat, 2007:1126) – gives no clue as to what needs to be done in providing that “more care”.

On the issue of experience, Chapman (2000:99) suggested that “learning science demands experience in science: the more, the better”. This could be achieved by the creation of models. He asserted that “models are scientists’ attempts to rationalize observations, phenomena and data” and that “if students are to learn science, they must create models” (Chapman, 2000:104).

Coll, France and Taylor (2005:184) argued that the use of analogies and models in the pedagogy of science education might provide a route for students to gain some understanding of the nature of science and the scientific enterprise. Coll, *et al.* (2005:184) asserted that “models play an essential role in the practice of science” and defined a model as a representation of an idea, object, event, process or system.

Coll, *et al.* (2005:184) also provided a framework for discussing different kinds of models, namely expressed mental models, consensus models, scientific models and historical models. Explaining expressed models further, the authors added that these are said to sometimes be identified as teaching models, which teachers sometimes used to explain ideas to students.

On the issue of models, the greatest criticism against models (and perhaps analogies) is the fact that they are not enough i.e. models never completely represent the concept being represented and when stretched, they can create misconceptions instead of enhancing conceptual understanding (Driver, Asoko, Leach, Mortimer & Scott, 1994:7). In fact, Coll, *et al.* (2005:186) summarized the following factors that researchers provided as impediments to models:

- some learners may learn the model rather than the concept it is meant to illustrate;
- lack of awareness of the boundaries between the model and the reality it is representing;
- misunderstanding caused by the unshared attributes between the model and reality;
- lack of the necessary visual imagery with some learners;
- mixing up of models

This criticism can be circumvented by ensuring that students are taught to compare, criticize and evaluate models as well as amend or discard models that prove inadequate Chapman (2000:105). In other words, “teachers are an important link for learners developing a more complex understanding and use of models and analogies” (Coll, *et al.*, 2005:186).

Analogies on the other hand, might be considered as subsets of models in that they involve a comparison between things that are similar in some respects (Coll, *et al.*, 2005:185). Glynn (2007:52) believed that analogies helped students bridge the gaps between the new often complex and hard-to-visualize concepts, and what is familiar to them.

Oliva, Azcárate and Navarrete (2007:52) criticised analogies as being often regarded as artefacts that the teacher invents and transmits to the pupils. They suggested that in order for analogies to be effective, one had to accept the importance of devoting enough time and effort to ensuring that the pupils make sense of the analogy that has been developed. Oliva, *et al.*, (2007:52) also asserted that not all analogies could be educationally useful. They therefore advised that the construction of analogies should not be left to the students alone, but should be accompanied by constant feedback and evaluation by the teacher.

### 2.4.2. Packaging and Delivery of Content

One of the causes for difficulty in science, as mentioned by Tobias' (1993) "students" was the manner in which the content was packaged, referred to as the "hierarchical nature of science instruction" (Tobias, 1993:298), as well as something they called the "tyranny of technique".

On the tyranny of technique, Tobias (1993:298) lamented the rigidity insisted on by professors on students solving problems only as taught, thereby robbing the students of a profound intellectual experience that science can offer. Simply put, "if creative, innovative students are to be retained in great numbers, instructors are going to have to give learners more of a sense that they are not just walking down the same trodden path of problem after problem to solve" (Tobias, 1993:300).

While Tobias' (1993) research group might be different to the conventional groups utilized in researching learner difficulties in science, the fact that they were novices in science made these learners quite a useful group and their high levels of education provided this study more depth and insight than would be found with younger students. The following quotation summarizes his views on the matter of science difficulty:

Unless and until courses in science play a wider variety of student learning styles, we may continue to suffer unnatural and nationally fateful shortfalls in the subjects you love. What makes science hard may not be science itself or the unpreparedness or prior alienation of high school and college students but rather how science is packaged and purveyed – something we can all do a great deal to change (Tobias, 1993:298)

One is inclined to agree with Tobias' assertion that what makes science difficult is how it is packaged and offered, but that might be oversimplifying a rather multifaceted problem as indicated by the issues she herself has raised. The main challenges, namely time and resources, seriously affect the packaging as well as the offering of science lessons. This of course is no excuse for innovation and creativity on the side of the science instructors.

### 2.4.3. Hands-on Science

Thornburg (2009:4) suggested that cutting back on hands-on science also contributed to learner difficulties in this subject. To provide more clarity to this, Thornburg agitated for a more student-directed approach to dealing with science as a process of inquiry. While

scientific inquiry is essential in the development of scientists in our learners, the main challenge with it is the time within which to allow the learners the process of inquiry.

For example, in a South African education high school science setting, where teachers are already struggling to complete the prescribed curriculum in the available time, those that do venture into practical work tend to ignore the process of inquiry. While Thornburg (2009:5) also acknowledged that this approach (scientific inquiry) has its challenges, namely staff development, he suggested a provision of regular support to teachers and students in helping learners to become more comfortable with the process of inquiry.

In addition to scientific inquiry, Thornburg (2009:7) expressed a need for STEM skills (Science, Technology, Engineering and Mathematics). In particular, he called for an integrated approach in the teaching of these skills as a means to strengthen the understanding of each skill as well as a tool to motivate the learners to explore these subjects more deeply.

#### **2.4.4. Information Technology and Computer Simulations in Science**

Chapman's other contribution to strategies to remedy learner difficulties in science involved the use of information technology (IT) in science teaching – mainly focusing on the internet (2000: 106). He claimed, "education, as we practice it, is coming dangerously close to irrelevance" (Chapman, 2000:106). While one cannot gainsay the value added by IT, especially in science education, the relevance of the current educational practices is still quite high, especially in developing countries for which IT is still a luxury of an elite few. Even in cases where IT is correctly integrated with science teaching, there is still a huge value in teaching and learning scientific skills that are not computer related.

However, in this day and age of technological advancement, where access to computers in schools is increasing, be it at an extremely slow pace, the use of computers in science is becoming prevalent. Computer simulations in science teaching, is also a strategy that more and more researchers (Sahin, 2006; Rutten, van Joolingen & van der Veen, 2012; Wellington, 1994) comment on. In literature review studies by Sahin (2006) and Rutten, *et al.* (2012), the common thread was that computer simulations are more and more being utilised by teachers in classrooms.

Sahin's (2006:132) study focused more on the role that computer simulations might play in the classroom. These roles included: giving students the opportunity to observe a real world experience and interact with it; contribution to conceptual change and provision of open-ended experiences; provision of tools for scientific inquiry and problem solving; potential for distance learning; potential to supplement constructivist learning; improving learners' hypothesis construction, graphic interpretation and prediction skills.

An immediate concern with computer simulations - not against use of computers per se in science teaching - is the high level of learner passiveness. For example, learners could watch a computer simulation of an acid/base titration but strictly speaking "titrating a solution to neutrality is best done with a burette, not with a piece of software that simulates the process" (Thornburg, 2009:4).

The other concern is on how educators can utilize computer simulations as the only tool and as a means to keep the students busy. The learners could also be busy for hours clicking on icons and learning very little in the process. After all, even though simulations can be used in careers like engineering and architecture, these professionals do not stop at the simulation stage, they go further to actually construct and experience the simulated scenario.

The latter concern, however, was addressed in the review by Rutten, *et al.* (2012:137), who researched the "extent to which science education can be enhanced by using computer simulations" and "how simulations and their instructional support are best shaped to optimize the use of simulations themselves". The authors found that simulations could be used in pre-lab training, i.e. in preparation for a real laboratory activity, thereby enhancing the learners' laboratory skills. Hofstein and Lunetta (2003:42) also concurred that simulations can supplement the practical experiences quite significantly, in that while the practical shows the observation or result, a simulation can provide a visual explanation of how the result or observation came about.

When simulations are compared with lab activities, laboratory activities are designed to engage students directly with materials and phenomena, while simulations generally provide meaningful representations of inquiry experiences that are often not possible with real materials in many science topics. Simulations also become useful in cases where the investigations are too long or too slow, too dangerous, too expensive, or too time or

material consuming to conduct in school laboratories (Hofstein & Lunetta, 2003:42; (Wellington, 1994:198).

Rutten, *et al.*, (2012:151) therefore concluded that the use of educational innovations like computer simulations could only be useful if properly utilized. Hofstein and Lunetta, (2003:42) agree that it is important to note that the learning that results from engaging in a well-conducted practical experience will be quite different from the learning that results from a good simulation. Therefore, the decision about when to have students work with simulations instead of equivalent activities in the laboratory should be made mainly based on the intended learning outcomes of a given lesson (Hofstein & Lunetta, 2003:42).

In other words, simulations can be a very useful tool but not to be utilised as the main tool and certainly not the only tool. Therefore, teacher training in this regard is crucial.

#### **2.4.5. Micro-Chemistry Kits**

A common excuse given by schools and teachers for not doing practical work is the issue of costs, practical work is considered costly. Referring to chemistry in particular, Bradley *et al.*, (1998:1406) cited that these budgetary pressures in both wealthy and poor countries have acted to inhibit practical work. As a result, “practical chemistry is either steadily cut back or fossilized (in wealthier countries) or simply never implemented (in poorer countries)”. The low or no implementation is certainly the case in South Africa.

To address the cost concern, at least in the chemistry component, Bradley *et al.*, (1998:1407) suggested the use of low cost microchemistry kits, where most of the apparatus are reduced to small sizes as well as smaller amounts of the chemicals needed. This product originated in South Africa (Bradley, *et al.*, 1998:1408) and has been spotted in many South African school laboratories. What the authors did not illustrate was the impact of the use of the microchemistry kits on learner performance in chemistry.

Other than the already acknowledged limitations of this kit, like the inability to do the organic experiments with plastic kits and other experiments; the inability to perform heat-requiring experiments, there are other limitations. The main one, not mentioned in their study, is the issue of class size. These micro-chemistry kits would be best utilized if learners would work either individually or in pairs because they are so small. In a country

like South Africa, with large class sizes, one would need to purchase a lot more kits, in order to allow adequate access for all of the learners. That would probably cost more money and therefore defeat the cutting cost purpose that motivated the design of the kits.

## **2.5. CONCEPTUAL DIFFICULTIES AND MISCONCEPTIONS IN CURRENT ELECTRICITY AND MAGNETISM.**

### **2.5.1. Introduction**

The difficulties experienced by learners with Physical Science in general, can also be found in the module of electricity and magnetism, even more so in this module than in others. In this section the literature review on the exact details of the actual E&M concepts posing difficulty will be discussed, as well as how these have been addressed. The module E&M consists of two subsections: current electricity and electromagnetism. The learner difficulties discussed in this section will be intermingled with learner misconceptions in E&M as these topics are very closely related. In fact, misconceptions contribute to the difficulties and some of the difficulties lead to misconceptions, as will be illustrated by the following literature.

### **2.5.2. Misconceptions**

Learner misconceptions were also mentioned by educators as contributors to these difficulties. In a study by Bahar and Polat (2007:1124), educators added that learner misconceptions and incomplete cognitive schemes of the science concepts also contributed to learner difficulties in Physical Science. Researchers in the field of science, with current electricity no exception and electromagnetism to a lesser extent, have also attributed most of the difficulties experienced by learners to, among other reasons, learner misconceptions.

Misconceptions research has generated a wide variety of terms to characterize students' conceptions. Terms like "preconceptions" and "alternative conceptions" (Bilal & Erol, 2009:193) are commonly used to describe misconceptions. For the purpose of this study, misconceptions are defined as student conceptions that produce a systematic pattern of error (Smith, diSessa & Roschelle, 1993:119).

In this section, some of the common misconceptions as found in existing literature will be listed. Their prevalence in the learners' pre- and post-tests is discussed in section 4.9. That way, the extent to which the practical activities based approach addressed learner difficulties will be observed.

*Misconception 1:* Batteries of the same type always supply a fixed amount of current regardless of what is in the circuit (Grayson, 2004:1131). This misconception is attributed to lack of an appropriate conceptual model for electric current.

*Misconception 2:* Current emanates from the battery, i.e. current "coming out" of the battery is less than the current "going into" the battery (Sengupta & Wilensky, 2009:26). This, the authors attributed it to careless use of language. They broke this misconception into two parts: first, that the circuit elements (resistors, light bulbs, etc.) actually hinder the flow of current, i.e. offer resistance. Secondly, current needs effort to overcome this resistance offered by the circuit.

*Misconception 3:* A bulb closest to the end of the battery, from which learners think current flows, is the brightest and the other bulbs glow dimmer and dimmer as the current gets used up in the process of passing through successive bulbs. (Grayson, 2004:1128; McDermott & Shafer, 1992a:997). An alternative name for this conception is sequential reasoning where students believe that changes made in preceding circuit elements (like bulbs; resistor and switches) cannot affect the elements following (Smaill, Rowe, Godfrey & Paton, 2012:29). The authors, using the words of Engelhardt and Beichner (2004:98), attribute this to the belief that current travels around a circuit and "is influenced by each element as it is encountered and a change made at a particular point does not affect that point until it reached that point".

*Misconception 4:* Authors, Smaill and company also mention a 'blind reliance on Ohm's Law' as another misconception. For example, students thinking that when current doubles, potential difference also doubles due to  $V=IR$ , not recognizing that potential difference is a property of the battery (Smaill, *et al.*, 2012:31). This also manifests itself in students' inability to recognise that potential difference is an independent variable.

*Misconception 5:* Students have a naïve concept of induction that involves the presence of a magnet as a source of the field, through which a loop is physically moving. The idea of

induction remains at a level that includes no useful representation of field or flux as a part of the explanation. If any explanation is given, it is rather at the unspecified level of 'magnetic force causing electric current'. It is also suggested that a stationary magnet exerts a force to a static charge (Saarelainen, Laaksonen & Hirvonen, 2007:58).

*Misconception 6:* The presence of the magnetic field or the magnetic flux alone is the cause of the induced current rather than the change in the magnetic field or flux (Mauk & Hingley, 2005:1166).

*Misconception 7:* Misuse of the right-hand rule and misapplication of Lenz's Law (Mauk & Hingley, 2005:1166).

*Misconception 8:* An electric field, rather than a magnetic field induces the current (Mauk & Hingley, 2005:1166).

*Misconception 9:* In magnetic induction, the induced field is opposite in direction to the field which induces it (Bagno & Eylon, 1997:733), rather than opposite in direction to the change in the field inducing it. (Thong & Gunstone, 2008:42)

*Misconception 10:* The induced current is directly proportional to the change in current in the solenoid i.e. an increase in current in the solenoid is accompanied by an increase in the induced current. The correct conception would be an increase in the rate of change of current in the solenoid would cause an increase in the current (Thong & Gunstone, 2008: 42)

*Misconception 11:* There must always be contact between the magnetic flux and the external coil in order for any emf to be induced in the coil (Thong & Gunstone, 2008: 42)

### **2.5.3. The Role of Teachers**

In an attempt to address learner difficulties in E&M, one also needs to investigate teacher involvement in this matter. Gunstone, Mulhall & McKittrick (2009:516) conceded that the abstractness and complexity of these topics makes learner understanding frequently dependent on teacher analogies and metaphors, which can also be problematic. The

authors also believed that appropriate teaching of direct current (DC) electricity concepts was a huge factor in learners' understanding of these concepts.

Gunstone *et al.*, (2009:518) conducted interviews with Australian teachers among which were textbook writers. In these interviews, they “explored teachers' perceptions of difficulties in student learning and their own teaching of DC electricity, their uses of models and analogies in this teaching, and their own understandings of the concepts of DC electricity”. From these interviews Gunstone *et al.*, (2009:531) concluded with “concerns about the nature of conceptual understanding held by a majority of these teachers and educators”.

Secondly, they also discovered that although the teachers admitted to the use of models and analogies, they could not differentiate between models and analogies – an indication of their inadequate understanding of the nature of Physics learning. The levels of teacher understanding of the nature science and science knowledge can clearly not be separated from some of the learner difficulties in this section of work. This is because teachers are the main source of scientific knowledge for their learners (Gunstone, *et al.*, 2009:529).

#### **2.5.4. Confusion of terms: current, potential difference, power, resistance**

Turning the focus to students, McDermott and Shaffer (1992a) investigated students' understanding of circuits, as a guide in curriculum development. Their study had three parts: examining student difficulties in current electricity, designing instructional strategies that address these difficulties and continuously designing, testing, modifying and revising the materials. These authors (McDermott & Shafer, 1992a:996) – in agreement with other researchers (Grayson, 2004:1127); (Driver, *et al.*, 1994b:121); (Fleer, 1994:252) – have clearly crystallised the learner difficulties with current electricity. Firstly, they summarized that students tend to confuse the concepts of current, potential difference, power and resistance, as explained below:

1. “Failure to distinguish among related concepts”. This often occurs between current and voltage where students sometimes perceive voltage as the strength or force of the current.

2. "Lack of concrete experience with real circuits". This is attributed to the fact that most students had no previous experience with circuits that they could use as a foundation for the formal concepts in current electricity.
3. "Failure to understand and apply the concept of a complete circuit". This manifested itself in the lack of care when drawing circuit diagrams involving a light bulb. A common error was to show only the bottom tip of the bulb in contact with the wire instead of both terminals of the bulb.

### **2.5.5. Inadequate Understanding of Electric Current**

1. Secondly, McDermott and Shafer (1992a:997; (Grayson, 2004:1127); (Driver, et al., 1994b:119-121) revealed that students' inadequate understanding of electric current is the main contributor to learner difficulties in current electricity. Students seem to have the following beliefs of electric current, some of which were discovered by other researchers as well:
  2. "The direction of current and the order of elements matter". This was especially the case when the light bulbs are labelled alphabetically.
  3. "Current is used up in a circuit". This was a very common misconception, where students tended to think that current is produced by the battery and is used up by the other circuit elements. In other words, for many students the fact that current is conserved in a given circuit remains an abstract idea that they cannot apply to qualitative current electricity questions (Driver, *et al.*, 1994b:119)
  4. "The battery is a constant source of current". This "most pervasive and persistent difficulty" was explained by the reasoning that students tend to overlook the critical role of resistance in determining the current in a circuit.

### **2.5.6. Failure to Distinguish Between Potential Difference and Current**

Thirdly, students often failed to make clear distinction between current and potential difference (McDermott & Shafer, 1992a:997-998). This difficulty usually manifests itself in the following failures:

1. "Failure to recognise that an ideal battery maintains a constant potential difference between its terminals". Most students did not realize that a battery and its potential difference are independent of the circuit to which it was connected.
2. "Failure to distinguish between branches connected in parallel across a battery and connected in parallel elsewhere". In this case the students simply ignored the presence of the other circuit components and treat it as a circuit with the parallel combination and the battery only.
3. "Failure to distinguish between potential and potential difference"

Engelhardt and Beichner (2004:106) attributed this difficulty to term confusion, associated with current. They explained that students assign properties of energy to current, and then assign these properties to voltage and resistance. Students, according to these authors, think that "both voltage and resistance can only occur in the presence of a current".

### **2.5.7. Inadequate Understanding of Resistance**

Fourthly, students did not have an adequate understanding of the concept of resistance, enough to apply it correctly (McDermott & Shafer, 1992a:998). This inadequate understanding was manifested at follows:

1. "Tendency to focus on a number of elements or branches instead of the relative resistances of the branches" (McDermott & Shafer, 1992a:998) In other words, they viewed a circuit with more resistors as having a higher resistance, regardless of what the actual effective resistance is.
2. "Failure to distinguish between the equivalent resistance of a network and the resistance of an individual element" (McDermott & Shafer, 1992a:999). This was especially true when it pertained to the use of equivalent resistance to determine total current and then brightness of bulbs.
3. "Difficulty in identifying series and parallel connections" (McDermott & Shafer, 1992a:998) especially when the circuits were unconventionally drawn.

### **2.5.8. Interpretation of Circuit Diagrammatic Representations**

Fifthly, students also had difficulty interpreting circuit diagrammatic representations and numerical measurements of electrical quantities (McDermott & Shafer, 1992a:999-1000). This was illustrated by the following failures:

1. "Failure to recognize that a circuit diagram represents only electrical elements and connections, not physical spatial relationships". This was observed in how students focus on the physical appearances in a circuit rather than the electrical connections.
2. "Failure to treat meters and circuit components and to recognize the implications for their connections"

Engelhardt and Beichner (2004:106) also attested to the ability of students to translate easily from a real circuit to a diagrammatic representation but struggled with the reverse translation. The authors suggested that this behaviour may be an indication of the students' difficulty to identify shorts within a circuit or lack of knowledge pertaining to the contacts for light bulbs.

### **2.5.9. Inability to Reason Qualitatively About Electric Circuits**

Lastly, McDermott & Shafer (1992a) indicated that, in addition to the above, students were unable to reason qualitatively about the behaviour of electric circuits. Because of this, it tended to be impossible to distinguish whether the difficulty was a conceptual or a reasoning difficulty. The following tendencies, illustrated this point further:

1. "Tendency to reason sequentially rather than holistically" (McDermott & Shafer, 1992a:1001). Students tended to think of a circuit as consisting of separate individual entities that could be analysed independently of one another. Explaining their sequential reasoning, Driver, Squires, Rushworth and Wood-Robinson (1994:120) added that students tend to think that "something from the battery travels around the circuit" meeting the circuit components in sequence. They attributed this "deep-seated notion" to the "cause and effect" experiences of everyday life.
2. "Lack of a conceptual model for predicting and explaining the behaviour of simple dc circuits" (McDermott & Shafer, 1992a:1001).

## **2.6. STRATEGIES TO REMEDY THE DIFFICULTIES**

### **2.6.1. Physics by Inquiry**

In part II and part III of their study McDermott and Shaffer (1992b) explained in detail two strategies that they successfully utilised to significantly reduce these difficulties.

The first was “a set of laboratory-based instructional modules collectively called Physics by Inquiry” (McDermott & Shaffer, 1992b:1003). This approach was aimed at “encouraging students to make the necessary mental commitment by guiding them through the process of constructing conceptual models” (McDermott & Shaffer, 1992b:1004) through hands-on experiences. In addition, there were strategies specifically designed for specific difficulties but they generally fit within the categories of conceptual models and hands-on experiences.

### **2.6.2. Tutorials**

The second strategy – tutorials – consisted of “curriculum materials for use in conjunction with the lectures and textbooks” (McDermott & Shaffer, 1992b:1003). This was used as an alternative measure for large classes in which the use of a laboratory-based curriculum was not feasible. Their purpose was not to deliver additional information but to help the students gain a deeper conceptual understanding and develop their scientific reasoning skills. A typical tutorial session would be an interactive lecture in which demonstrations of the key experiments are done. This was followed by worksheets and questions to guide students in critical observations and reasoning and then small groups of students working together in analysing circuit diagrams of various configurations (McDermott & Shaffer, 1992b:1010).

The detailed list of current electricity difficulties as provided by McDermott and Shafer (1992a) can hardly be disputed as it is quite evident in learners, even today, as discussed in the misconceptions prevalence section 4.9. The common feature of learner involvement and an encouragement of learner reasoning in both strategies is applauded.

However, more could be done to increase the “hands-on” component of the tutorials strategy. The problem with demonstrations done in front of a big class, even when supersized, is that not all the students can actually see what is going on. They certainly do not own that practical experience, as they did not construct the circuit themselves. Seeing

that there are the small groups after the demonstrations, perhaps the experiments could be done in these groups and then the discussions after that. Small groups allow the students to be hands-on, to repeat as much as necessary, and to learn to troubleshoot if necessary. The best way to learn something is not show and tell but doing.

### **2.6.3. Concept Substitution**

Another strategy, employed to address the misconceptions that “current is used up in the circuit” and that “a battery supplies a fixed amount of current, regardless of what is in the circuit” (McDermott & Shafer, 1992a:997), as proposed by Grayson (2004), is a strategy called “concept substitution”. The author utilized this remedy to assist “academically talented” (Grayson, 2004:1127) Science Foundation program black disadvantaged students at the University of Natal who seemed to have the Physics concepts entangled.

Concept substitution as defined by (Grayson, 2004:1128) is

“a teaching strategy of building on correct students’ intuitions by substituting the name of the appropriate Physics concept for an inappropriate one. Concept substitution involves creating a situation in which it is likely that students will associate a correct intuitive idea with an inappropriate Physics concept. When this happens, the instructor reinforces the student’s correct idea, but assigns it another label. In other words the instructor substitutes the name of the concept with which the student’s idea can be correctly associated for the one used by the student”.

The nature of the intervention was such that “a circuit was shown consisting of a battery in series and three bulbs” (Grayson, 2004:1128) i.e. a practical demonstration. The students predicted the outcome before the demonstration. They were then shown the circuit, discussed their observations and explanations afterwards. This is where the author substituted their incorrect preconceptions with the correct explanations and terms for this topic. Before the next lecture students did a two and a half hour laboratory session on series and parallel combinations of bulbs using ammeters to measure currents and nichrome wires of different lengths instead of bulbs (Grayson, 2004:1128).

In terms of the identification of the stated misconceptions among the learners, Grayson’s (2004) concept substitution cannot be disputed. This strategy has been tested among a group of university first year students, who would have come across these current electricity concepts in almost all their high school science career. Yet one wonders about

the effectiveness of concept substitution in addressing the very same misconceptions to students to whom the concepts of “current” and “energy” had not yet been introduced.

The other area of concern, in the process of “the instructor substituting the student’s idea with a new label” (Grayson, 2004:1128), is that there does not seem to be enough time spent, at the very early stages of this intervention, actually explaining the meaning of the terms “current” and “energy” (foundational concepts) in helping the students understand why their concept is incorrect and the instructor’s idea correct. This simple substitution, without explanations of the terms at the beginning of the intervention, might be the cause of the misconceptions taking much longer to be cleared. For example, (Driver, *et al.*, 1994b:122) also showed that it is best to start by introducing “voltage” initially as a property of a battery and a precondition for current and that “voltage” is present even when there is no current flow.

The use of “more demonstrations to reinforce” the newly learnt concepts was certainly another strength of this intervention (Grayson, 2004:1129). It does, however, seem a little incomplete without spending a lot more time on more complex problems showing different scenarios where the learners get to apply their newfound concepts. Such an exercise, combined with the increased use of experiments, would improve the learners’ confidence as well as assist in learners forgetting their old terms and formally adopting and using the substituted ones.

In summary, current electricity is a challenging science topic at all school levels. Learners often have many misconceptions and difficulties in understanding and learning it. As a solution, a learning environment which combines the strengths of traditional laboratory exercise and simulations working with tasks that structure student work and explicitly address common difficulties in learning electricity must be developed (McDermott & Shafer, 1992a; 1992b).

## **2.7. ELECTROMAGNETISM DIFFICULTIES AND MISCONCEPTIONS**

### **2.7.1. Introduction**

Learner difficulties in electromagnetism have not yet been as well documented as those in current electricity but one tool that has been successful in surveying students’ conceptual

difficulties' in E&M is the Conceptual Survey of Electricity and Magnetism (CSEM) as designed by Maloney, *et al.*, (2001:12). The CSEM, a highly analysed and reviewed broad survey instrument, consists of a series of multiple-choice questions covering conceptual areas in E&M. This survey's pre- and post-tests have generally been used to survey learners' difficulties before and after normal instructions either at university or at high school level.

The one weaknesses of the CSEM, however, is the fact it consists of multiple-choice questions only. Though the questions have been carefully selected and continuously reviewed, one can never completely eliminate the guess factor when it comes to multiple-choice questions. This might lead to misdiagnosis of the difficulties, and therefore mistreatment.

Making use of the CSEM, in a comparative study between American and Croatian university students, Planinic (2006:1143) endorsed the generalizability of the difficulties diagnosed through it. This is because both groups, though different, exhibited the same difficulties.

### **2.7.2. Reliance on Other Domains and Issues of Language**

Maloney, *et al.*, (2001:12) discovered that one of the reasons for difficulty in E&M is the fact that this section is quite broad and relies on understanding in other domains such as force, motion and energy. Current electricity can also be added to these domains. Therefore, lack of understanding in the other domains will clearly translate in lack of understanding in E&M as well.

Maloney, *et al.*, (2001:19) also emphasized the challenge of language in E&M. This is because of the vast difference between the everyday student language and the Physics language making it difficult to know how students actually interpret the questions versus how teachers interpret the questions.

### **2.7.3. Abstractness of Terms and Mathematical Skills**

In addition to the reliance of electromagnetism on some mechanics concepts, Planinic (2006:1147) also discovered that electromagnetic induction was the most difficult concept due to the abstractness of the concept of magnetic flux.

Focusing on university students in an introductory calculus-based Physics course, Chabay and Sherwood (2006:329) also admitted that in the E&M segment of this course there are many new and abstract concepts embodied in complex relations, which students find significantly more difficult than classical mechanics. The main central concept was that of field – magnetic and electric field. This is especially the case when these concepts are introduced at a rapid pace, which can be overwhelming to the students. Chabay and Sherwood, (2006:329) therefore concurred that the levels of abstraction made E&M difficult. In addition, they also submitted mathematical sophistication as another main difficulty in E&M.

Related to the abstractness experienced in E&M, researchers Dori and Belcher (2005:249) asserted that two other causes contribute to the serious difficulties that confront students in E&M. The first is the fact that humans “are simply not equipped to gauge magnetism”. They exemplified that although current electricity could be indirectly observed (e.g. light bulb glowing) or felt by electric shocks, there was almost no sensual indication of magnetic fields.

Secondly, Dori and Belcher (2005:249) submitted that electromagnetism is in a realm of Physics that is not covered by any of the five human senses, which posed a greatest challenge when students are trying to make electromagnetic concepts concrete. Therefore, “visual imagery” could help make the abstract concepts encountered in electromagnetism more concrete (Dori & Belcher, 2005:250).

Related to the abstractness of E&M and the Mathematics involved, students were also found to have a difficulty effectively using and retaining knowledge in electromagnetism (Bagno & Eylon 1997:726). This was demonstrated in a study conducted with high school students majoring in Physics and had completed their course in electricity and magnetism.

These difficulties were also attributed to the fact that the electromagnetism concepts were far removed from students’ experience and the “mathematical aspects add another obstacle to those who are unsophisticated mathematically” (Bagno & Eylon, 1997:726).

Therefore, in order for the learners to succeed in this section, there needed to be an acquisition and application of the abstract concepts and relationships involved (Bagno & Eylon, 1997:726).

#### **2.7.4. Fuzzy Encoding**

Bagno and Eylon, (1997) diagnosed a few difficulties, some of which are not relevant for this paper, but notably

“students have difficulty in determining the direction of the induced magnetic field. The major source of this difficulty has to do with fuzzy encoding. An examination of the relevant textbooks suggests that sentences like ‘*the induced current resists its cause*’ are too vague. Students interpreted these sentences incorrectly. For example, *opposes the change* is interpreted as *being in the opposite direction* (Bagno & Eylon, 1997:729)”.

### **2.8. REMEDIES**

#### **2.8.1. Restructuring of E&M courses**

As a remedy to some of these difficulties, Chabay and Sherwood (2006:329) suggested a restructuring of the E&M course that “stresses conceptual coherence, connects the abstract field concepts to concrete microscopic models of matter, and follows a clear story line, culminating in the classical model of the interaction of electromagnetic radiation and matter”. They believed that this sequence could be effective in teaching the basic concepts on E&M.

Although this paper of Chabay and Sherwood (2006) did not seem to have been tested for success, one is inclined to believe that it could work – given enough time. The challenge in the South African context however, would be the fact that in the current national curriculum statement (NCS) and Curriculum and Assessment Policy Statement (CAPS), a module spans over three years (grade 10, 11 and 12). This means that one starts a concept, for example, E&M in grade 10, but stops at a certain point, only to continue in Grade 11 and finish it in grade 12.

This spreading of related content over three years offers no opportunity for a “unified approach” (Chabay & Sherwood, 2006:329) and it also means that educators almost start from scratch each time they cover that module as learners tend to forget what was done the previous year. This is exactly the case with E&M at schools. The grade 12 examination

guidelines that the DBE publishes every year exacerbate this problem in that educators – in the grade 10 and 11 years – only teach that which is examinable in Grade 12, thereby providing little or no foundation at all for these concepts when they have to be taught in the grade 12 year.

### **2.8.2. Tutorials**

In a study aimed at measuring the impact of using tutorials in introductory Physics to teach E&M, Mauk and Hingley (2005:1164), working with tertiary students, concluded that tutorials did a better job of addressing the E&M concepts they were investigating. “Tutorials”, according to the authors is a strategy that

“emphasized concept development and scientific reasoning, rather than problem solving, and consisted of a pre-test designed to probe student conceptions, worksheets that support hands-on activities and homework. The hands-on activities are conducted in groups of three to four students with the guidance of a teaching assistant whose job is not to teach but to engage the students in dialogues to help the students construct their own knowledge” (Mauk & Hingley, 2005:1164).

In this study, Mauk and Hingley (2005:1166) discovered that learners had difficulties with E&M concepts like induced current – the cause and the direction thereof; magnetic force – determining the direction and the superposition principle. On induced current, the most common error was that “the presence of a magnetic or the magnetic flux alone was the cause of the induced current rather than a change in the magnetic flux” (Mauk & Hingley, 2005:1166).

As the authors showed with their results, the benefits of the tutorials approach, certainly to their students, showed a lot of promise. One of its strengths is the strong focus on learner-centeredness rather than teacher focus, through their hands-on experiences, worksheets and homework activities. Its greatest limitation however, as acknowledged also by them, would be time. The amount of time required would make it difficult to roll out such an approach to an entire department for the whole curriculum.

### **2.8.3. Concept Maps**

To remedy the difficulties in electromagnetism, Bagno and Eylon (1997:735) suggested

“an integrative instructional approach that is centred on the construction of a hierarchical concept map by the students. The map is constructed by students in five stages (SOLVE, REFLECT, CONCEPTUALIZE, APPLY, LINK). Students solve problems and add concepts and relationships that are used in the problems in the map. As a result, a well-organised linkage is formed between conceptual knowledge and how it is used in problem solving. When new concepts are added to the map, the relevant conceptual issues and difficulties are treated and thus conceptual knowledge is naturally linked to the structure. The hierarchical design of the map at different levels of detail is helpful for recall and problem solving: higher level information helps retrieve more detailed information”.

The results of this intervention showed an overall advantage on students in aspects of recall, conceptual understanding and problem solving. The students also learnt how to identify important ideas and relationships in the presentation of an unfamiliar topic. The authors concluded that a useful knowledge representation formed by the students exposed to their intervention is the cause for the above learning outcomes (Bagno & Eylon, 1997:735).

Although the authors mention an increase in problem solving abilities, they have not shown clearly however, the impact of this concept-map strategy in solving the mathematical aspects of electromagnetism. Another concern is that it might not be appropriate to use in cases where the students have not been taught the concepts yet, particularly second language speakers.

The reason for this assertion is that for the students to know where to place an idea on the concept map depends on the students' understanding of that concept. The strategy does however, encourage, among other things, student ownership of their own learning, but it would be more effectively utilized in conjunction with other strategies.

#### **2.8.4. Peer Instruction**

Adding his contribution to the remedies research, Gok (2012:418) proposed peer instruction (PI) as a strategy to increase student understanding in E&M. Peer instruction, a student-centred approach to teaching, was defined as a modification of the traditional lecture format to include questions aimed at engaging students and thus uncovering their difficulty with the content. These ideas were then voiced and misunderstandings resolved by talking with their peers. In other words, students learnt new concepts by working together, thereby creating a more cooperative learning environment in which they “learn as a community in the classroom” (Gok, 2012:418).

Gok (2012:417) tested this strategy with college students, making use mainly of the CSEM (Maloney, *et al.*, 2001) among other surveys. The research revealed a significant improvement in correct responses to the CSEM in the group of learners that took part in the PI treatment and therefore asserted the effectiveness of this strategy.

Among other advantages, as listed by Gok (2012:419), peer instruction encouraged students to take responsibility for their own learning. It does have its limitations however, in cases where the expert student might be harbouring his or her own misconceptions concerning a particular topic, those might be transferred to his peers, thereby perpetuating the cycle of misconceptions. While the role of PI in students gaining insight on various E&M topics through discussions with their peers, is acknowledged, one would need to be careful to ensure that the necessary confidence in the participating students is adequately cultivated, otherwise this activity might be a waste of unavailable time and a cause of stress for some of the shy students.

### **2.8.5. TEAL Project**

In order to assist learners conceptualize electromagnetism phenomena and processes, thereby narrowing the gap between abstract and concrete, Dori and Belcher, (2005:243) made use of the Technology-Enabled Active Learning (TEAL) Project. This project was designed motivated by the desire to involve students in technology-enhanced active learning. The project is

“a carefully thought-out blend of mini lectures, recitations, and hands-on laboratory experiences, which are merged into a technologically and collaboratively rich experience for students. It incorporated a variety of passive and active visualizations that enable students to develop intuition about various electromagnetic phenomena, by making the unseen seen in game playing and experimentation. TEAL was innovative in that it applied state-of-the-art visualization technologies to transform the main E&M topics of the introductory course from abstract to concrete” (Dori & Belcher, 2005:252).

The researchers utilised pre- and post-tests to assess the impact of the TEAL project on a group of first year Physics students and they discovered that the TEAL students' conceptual understanding improved to a much higher level compared to their peers in the control group.

As successful, relevant and multi-faceted as the TEAL Project seems, in the South African context, it would take a long time to be implemented as a strategy in most schools and / or universities due to the cost implications attached. Some South African education institutions are still struggling to fund even the basic needs of science departments like laboratories.

## **2.9. THE USE OF PRACTICAL ACTIVITIES IN SCIENCE**

### **2.9.1. Introduction and Definition of Terms**

As a theoretical base for this research paper, it is proposed that some of the solutions to the challenges in E&M can be remedied by the use of practical activities. It is therefore imperative to also review the existing literature arguing for or against the use of practical work in teaching and learning Physical Science. This section will start by clearly defining practical activities as applicable to this study as well as discuss other related concepts like scientific investigations, inquiry, experiments, etc.

Practical activities in Physical Science teaching take two forms: scientific inquiry or investigations and practical work (or laboratory work) or what this study refers to as “practical activities”.

For the purpose of this study, scientific inquiry or investigations refers to

“diverse ways in which scientists study the natural world, propose ideas, and explain and justify assertions based upon evidence derived from scientific work. It also refers to more authentic ways in which learners can investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of Science” (Hofstein & Lunetta, 2003:30).

To expand on the above definition of scientific inquiry, Hofstein and Lunetta (2003:30) emphasize that

“inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what are already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations”.

Practical work on the other hand means “any teaching or learning activity which involves students observing and manipulating real objects and materials” (Millar, 2004:2) in order to

achieve scientific knowledge. In a way, practical activities are only part of scientific inquiry, teaching content knowledge while inquiry also emphasizes the process skills as mentioned above.

Wellington (Wellington, 1998, p. 12) suggested least six types of activities that take place in school science could be categorised as practical work, These activities included “teacher demonstrations; class practicals, with all learners on similar tasks, working in small groups; a circus of ‘experiments’ with small groups engaged in different activities, rotating in a carousel; investigations, organized in one of the above two ways; and problem-solving activities”.

The purpose of this research paper is to explore and discuss the effectiveness of practical work (the latter) in addressing learner difficulties in Physical Science (specifically E&M) i.e. in affecting learner knowledge in this module.

### **2.9.2. Practical Work and Science Curriculum**

“A distinctive and prominent feature of science education”, practical work is seen by many as an “essential element of good science teaching” (Millar, 2009:1). The aims of the science curriculum in most countries are well summarized in the words of Millar (2004:2) who states that most countries have two distinct purposes. The first purpose is to provide every young person with “scientific literacy”, i.e. a sufficient understanding of science to confidently and effectively participate in the modern world. The second purpose is to provide society with a steady supply of new recruits for jobs that require more detailed scientific knowledge and expertise and science in schools provides the foundation for the more advanced study leading to these jobs (Millar, 2004:2).

South Africa as a country also subscribes to Millar’s (2004) purposes, at least on paper, as indicated in their NCS for Physical Science. According to the DoE (2003:9), among other aims, the study of Physical Sciences is aimed at contributing towards the holistic development of learners in the following ways:

- giving learners the ability to work in scientific ways or to apply scientific principles which have proved effective in understanding and dealing with the natural and physical world in which they live (DoE, 2003:9);

- developing useful skills and attitudes that will prepare learners for various situations in life, such as self-employment and entrepreneurial ventures (DoE, 2003:10).

In tandem with the country's' aims, science education generally has two aims, first to increase students' scientific knowledge and then to develop their understanding of the nature of science (Millar, 2004:4). The second aim – understanding the nature of science – is generally attained through an engagement in scientific inquiry among other things. The first aim – scientific knowledge i.e. the content that you will find in science textbooks - is what this study theorises that its attainment is highly increased by the use of practical work.

In the South African context, the National Curriculum Statement (DoE, 2003:12) encompasses the above aims of science education in two of the three learning outcomes (LO's):

#### LO1: Practical Scientific Inquiry and Problem-solving Skills

The thrust of this Learning Outcome is on the doing aspects and the process skills required for scientific inquiry and problem solving. Learners' understanding of the world will be informed by the use of scientific inquiry skills like planning, observing and gathering information, comprehension, synthesising, generalising, hypothesising and communicating results and conclusions. In addition to investigation of natural phenomena, information will be used in problem solving. Problem solving is central to the teaching and learning of Physical Sciences. (DoE, 2003:12)

#### LO2: Constructing and Applying Scientific Knowledge

Underlying this Learning Outcome is the notion of constructing, understanding and applying knowledge in socially, technologically and environmentally responsible ways. The content (facts, concepts, principles, theories, models and laws) and skills studied in Physical Sciences helps learners to gain a better understanding of the world they live in, and to explain physical and chemical phenomena (DoE, 2003:13).

### **2.9.3. Scientific Inquiry vs. Practical Activities**

The contradiction, this study proposes however, is that the scientific inquiry, as one of the outcomes, does not seem to have contributed much in improving the standard of Physical Science education (i.e. increasing scientific knowledge) in the majority of South African learners. The challenges as expressed by teachers at teacher meetings include time, their inadequate knowledge of the scientific process and when known, too much focus on the process and little on the knowledge to be gained from the process.

In 1996, the US National Research Council's (1996:23) *National Science Education Standards*, defined scientific inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of how scientists study the natural world".

While scientific inquiry might help learners with regards to knowledge about the nature of science, "as a method of teaching established scientific knowledge" however, it has serious shortcomings (Millar, 2004:3). These shortcomings are as follows:

1. The observations and measurements made by the students are often incorrect, incomplete or inaccurate. This could be due to their inexperience with equipment or the quality of equipment provided and / or the amount of time available (Millar, 2004:3). Although this is not peculiar to scientific inquiry, the nature of scientific inquiry makes it difficult to deal with inaccurate results.
2. Even when students manage to collect the correct data, they often struggle to draw the necessary conclusions from their data. This is because in the students' mind, ideas and explanations are not obvious from the data and the difficulty of this step is often underestimated by teachers (Millar, 2004:3).
3. The unintended reliance on the teacher for correctness of results is a common feature because students know that the teacher knows the answer, if they do not. (Millar, 2004:3)

Another challenge with using scientific inquiry in assisting learners acquire scientific knowledge is that it "draws erroneous parallels between the teaching laboratory (classroom) and the research laboratory and between the purposes of learners and scientists" (Millar, 2004:6). The truth, according to Millar (2004:6) is that in the teaching and learning of high school science, students are not really expected to discover new theories but to rather learn what others (scientists) have already discovered and already know.

To return to the South African context, the revised version of the National Curriculum statement, CAPS (Curriculum and Assessment Policy Statement) has actually adopted a different view concerning practical work – shifting focus from scientific inquiry to practical activities again. The recommendation now from the South African DBE, as per the CAPS documents is that learners must do at least one practical activity per term and this activity

is prescribed and then accompanied with recommended practical activities as well (DBE, 2011:9).

One practical activity per term is clearly not enough, yet there seems to be an acknowledgement that for the purposes of teaching learners science, practical activities are better than scientific inquiry. If the recommended practical activities would also be done with the learners, better results would emerge.

#### **2.9.4. Practical Work and Scientific Knowledge**

Practical work is one of the distinctive features of science teaching and one of the great expectations of pupil learning (Wellington, 1994:128). In a paper that can also be extrapolated to the South African context, referring to secondary schools in the United Kingdom (UK), Toplis and Allen (2012:4) cited that the main aim of practical work is to aid in the learning of theory. These authors pointed out that the aim of secondary school education is the presentation of scientific facts and ideas to children in the hope that they construct meaningful concepts from this experience for use in either further scientific study or everyday life. Toplis and Allen (2012:4) then suggested that this is done first by spending time on the theory and then followed up by the practical work relevant to the theory. This practical work “is seen as a continuance of this substantive learning, providing for the elucidation, consolidation and discovery of material” covered during the theory session.

Practical work is generally believed to be part of what teaching and learning of science is all about (Woodley, 2009:49). Therefore, in this regard the issue is not whether or not to use practical activities but how to use them and how efficiently, as they play a crucial role in augmenting other forms of communication (verbal, graphical, pictorial, and symbolic) that teachers use in their teaching (Millar, 2004:6).

Woodley (2009:59) defined practical work in science as “a hands-on learning experience which prompts thinking about the world in which we live”. Millar (2004:6) contributed also that the subject matter of science is the real world. Therefore learning of science should involve “seeing, handling, manipulating real objects and materials” and the teaching of science should involve “acts of telling and showing” (Millar, 2004:6). This is best achieved by properly executed practical activities, especially in cases of abstract phenomena. It is

important to note that the data collection and interpretation phase should be seen as part of the practical activity as well (Millar, 2004:8).

Woodley (2009:49) also submitted that “good quality practical work could engage students, help learners to develop important skills, help them to understand the process of scientific investigation and develop their understanding of scientific concepts”, thus increasing their scientific knowledge. Citing the work of Kerr (1963), Wellington (1994:129) mentioned ten possible aims for practical work, some of which included

- to elucidate the theoretical work so as to aid comprehensions;
- to verify facts and principles already taught;
- to be an integral part of the process of finding facts by investigation and arriving at principles
- to arouse and maintain interest in the subject and
- to make biological, chemical and physical phenomena more real through actual experiences.

Wellington (1994:131) also went further to offer the following as the roles of practical work in science:

- to develop skills like practical skills, procedures, working with others, investigation strategies, communication and problem solving;
- to illustrate (i.e. provide first-hand knowledge of) an event, a phenomenon, a law, a concept, a principle or a theory;
- to motivate in order to arouse curiosity, enhance attitudes, develop interest and or fascinate;
- as well as to challenge and or confront ideas.

Although, it might be difficult to design one practical activity that would be able to achieve all these roles, practical work as an approach to science teaching can certainly go a long way to achieving these roles.

Wellington (1994:132-133) went further to propose six types of practical work. These were demonstrations, whole-class practical work, circus if experiments, simulations and role-play, investigations and problem solving activities. The preceding roles of practical work are then achieved differently, in the types of practical work. The practical activities based approach utilised in this study is represented on Wellington’s (1994) list by the whole-class practical work.

Expounding on scientific knowledge, Millar (2004:8) established that there are two domains of knowledge: the domain of real objects and observable things as well as the domain of ideas. The role of practical work is to “help students make the link between these domains” (Millar, 2004:8).

The manner in which the link between these domains can be successfully achieved depends, according to Millar (2004:9), on the intended learning objectives of that practical task and he listed five main science content objectives of practical tasks. These objectives were, to help students to

- i. identify objects and phenomena and become familiar with them;
- ii. learn a fact or facts;
- iii. learn a concept
- iv. learn a relationship
- v. learn a theory or model (Millar, 2004:9)

With regards to the identification of phenomena and objects (i) as well as learning facts (ii), Millar (2004:9) asserted the important role of practical work in the teaching and learning of science. These two objectives provide the learners with first-hand experience of the world thereby increasing their understanding. Another reason for the importance of practical work, related to the two objectives, is that it allows students to observe more than what they would observe in their everyday lives and to observe the relevant features closely enough (Millar, 2004:8).

According to Millar (2004:9) practical work with the last three objectives: learning a concept; learning a relationship and learning a theory or model, tends to fall more on the domain of ideas. It is important to note however, that the achievement of these objectives is unlikely to be achieved as a result of a single practical task no matter how well designed. This achievement is rather a “gradual process of acquiring deeper and more extended understanding of an abstract idea or set of ideas” (Millar, 2004:9).

In fact, Millar (2009:5) later added that practical activities that involve the domain of ideas have a significantly higher cognitive demand on the learner than those in the domain of objects and observables. For this reason, reiterated Millar (2009:5), it would be unreasonable to expect mastery on this domain to happen from a single, brief practical

activity. Learning is likely to be a result of a series of carefully planned activities of various kinds including some practical activities at times.

### **2.9.5. Effectiveness of Practical Work**

On the matter of effectiveness of practical work, Woodley (2009:49) advised that a good practical task is one that achieves its aims of effectively communicating a clearly defines set of ideas. Woodley (2009:49) also added that with a practical activity, communicating its purpose and learning objectives to the learners, one could increase its effectiveness as a learning experience and enable the learners to get the most out of it. When properly executed, practical work can stimulate and engage students' learning at different levels, challenging students mentally and physically in ways that other science experiences cannot (SCORE, 2009:2).

Woodley (2009:50) further extrapolated that if the goals and objectives of a practical activity are not expressed; there is a danger of students simply following 'recipes' during practical activities. In fact, critics on practical work have expressed doubt about the effectiveness of practical work for teaching scientific knowledge. For example, Hodson (1991 cited in Millar, 2004:9) argued that

“as practiced in many schools, practical work is ill-conceived, confused and unproductive. For many children, what goes on in the laboratory contributes little to their learning of science or to their learning about science and its methods. Nor does it engage them in doing science in any meaningful sense. At the root of the problem is the unthinking use of laboratory work”

In agreement with the above sentiments and advocating for scientific inquiry, Clough (2002:86) used the term 'cookbook laboratory' to illustrate the point that these laboratory experiences do not promote and they often hinder deep conceptual understanding. Clough (2002:87) further added that 'cookbook laboratories do an extremely poor job of making apparent and playing off students' prior ideas, engendering deep reflection and promoting understanding of complex content', thus making the facilitation of the desired learning outcomes more difficult.

While it is true that an “ill-conceived” practical work session can result in nothing but a source of entertainment for the learners, this does not mean than practical work itself cannot work in teaching scientific knowledge. The “ill-conceived” practical session points more to the inability of the teacher to adequately use practical work. Therefore, more effort

and energy needs to be spent on teacher training, guiding their use of practical work as an effective tool to increase scientific knowledge.

In other words, in order “to guide teaching and learning, it is very important for both teachers and students to be explicit about the general and specific purposes of what they are doing in the classroom. Explicating goals for specific students’ learning outcomes should serve as a principal basis upon which teachers design, select, and use activities” (Hofstein & Lunetta, 2003:38). Practical activities have to be appropriately designed and managed and the teacher is at the centre of that. If the recommendations above are not met, the enthusiasm of both teachers and learners quickly declines, because they see no value in it (Bradley, *et al.*, 1998:1406).

Practical activities can also be integrated with other meta-cognitive learning experiences such as the Predict-Observe-Explain (POE) approach by Gunstone (1992), cited by Wellington (1994:131). In the POE, students are asked to predict what they would expect to happen in a given situation and to record the predictions, then to carry out the task and make some observations and finally explain what they have observed. The POE can help challenge students’ misconceptions about matters of fact, more so because of students ideas have been declared upfront, the students are more convinced when an observation either endorses or refutes another. These predictions also make the classes more interactive instead of being dull and uninspiring (Millar, 2004:11).

Another weakness of some practical work tasks, according to Millar (2004:11) is taking into insufficient account, the need of learners to make the links between the domain of ideas and that of real objects and observable things. This weakness generally pertains to the three objectives: learning a concept; a relationship; and a theory or model. This is caused by teachers’ underestimation of the cognitive challenge involved in these three objectives compared to the first two: identifying objects and phenomena, and learning facts (Millar, 2004:11).

Millar (2004) went further to suggest a key to improving on the weakness mentioned in the preceding paragraph. He suggested that teachers needed to “appreciate that tasks which require students to make explicit links between the domain of objects and the observables and the domain of ideas, are challenging” (Millar, 2004:12). Teachers and facilitators need

to design practical activities that take this relationship more explicitly and fully into account and thus “scaffolding” students to make these links.

The teacher therefore remains at the centre of the effectiveness of practical activities by his remaining clear of the intended learning outcomes of the practical activity. Millar (2004:12) therefore summarizes the following as the characteristics of more effective practical work:

- Clearly outlined learning outcomes.
- A limited number of learning outcomes per practical activity. Otherwise, the practical task becomes too complex that students can end up lost. If a certain skill is necessary for a practical task, then students need to be made competent in that skill prior to the practical task. If not addressed, the lack of that skill may stand in the way of learning.
- The structure of the practical tasks must scaffold the learners’ thinking if the task requires learners to link the domains of ideas and objects and observables (Millar, 2004:12).

Woodley (2009:50) summarized that really effective practical activities should therefore enable students to build a bridge between what they can see and handle (hands-on) and scientific ideas that account for their observations. Contributing on the concept of “effectiveness” of practical activities, Millar (2004:13) submitted four development and implementation stages for a practical task. These stages were:

- A. Objectives (what students are intended to learn);
- B. Practical task (what students are intended to do)
- C. Classroom actions (what students actually do)
- D. Student learning (what students actually learn)

Effectiveness, therefore, according to Millar (2004:13) means the link between stage A and D, i.e. students learning what was intended for learners to learn. In order however, to be effective in linking A and D, the practical task must be effective at linking stage B and C, i.e. the students must do and be able to do the things that were designed for learners to do.

This link, added Millar (2004:13), usually meets with criticism that the practical work would end up being a “recipe following” exercise with the students often not thinking about what and why they are doing what they are doing. He defended this “recipe” as a reflection of the teacher or task designer’s need to ensure the B-C link. This link however, is just one of the means that can be utilized to achieve the main outcome – linking what students learn to what they were intended to learn.

The absence of these links can result in what Hofstein and Lunetta (2003:39) call a “mismatch” between a teacher’s rhetoric and classroom behaviour. In other words, sometimes teachers do not do in laboratories what they say they intend to do. This can also send mixed messages to the students and has a potential of rendering the lesson ineffective.

In a subsequent study, aimed at exploring the effectiveness of practical work by analysing 25 “typical science lessons involving practical work”, Abrahams and Millar (2008:1945) discovered that the practical tasks they observed were generally effective in getting students to do what is intended with physical objects, but were much less effective in getting the students to use the intended scientific ideas to guide their actions and reflect in the data collected.

Abrahams and Millar, (2008:1945) also found little evidence that the cognitive challenge of linking observables to ideas was recognized by those who designed the practical tasks. These tasks hardly included clear strategies to help students to make such links neither were they presented in class in ways that reflected the size of the learning demand involved.

On this analysis of Abrahams and Millar (2008: 1945), the teachers’ focus in these analysed lessons was mainly on developing students’ substantive scientific knowledge, rather than on developing an understanding of scientific enquiry procedures. The authors utilized the following framework as a tool for analysing the effectiveness of practical work. This is a tabulated version of the objectives of Millar (2004).

**Table 2.1. Abrahams and Millar's (2008:1949) Analytical Framework of the effectiveness of a practical task.**

Effectiveness	Domain of observables	Domain of Ideas
A practical task is effective at the "doing level" (i.e. linking objectives B and C above) if.....	....the students do with the objects and materials provided what the teacher intended learners to do, and generate the kind of data the teacher intended.	....whilst carrying out the tasks, the students think about their actions and observations using the ideas that the teacher intended learners to use...
A practical task is effective at the "learning level" (i.e. linking objectives A and D above) if .....	....the students can later recall things they did with objects or materials, or observed when carrying out the tasks, and the key feature of the data they collected	....the students can later show understanding of the ideas the task was designed to help learners learn.

Making use of the above framework, Abrahams and Millar, (2008:1955-1959) made the following observation of the 25 practical tasks:

- Firstly, the practical tasks observed were effective in enabling the majority of the students to reproduce the phenomenon i.e. to do what the teacher intended, with the objects provided. This was made easy by the use of the "recipe style" tasks. They cautioned however, against the making this reproduction of the phenomenon the sole aim of the practical task, because then the learning value of practical work would be lost.
- Secondly, there was little evidence to show that the tasks were effective in getting the students to think about the observables using specific scientific ideas that were implicitly or explicitly intended by the teacher. There was only one exception in which the teacher observed first did the theory pertaining to the tasks prior to the task thereby ensuring that the students understood what the scientific terms meant and were thus able to use learners appropriately in talking about the task.

The extrapolation from this analytical assessment therefore is that practical work runs the same risk as the scientific investigations if teachers give low priority to the scientific ideas

compared to reproducing the phenomenon. In other words, practical work would be more effective if teachers would be more aware that practical tasks require students to make the links between the domains of objects and ideas and those links are more demanding than simply observing and remembering. Teachers therefore need to develop practical tasks such that the learning of scientific ideas and concepts is scaffolded for the learners (Abrahams & Millar, 2008:1966).

The assessment tool utilized by the authors is a very useful one, especially also utilized as a tool to improve the practical tasks. It is however, important to note that one practical session might not incorporate all the components i.e. one practical task or session might focus for example only on ensuring that the learners do as intended and perhaps continue with the ideas in the following lesson. It is therefore possible that they might have missed that in their analysis as they only assessed one practical session per school.

#### **2.9.6. Advantages of practical work**

Hofstein and Lunetta, (1982:212) also gleaned from the pro-laboratory work literature that laboratory activities when appropriately performed can be effective in promoting logical development and the development of some inquiry and problem-solving skills. Skills like manipulative and observational skills that assist in understanding scientific concepts. Laboratory work, according to Hofstein and Lunetta (1982:212) can also promote positive attitudes, foster the development of cooperation and communication skills as well as provide opportunities for student success.

In this later study, Hofstein and Lunetta (2003:38) crystallize the advantages of “laboratory experiences” (i.e. scientific inquiry and practical activities) to include the enhancement of students’:

- understanding of scientific concepts;
- interest and motivation;
- scientific practical skills and problem solving abilities;
- scientific habits of mind;
- understanding of the nature of science.

Bradley, *et al.*, (1998:1406) also added that practical work makes chemistry more real and interesting, make abstract concepts more understandable, illustrate the methods of science and develop learner practical skills.

Although this research study cannot claim to have achieved all the above advantages during the short research period, the results indicate that practical activities do increase learner understanding of scientific concepts as well as their interest and motivation towards science. Scientific practical skills and problem solving abilities of the research sample have also been impacted, although minimally at this stage. More exposure to practical work would certainly increase these skills on these learners. The last two advantages of Hofstein and Lunetta (2003:38) – scientific habits of mind, understanding of the nature of science – are best achieved when learners engage in full scientific inquiry and not necessarily by practical activities (Millar, 2004:12).

### **2.9.7. Criticism and Limitations of Practical Work**

In terms of research against practical work, Hofstein and Lunetta (1982:203) discovered the following arguments rose against extensive student laboratory activities:

- few teachers in secondary schools are competent to use the laboratory effectively;
- too much emphasis on laboratory activity leads to a narrow conception of science;
- too many experiments performed in secondary schools are trivial; and
- laboratory work in schools is often remote from, and unrelated to, the capabilities and interests of the children.

Twenty years later, the authors (Hofstein & Lunetta, 2003:47) now have expanded their list of “factors that inhibit learning in the school science laboratory”. Some of these factors are:

- “cook-book” lists of tasks for students to follow ritualistically. They do not engage students in thinking about the larger purposes of their investigation and of the sequence of tasks they need to pursue to achieve those ends.
- Teachers and school administrators’ lack of understanding of best professional practices in the science laboratory. Thus, there is a high potential for mismatch between a teacher’s rhetoric and practice that is likely to influence students’ perceptions and behaviours in laboratory work.
- Limitations in resources (including access to appropriate technology tools) and by lack of sufficient time for teachers to become informed and to develop and implement appropriate science curricula.

- Large classes
- Inflexible scheduling of laboratory facilities, and the perceived focus of external examinations. (Hofstein & Lunetta, 2003:47)

Some of these factors like class sizes, available time and resources are factors that are commonly cited by teachers as reasons for not engaging learners in practical activities. These are genuine challenges but they could be solved when one is determined to use practical activities in their science class.

That determination might itself cost time spent in planning and equipping oneself to resolve these challenges. All the critique as mentioned above, does not dispute the ability of practical activities in assisting learner understand but the criticism is against the mode of operation – it does need attention.

Hofstein and Lunetta, (2003:29) admitted that the laboratory provides a unique medium for teaching and learning in science, however, they also caution that researchers have not comprehensively examined the effects of laboratory instruction on student learning and growth compared to other modes of instruction, and there is insufficient data to convincingly confirm or reject some of the statements made about the importance and the effects of laboratory teaching (Hofstein & Lunetta, 2003:29). In other words, the research reviewed in 1982 failed to crystallize the relationship between experiences in the laboratory and student learning. This research paper, to a certain extent attempts to do exactly that.

For the purposes of this study, it is important to note that the term “laboratory work” as used in this article by Hofstein and Lunetta (1982) tends to refer both to scientific inquiry (investigations) as well as to practical activities. Millar (2004:2) criticizes the use of the term “laboratory work” as “the location is not a salient feature” in characterizing practical activities. The lack of distinction therefore leaves room to extrapolate that the analysis refers to both scientific inquiry and practical activities.

Other objections against practical work or reasons for the absence thereof, given by teachers, include the following:

- There is not enough equipment or chemicals.

- There is no laboratory.
- There is not enough time.
- There is no laboratory assistant.
- Practical work is hazardous.
- Safety regulations inhibit practical work.
- Practical work is not examined.
- Teacher feels inadequately prepared or lacks experience (Bradley, *et al.*, 1998: 1406).

Although the above reasons were given on a study looking at practical work in the chemistry section of Physical Science, these are the same reasons given by teachers against practical work in general. In fact, almost all of the above reasons were also cited by the research learners as the reasons given to learners by their teachers for not doing practical work. Once again, they have nothing to do with practical activities as such but more to do with teacher inadequacies when it comes to utilising practical work in their teaching of science.

## **2.10. THE TRAC APPROACH – INCLUSION OF COMPUTERS IN PRACTICAL ACTIVITIES**

Information technology (IT) can be a valuable tool in learning and teaching both the processes and content of science (Wellington, 1994:191). Science education has in fact entered into a new era of reform where both the content and pedagogy of science learning and teaching are being scrutinized, and new standards intended to shape meaningful science education are emerging (Hofstein & Lunetta, 2003:29). This new era has brought a lot more resources to the science teachers' disposal in terms of the teaching and learning of science. These resources include computer simulations, micro-science kits, internet, etc. These new tools and resources for empowering teaching and learning science can be utilised as a means to enhance teaching and learning as well as complement experiences in the school laboratory (Hofstein & Lunetta, 2003:46).

Hofstein and Lunetta, (2003:41) also asserted that

by using associated software, students can examine graphs of relationships generated in real time as the investigation progresses, and examine the same data in spread sheets and in other visual representations. When inquiry empowering technologies are properly used by teachers and students to gather and analyse data, students have more time to observe, to reflect, and to construct conceptual knowledge that underlies the laboratory experiences.

A company that has successfully combined computer software with practical activities is TRAC (Technology Research Activity Centre) South Africa. A Physical Science intervention program operating in all nine South African provinces TRAC provides high schools with a mobile laboratory service on which learners can do curriculum based practical activities. For data collection and analysis however, TRAC generally makes use of computer software and probe ware i.e. data logging and graphics. This allows learners to collect and analyse even the otherwise difficult to collect data and therefore obtain much more accurate results compared to the manual means of data collection.

Through the TRAC approach, learners have access to many benefits, the main one being the ability to conduct hands-on actual practical activities. Using the words of Thornburg (2009:5), “students benefit when they do science, not just learn about science”. Thornburg (2009:5) added that experiments also allow students to observe non-intuitive phenomena they can then study in the course of resolving the gap between their intuition and the underlying Physics or chemistry of an experiment. In this setting, Thornburg (2009:5) endorsed that a well-equipped laboratory can take advantage of versatile probe ware and hand-held devices to capture real data that can be transferred to a computer for further analysis and inclusion in a report. This is exactly what TRAC SA does and they believe is a good approach to science education.

TRAC SA mainly works with previously disadvantaged schools, which are generally “underperforming” (TRAC, 2011:14) and hardly have science laboratories and equipment. According to TRAC SA, “78.5% of TRAC schools improved in Physical Science pass rate from either 2010 to 2011 or the specific group from Grade 11 to 12” (TRAC, 2011:15). In addition, TRAC seeks to address the SET skills shortage in the country, by enabling the grade 12 learners to go into these careers, with a special focus on engineering. The number of learners they have helped to enrol for these studies at university level has been increasing quite steadily, for example, an increase “from 464 in 2010, 734 in 2011 and 848 in 2012)” (TRAC, 2011:16).

Millar (2004:13) however, cautioned about the use of “computer-based instrumentation”. He reckoned that while this instrumentation could enhance some practical activities, “it can also add additional layers of opacity and increase the physical and cognitive ‘clutter’” (Millar, 2004:13). He concluded that the effectiveness of computer-based instrumentation “depends on how it is used, not that it is used” (Millar, 2004:13).

This is certainly a matter also experienced during the fieldwork component in this study as most of the experiments were done using the TRAC program. One of the items that certainly could be defined as “physical clutter” is the presence of too many wires: the laptop charger wires, the cable connecting the LabPro interface to the laptop, the cables connecting the various sensors to the actual experiment. This is especially the case when working with electric circuits that already have crocodile and banana clips as additional cabling in the circuit.

Millar (2004:12) recommended that more effective practical work should have a limited number of learning outcomes per practical activity, otherwise the practical task becomes too complex that students can end up lost. Most of the current TRAC worksheets are too long. One worksheet, for example EM2, covers both series and parallel circuits in one worksheet with all the concepts relating to that (see Appendix P). It therefore covers too many concepts thereby having too many learning outcomes. These outcomes are difficult to achieve within one practical session, which therefore leads to one practical session spanning over a few days in cases of limited time.

The challenge with a lesson spanning over a few days is the fact that learners lose the worksheet, lose interest and sometimes even the results obtained in the previous session. This compromises continuity and ultimately the proper achievement of the learning outcomes. The TRAC practical activities would be even more effective in increasing learner scientific knowledge if they were to be made much shorter covering “a limited number of learning outcomes” (Millar, 2004:12) per worksheet.

Millar (2004:12) also recommended that if a certain skill is necessary for a practical task, then students need to be made competent in that skill prior to the practical task. If not addressed, the lack of that skill may stand in the way of learning. In addition to worksheet and practical activity length, the TRAC program does not take into consideration the learners’ mathematical and computer skills. These skills are directly required for a better success of the practical activities and in most cases (certainly the computer skills) they

slow down the progress of the practical activity and if not addressed could certainly stand in the way of learning.

## 2.11. SUMMARY AND CONCLUSION

This literature review has illustrated the clear presence of challenges in science education within the South African context as well as globally. In general, students experience a lot of difficulties in Physical science learning, namely abstractness, mathematical skills, issues of language and others. These difficulties also transcend onto the module E&M. On E&M, students have difficulties with a lot of current electricity and electromagnetism concepts, exacerbated again by abstractness and mathematical skills and lack of connection between the real and the abstract.

Various strategies have been implemented to remedy these general as well as specific difficulties. Some of these strategies include concept mapping, rearrangement of E&M courses, concept substitution, PI, the TEAL project, microchemistry kits and others.

The missing trend in most of these strategies, however, is a concerted effort on closing the gap between what the learners are told as well as what the learners do or experience i.e. allowing learners to be hands-on in the acquisition of scientific knowledge through hands-on practical activities. Some of the strategies mentioned have only used practical activities as a small portion of their proposed strategies, namely concept substitution and the TEAL project. The strategy that comes closest is the “Physics by Inquiry” strategy.

While it is true that some form of direct and linear (apparently teacher independent) path from observation (done in practical work) to learning is a clearly naïve view (Gunstone, *et al.*, cited in Millar 2004:3), the role of practical work in enhancing content knowledge in science cannot be underestimated. Practical work falls in the category of “active learning” – which can be difficult – but compared to traditional chalk and talk, it has many benefits, namely “deeper understanding, improved attitudes towards the subject, and greater self-confidence” (Felder, 1996:1).

In the South African context, despite the documents on the contrary, the traditional and still most prevalent means of teaching science is “chalk and talk” combined with material in textbooks. This passive setting may, at least once a term, be exchanged with a scientific investigation session out of which the learners have to submit CASS write-ups whether or

not learning would have taken place. As excellent as a teacher may be, “chalk and talk” is based on the assumption that the instructor can “pour out” knowledge from his or her vast reservoir into the empty glasses of learners minds (Dori & Belcher, 2005:244) and that approach can certainly be improved upon.

In conclusion, indeed practical work is “under siege” in both developed and developing countries, although the reasons differ. The inactivity in science teaching is creeping in on all levels of education i.e. primary/ elementary school to secondary/high school and even to tertiary level (university, teacher-training college) education. In this spectator chemical education, concrete concepts become abstractions, rather than the other way around (Bradley, *et al.*, 1998:1406).

It is therefore important to note that

“in courses whose purpose is to enhance students’ scientific literacy (as distinct from the pre-professional training of scientists), practical work is a means to an end, not an end in itself. Students are consumers of scientific knowledge, not producers of it. To become more intelligent consumers, they may benefit from some experiences of practical work, but the aims need to centre on developing the knowledge and understandings required to respond intelligently to scientific information as it is encountered in out-of-school contexts” (Millar, 2004:18)

A range of activities were also identified which complement, but should not be a substitute for practical work. These complimentary activities include science related activities, surveys, presentations and role-play, simulations including use of ICT, models and modelling, group discussions and group text-based activities. These activities have an important role to play in supporting practical work in developing understanding of scientific concepts (Woodley, 2009:49).

## CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

### 3.1. INTRODUCTION

The following research questions have guided the choice of the research method utilised in this study:

1. What are the conceptual difficulties experienced by learners in the module E&M?
2. How does the use of practical activities address these conceptual difficulties?
3. Do the learners exhibit some of the commonly known misconceptions experienced by learners in the module E&M and has the practical-activities based approach addressed them?
4. If the practical-activities based approach does have an effect, how does it enhance the learning of E&M?

A mixed methods approach was employed, that utilized a variety of data collection techniques, to incorporate qualitative and quantitative data. Specifically, the study employed a mixed methods approach in which the qualitative research method is embedded within the predominantly quantitative method. The mixing of these methods took place at the data collection and data analysis phases of this study.

The philosophical underpinning or worldview espoused in this mixed methods study is pragmatism. According to (Creswell, 2009:10) this worldview arises from “actions, situations and consequences rather than antecedent conditions”.

The following characteristics of pragmatism (Creswell, 2009:10-11) also guided this research:

- Just like pragmatism is not committed to one reality, this mixed methods study drew liberally from quantitative and qualitative assumptions.
- There was freedom of choice when it came to methods, techniques and procedures implemented in this research, based on the needs and purposes of the research.
- The multiple approaches used in data collection and analysis are also a feature of pragmatism.
- During this study, the use of both qualitative and quantitative data allowed the researcher to reach the best understanding of the research problem.

In summary, the pragmatic worldview provided the best access to multiple methods, different worldviews and different assumptions; as well as different forms of data collection and analysis.

There were two purposes for choosing the mixed methods approach. Firstly, to seek complementarity within the collected data in order to elaborate, enhance, illustrate and clarify the results from the quantitative data with the detailed analysis of the qualitative data (Johnson & Onwuegbuzie, 2004:22). Secondly, this approach was chosen for development purposes to “expand the breadth and range” (Johnson & Onwuegbuzie, 2004:22) of the different data collection tools used.

The quantitative data provided an answer to the main research question of whether or not the use of practical activities was effective in addressing learner difficulties in Physical Science. The qualitative data, however, provided an in-depth platform of investigation on the specific difficulties that the learners were dealing with prior to the practical intervention and to what extent these difficulties still existed after the intervention.

The qualitative data included observations, pre- and post-intervention questionnaires as well as the actual contents of the learner transcripts. This qualitative data was quantitized by encoding the various responses to the questionnaires and tests, thereby allowing the researcher to express the observed trends in percentage form. The main technique, however, was still the use of pre- and post-tests providing quantitative data.

This chapter will therefore begin by explaining the research strategy employed and its suitability for this study. This will be followed by a discussion on the data collection techniques used to collect the data and reasons for using the techniques used. The framework for the analysis of findings will then be given in detail. This chapter concludes with a look at some of the limitations to this research. This includes the problems and challenges experienced during this research process. These include issues of the research participants or validity and or reliability of the collected data.

## **3.2. RESEARCH DESIGN**

### **3.2.1. Mixed-Methods and Mixed-Model**

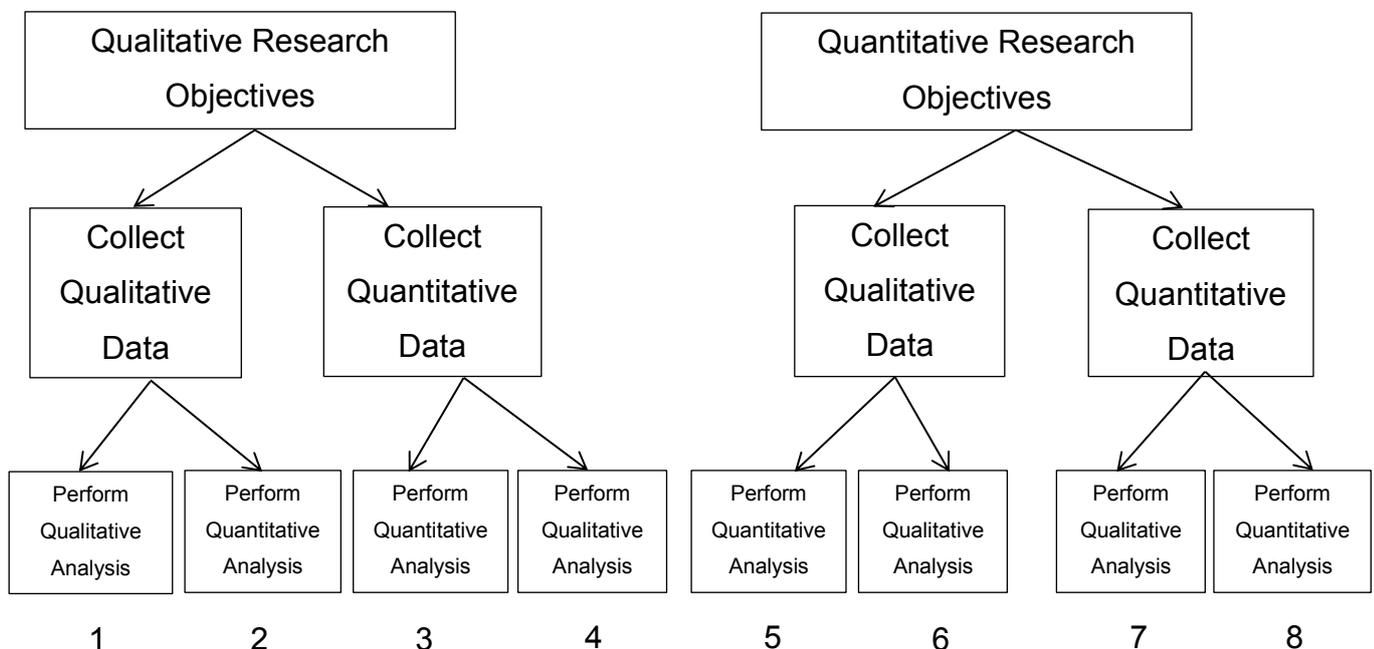
Mixed methods research is defined as a class of research that combines qualitative and quantitative research techniques, methods, approaches, concepts or languages in one

study (Johnson & Onwuegbuzie, 2004:17). This mixing or integration of the research techniques can happen at data collection, data analysis or even at data interpretation (Terrel, 2012:260), depending on the research question.

Johnson and Onwuegbuzie (2004:17) presented the mixed methods research as an attempt to legitimize the use of multiple approaches to answering research questions, rather than restricting researchers' choices. In other words, rather than a limiting form of research, mixed methods is an expansive, creative, inclusive, pluralistic and complimentary form of research (Johnson & Onwuegbuzie, 2004:17).

Johnson and Onwuegbuzie (2004:20) differentiated between two major types of mixed methods research depending on the phase where the mixing occurs: mixed-model and mixed methods. Mixed-model involves mixing qualitative and quantitative approaches within or across the stages of the research process, while mixed method involves the inclusion of a quantitative phase and a qualitative phase in an overall research study.

Johnson & Onwuegbuzie, (2004:21) suggested that there are six mixed-model designs as shown by design 2 to 7 in Fig 3.1.



Note: Designs 1 and 8 at the outer edges are the monomethod designs. The mixed-model designs are 2, 3, 4, 5, 6, 7

**Fig 3.1. Mixed Model Designs (and monomethods)**

These six designs (2 to 7) are called across-stage mixed-model designs because the mixing takes place across the stages of the research process (Johnson & Onwuegbuzie, 2004:20). The authors exemplified the use of a questionnaire that includes a summated rating scale (quantitative data collection) and one or more open-ended questions (qualitative data collection) as an illustration of a within-stage mixed-model design.

Expounding on mixed-methods, Johnson and Onwuegbuzie, (2004:20) added that there are nine mixed-method designs, and these are better illustrated in Fig 3.2.

		Time Order Decision	
		Concurrent	Sequential
Paradigm Emphasis Decision	Equal Status	QUAL + QUAN	QUAL → QUAN QUAN → QUAL
	Dominant Status	QUAL + quan QUAN + qual	QUAL → quan Qual → QUAN QUAN → qual Quan → QUAL

**Fig 3.2. Mixed-methods design matrix with mixed method research designs shown in four cells (Johnson & Onwuegbuzie, 2004:22).**

Note: "qual" stands for qualitative, "quan" stands for quantitative, "+" stands for concurrent, "→" stands for sequential, capital letters denote high priority or weight, and low case letters denote lower priority or weight.

The notation used is based on Morse's model cited in Johnson & Onwuegbuzie, (2004:22) and is explained at the bottom of Fig 3.2.

Contrasting mixed-model and mixed-method designs, Johnson and Onwuegbuzie (2004:20) stated that in comparison to mixed-model designs, mixed-method designs are similar to conducting a quantitative mini-study and a qualitative mini-study in one overall research study.

However, in order for a study to be considered a mixed-method design,

“the findings must be mixed or integrated at some point (e.g., a qualitative phase might be conducted to inform a quantitative phase, sequentially, or if the quantitative and qualitative phases are undertaken concurrently the findings must, at a minimum, be integrated during the interpretation of the findings” (Johnson & Onwuegbuzie, 2004:20).

Onwuegbuzie and Johnson (2006:53) later added that mixed research can also be conceptualized as combining quantitative or qualitative research in *concurrent, sequential, conversion, parallel, or fully mixed designs*.

According to Onwuegbuzie and Johnson (2006:53), there are four conditions in *concurrent* mixed designs:

- both the quantitative and qualitative data are collected separately at approximately the same point in time,
- neither the quantitative nor qualitative data analysis builds on the other during the data analysis stage, and
- the results from each type of analysis are not consolidated at the data interpretation stage, until both sets of data have been collected and analyzed separately, and
- after collection and interpretation of data from the quantitative and qualitative components, a meta-inference is drawn which integrates the inferences made from the separate quantitative and qualitative data and findings.

In basic *sequential* mixed designs, Onwuegbuzie and Johnson (2006:53) explained that the data collected and analyzed from one phase of the study (i.e., quantitative/qualitative data) is used to inform the other phase of the investigation (i.e., qualitative/quantitative data). In this case, data analysis begins before all the data is collected.

Sequential mixed designs also can be applied via the following two strategies:

- switch strategy (e.g., first applying qualitative methods to illuminate program theory of stakeholders and then use quantitative methods to assess the program theory) and
- contextual overlaying strategy (e.g., utilizing qualitative approaches to collect contextual information for facilitating the interpretation of quantitative data or reconciling finding (Onwuegbuzie & Johnson, 2006:53).

*Conversion* mixed designs involve data transformation where one form of data is converted into another and then subsequently analyzed (Onwuegbuzie & Johnson, 2006:53). In other words, the other data type evolves from the original data type either by converting the data from quantitative to qualitative or from qualitative to quantitative. Onwuegbuzie and Johnson, (2006:53) also add that this conversion occurs via techniques such as quantizing data (i.e., transforming the qualitative data to a numerical form; or qualizing data (i.e., converting quantitative data into data that can be analyzed qualitatively). Both data types are analyzed or re-analyzed, and inferences are made based on both sets of analyses.

Explaining *parallel* mixed method designs, Onwuegbuzie and Johnson (2006:53) stated that similar to concurrent designs, the data is collected and analyzed separately. However, while inferences are made in concurrent designs on both sources of data in an integrated manner, in parallel mixed designs, each data source leads to its own set of inferences, and no attempt is made to reach meta-inferences, in which both sets of inferences are combined into a coherent whole. Such designs lead either to two separate reports that would be presented or published separately or two separate write-ups that are presented in two distinct sections of the same report (Onwuegbuzie & Johnson, 2006:53).

*Fully mixed or fully intergrated* research designs involve mixing quantitative and qualitative approaches in an interactive way at all stages of the investigation such that at each stage, one approach influences the formulation of the other approach (Onwuegbuzie & Johnson, 2006:53).

In illustrating the point that the researcher needs to be creative and not be limited by the designs listed above, Johnson & Onwuegbuzie (2004:20) added that one can easily create more user specific and more complex designs than the ones shown in Figures 3.1 and 3.2. They exemplify that one can for instance develop a mixed-method design that has more stages (e.g., Qual -> QUAN -> Qual); one also can design a study that includes both mixed-model and mixed-method design features.

In light of the literature in this section, this study has features of sequential, concurrent and conversion mixed method designs. This is because the qualitative data in the form of questionnaires was collected and although it did not necessarily inform the quantitative data, it was followed by it. However, the concurrent feature is the strong one when it

comes to the quantitative and qualitative data obtained from the pre- and post-tests, which was collected concurrently and inferences were made. The conversion character also featured strongly in the analysis of the data through the quantizing of the qualitative data (learner transcripts) and the qualifying of the quantitative data (test scores).

### **3.2.2. Mixed Methods Research Process**

Johnson and Onwuegbuzie's mixed methods research process model comprises eight distinct steps (2004:21):

- (1) determination of the research question;
- (2) determination of whether a mixed design is appropriate;
- (3) selection of the mixed-method or mixed-model research design;
- (4) collection of the data;
- (5) analysis of the data;
- (6) interpretation of the data;
- (7) legitimization of the data; and
- (8) drawing conclusions (if warranted) and write the final report.

The researchers admitted, however, that the steps were not necessarily fixed: they could, in fact, actually vary, and even the question and/or research purpose could be revised if necessary. Some of these steps – purpose (step 2), data analysis (step 5) and legitimations (step 7) – will be discussed in detail in the following paragraphs.

Expanding on purpose (step 2), Johnson and Onwuegbuzie (2004:21), utilizing the work of Greene, Carecelli & Graham, (1989:259) noted that there are five major purposes or rationales for conducting mixed methods research:

- a) triangulation (i.e. seeking convergence and corroboration of results from different methods and designs studying the same phenomenon);
- b) complementarity (i.e. seeking elaboration, enhancement, illustration, and clarification of the results from one method with results from the other method);
- c) initiation (i.e., discovering paradoxes and contradictions that lead to a reframing of the research question);
- d) development (i.e. using the findings from one method to help inform the other method); and

- e) expansion (i.e., seeking to expand the breadth and range of research by using different methods for different inquiry components).

Johnson and Onwuegbuzie (2004:22) explained data analysis (step 5) by incorporating Onwuegbuzie and Teddlie's (2003) seven-stage conceptualization of the mixed methods data analysis process. According to Onwuegbuzie and Teddlie (2003:375) there are seven data analysis stages:

- a) data reduction – which involves reducing the dimensionality of the qualitative data (e.g. via exploratory thematic analysis, memoing) and quantitative data (e.g., via descriptive statistics, exploratory factor analysis, cluster analysis).
- b) data display – which involves describing pictorially the qualitative data (e.g., matrices, charts, graphs, networks, lists, rubrics, and Venn diagrams) and quantitative data (e.g., tables, graphs).
- c) data transformation – wherein quantitative data are converted into narrative data that can be analysed qualitatively i.e. qualitized and/or qualitative data are converted into numerical codes that can be represented statistically i.e., quantitized (Tashakkori & Teddlie, 1998:1226).
- d) data correlation – involves the quantitative data being correlated with the qualitized data or the qualitative data being correlated with the quantitized data,
- e) data consolidation – wherein both quantitative and qualitative data are combined to create new or consolidated variables or data sets.
- f) data comparison – involves comparing data from the qualitative and quantitative data sources.
- g) data integration – characterizes the final stage whereby both quantitative and qualitative data are integrated into either a coherent whole or two separate sets (i.e., qualitative and quantitative) of coherent wholes.

According to Johnson and Onwuegbuzie (2004:22), the legitimation step involves assessing the trustworthiness of both the qualitative and quantitative data and subsequent interpretations. They also caution that the legitimation process might include additional data collection, data analysis, and/or data interpretations until as many rival explanations as possible have been reduced or eliminated.

### 3.2.3. Rationale for Mixed Methods in this study

Mixed methods research follows research questions in a way that offers the best chance to obtain useful answers, because many research questions are best fully answered through mixed research solutions (Johnson & Onwuegbuzie, 2004:18). This is certainly true for the research questions in this study, all of the questions could not be simply answered by making use of one approach only, they all required qualitative and quantitative data.

For example, research question 1, the conceptual difficulties experienced by the learners in the module E&M, has two aspects to it. It has a qualitative aspect – the examination of learners' scripts to pull out the exact difficulties experienced. It also has a quantitative aspect – a determination of the prevalence of the specific difficulty in this particular research group.

Therefore, this study makes use of complementarity and expansion rationales (Greene, *et al.*, 1989:259) for choosing mixed methods as the research method utilised. In order to elaborate, enhance, illustrate and clarify the quantitative data collected as well as to provide more depth to the research, the learner transcripts were also analysed to provide qualitative data as to the exact difficulties as well as misconceptions exhibited. Some of this qualitative data was quantitized in order to provide a clearer picture of the prevalence of the difficulties and misconceptions. More qualitative data was collected by means of questionnaires and observations, with the questionnaire data also quantitized for clearer presentation.

It is for these reasons that the mixed-methods design was chosen and utilised in this study.

### 3.3. RESEARCH INSTRUMENTS (DATA COLLECTION TOOLS)

In order to be able to answer the research questions in this study and to obtain more information about the context in which the research took place, the following data collection instruments were utilized, and will be discussed in the subsections following:

- pre- and post-intervention questionnaires
- pre- and post-tests
- observation schedules

### 3.3.1. Pre and Post-Tests

The main data collection instrument that was utilized in this study was pre- and post-testing, in particular one group pre- and post-test design. The pre-tests provided two forms of data:

- quantitative data in the form of pre-test scores to give an indication of the extent and prevalence of the difficulties,
- qualitative data to be compiled into a list of areas of conceptual difficulties and misconceptions exhibited by the participants.

The post-test scores, on the other hand, gave an indication of the effect of the practical activities in addressing the identified difficulties and misconceptions and a measure of which difficulties and misconceptions, if any, still need to be addressed. The tests comprised of two types of questions: multiple choice and long (open-ended) questions.

Zimmermann, Hurtig and Small (2008:39) suggested various advantages and disadvantages to pre-testing and post-testing. The advantages are that these tests allow the researcher to look at changes taking place in a group over time, they also provide quantitative data which administrators and funders may prefer. Some of the disadvantages of pre-tests and post-tests as submitted by Zimmermann *et al.*, (2008:29) included: the length of time required to set up the tests; the appropriate sample size for statistical purposes; and other factors' influence on the test scores (e.g. literacy levels, language fluency, negative attitudes towards school and tests).

Cohen, Manion and Morrison (2011:488) also added to this discussion the effect of the types of questions asked on the validity of the test i.e. the ability of the tests to assess that which they intended. For example, these authors suggested potential problems with multiple choice questions: having one or more correct answers; obvious distractors and redundant items; location of the correct responses; and the sequence of items and their effects on each other. In this investigation, the researcher, in designing the small portion of multiple choice questions in these tests, took all the possible care to minimize these problems.

In fact, the following guidelines as suggested by Cohen, *et al.*, (2011:493), were implemented as closely as possible:

- the pre-tests had questions which differed in form and wording from the post-tests, though the two tests covered the same content,

- enough care was taken in the construction of both tests to ensure the same level of ease of difficulty.

### 3.3.2. Questionnaires

Some of the qualitative data of this research was obtained by making use of questionnaires. These were utilised to establish contextual information pertaining to the participants, to explore the learners' experiences of the practical activities, and to also discover areas of improvement for the TRAC program itself as the proponents of a practical activities based approach. Two questionnaires (Appendix T) were utilized, one at the beginning of the intervention to determine their level of skills pertaining to E&M, the other at the very end of the data collection process to determine their experience of this intervention as well as possible areas of improvement.

In order to obtain all the information that the researcher deemed necessary, the types of questions that were included during the design of this questionnaire included dichotomous questions, multiple choice questions, rating scales, ratio data and open-ended questions. Open ended questions in general provide freedom and spontaneity of the answers, as well as opportunities to probe (Oppenheim, 1992:115). Oppenheim (1992) added that the disadvantages of open ended questions included their being time consuming especially the analysis and processing as well as demanding more effort from the respondents.

Dichotomous questions, multiple choice questions and rating scales made up closed ended questions. These were especially chosen because they are quick to complete, easy to code and do not discriminate unduly on the basis of how articulate respondents are (Wilson & McLean, 1994 cited in Cohen, *et al.*, 2011:382). These questions also require no extended writing, are low cost, make group comparison easy and are useful for hypothesis testing (Oppenheim, 1992:115).

Conversely, these same question types do not enable respondents to add any remarks or explain or qualify their responses and there is also the risk that the number of options available has not been exhausted (Cohen, *et al.*, 2011:382). In addition, closed ended questions may sometimes be too crude and thus irritate the respondents, might also contain researcher biases in the responses and are low in spontaneity of responses (Oppenheim, 1992:115).

According to Cohen *et al.*, (2011:383), dichotomous questions provide clear and unequivocal responses, quick to code and are useful as a sorting device for subsequent questions. In this study, this form of questioning was implemented in order to obtain information on the learners' class, gender, whether or not experiments were covered in a certain section (yes or no), whether or not they had other science interventions on E&M, and if yes whether these were on certain subtopics (yes or no).

Another useful type of questions utilised in the questionnaire – multiple *choice questions* – are also quickly coded and aggregated to give frequencies of response (Cohen *et al.*, (2011:384). Cohen *et al.*, cautioned that these questions seldom give more than a “crude statistic” due to the inherent ambiguity of words, however. The authors illustrated that respondents could interpret words differently in their contexts thus rendering the data ambiguous. They then suggested the use of “anchor words” (Cohen, *et al.*, 2011:384) to allow a degree of discrimination in response. Examples of anchor words include “agree” or “strongly disagree”, but there is still no guarantee that the respondents will interpret these words in the same way intended.

In order to establish the learners' attitudes toward science, their perceived understanding of E&M, the frequency of practical activities, which practical activities were done if any and learners computer skills, multiple choice questions were utilized in this study. In addition, to reduce the level of ambiguity in some cases as raised by (Cohen, *et al.*, 2011:384), the anchor words like “agree”, “strongly agree”, “disagree” and “strongly disagree” were used.

One way in which degrees of response, intensity of response can be managed can be seen in *rating scales* (Cohen, *et al.*, 2011:386). Rating scales, according to the authors, build in a degree of sensitivity and differentiation of response whilst still generating numbers. Cohen, *et al.*, (2011:387) further add that these scales offer an opportunity for a flexible response with the ability to determine frequencies, correlations and other forms of quantitative analysis. The authors were, however, also quick to mention limitations of rating scales, namely their inability to make assumptions of equal intervals between categories based on the numbers; different meanings assigned to different numbers by respondents; unbalanced rating scales and inability to check for the truth.

In this study, rating scales were used for their ability to provide more opportunity for rendering data more sensitive and responsive to students (Cohen, *et al.*, 2011:390). The scales were especially useful in revealing the learners' attitudes, opinions and perceptions.

For the rest of the questionnaires open-ended questions were utilised. These were used in cases where an honest personal comment from the respondents was required and in cases where the choices offered were not exhaustive, thus allowing the respondents to give their own answers. Open-ended questions contain the 'gems' of information that otherwise might not be caught in the questionnaire and they put the responsibility for and ownership of the data more firmly on the respondents' hands (Cohen, *et al.*, 2011:391).

Open-ended questions did, however, come with the problem of data handling in that it became difficult for the researcher to make comparisons between respondents as there was at times little to compare. In addition, these questions took longer to complete thus creating time constraints and there was also the challenge of some of the respondents not being sufficiently capable of articulating their thoughts clearly (Cohen, *et al.*, 2011:393). For these reasons, the percentage of these open-ended questions was fairly low, the majority of the questionnaire was multiple choice and followed by dichotomous questions.

Some of the advantages of questionnaires include greater reliability, greater honesty due to the anonymity element and they are more economical in terms of time and money (Cohen, *et al.*, 2011:209). An important issue however pertaining to questionnaires is that of reliability and validity which is centred around sampling and the issue of a sample size that is sufficient. There is a generally accepted norm in quantitative research that the larger the sample the better as this not only helps with reliability but also allows more sophisticated statistical analysis (Cohen, *et al.*, 2011:144).

Cohen, *et al.*, (2011:144) also add that a sample size of 30 was held by many to be the minimum number of cases if researchers plan to use some form of statistical analysis on their data. The issue of sample size also gave an indication of the chances of that particular statistic to be representative. In addition, confidence levels and confidence intervals i.e. indications of error margins that one wished to tolerate were also consideration to be made when dealing with sample sizes (Cohen, *et al.*, 2011:145).

According to Cohen, *et al.*, (2011:145), confidence level, usually expressed in percentage forms (usually 95 or 99 percent), is an expression of how sure we can be (95 percent or 99 percent of the time) that the responses lie within a given variation range. The authors explained the confidence interval as that degree of variation or variation range that one wished to ensure.

Cohen, *et al.*, (2011:146) illustrated the confidence level and confidence interval relations with sample size as follows:

“if we want to have a very high confidence level (e.g. 99 percent of the time) then the sample size will be high. On the other hand, if we want a less stringent confidence level (e.g. 90 percent of the time), the the sample size will be smaller. Usually a compromise is reached, and researchers opt for a 95 percent confidence level. Similarly, if we want a very small confidence interval (i.e. a limited range of variation, e.g. three percent) then the sample size must be high, and if we are comfortable with a larger degree pf variation (e.g. 5 percent) then the sampe size will be lower”.

Due to circumstances beyond the control of the researcher, the size of the sample ranged from a minumum of 23 participants to a maximum of 47. These were the numbers of participants who attended all three phases of the research, i.e. the pre-tests, the post-tests as well as the practical activities intervention in between. This meant that the researcher’s confidence levels range between 90 and 95 percent and the confidence intervals begin at five percent and slightly higher. Thus the representativeness of the data was slightly weakened.

### **3.3.3. Observations**

During the practical activities sessions, observations of learner behaviour were also made and recorded as per observation schedule attached in Appendix U. This was done in order to evaluate the learners’ experiences of the sessions and to diagnose any challenges that they experienced, to document what happened during the practical activities i.e. the context, activities, processes and discussions (Zimmermann, *et al.*, 2008:32).

Observations were made in order to

- determine whether the learners executed the practical activities as intended,
- assess whether the outcomes for each practical activity have been met by the group,

- make general observations about general learner attitudes and difficulties and successes experienced during the practical activities.

These were documented in the form of an observation schedule as well as photos captured during the practical activities.

The disadvantages to this data collection instruments were the issue of available time to make the observations as well as facilitating the sessions as in this case the facilitator was also the observer. Also, the participants became too aware of the recording being made and photographs taken and thus “played to the gallery” at times. The advantage of observations was that one could document issues as they happened instead of relying on memory afterwards. As a result of the disadvantages and advantages mentioned, this research tool was not strongly utilised during the research, especially in the latter part of data collection.

#### **3.3.4. Validation of the Research Instruments**

Of the three research instruments utilised in this study, the main source of data, the pre- and post-tests were tested for validity more than the other two instruments. It can however be said that the results from the observation schedules could be triangulated with the data collected from the questionnaires and tests.

As far as the questionnaires were concerned, steps were taken to ensure that the participants and the researcher entered data into the relevant categories consistently and accurately. In addition to that, the responses were kept the same as much as possible to avoid ambiguity. There was however no pilot questionnaire administered.

The pre and post-tests were however extensively scrutinized to avoid some of the reliability threats. All the scripts were marked by one person in order to avoid having different marks for the same or similar pieces of work. The Halo effect (Cohen, et al., 2011, p. 159) could easily be avoided by the marker as she did not know the participants enough to be able to give undeserved favourable or unfavourable assessment to participants judged to be doing well or badly in other assessments.

### 3.4. DATA

#### 3.4.1. The Research Sample

The research project was conducted with a group of Grade 11 learners in a black township school of the Western Cape Province of South Africa. The original group consisted of 60% males and 40% females who were predominantly (94%) Xhosa-speaking. All the participants had been doing Physical Science from grade 8 at the school, although they had a different natural science teacher in grade 8 and grade 9. They were also all doing pure Mathematics and not Mathematics Literacy. Although the medium of instruction at the school was meant to be English, the learners indicated that 32% of the time the educators tended to mix between English and isiXhosa during the Physical Science lessons.

In terms of their attitude towards Physical Science as a subject, 60% of the learners “agreed” that science was their favourite subject while 40% “strongly disagreed” with that statement. In the whole group, 56% of the learners agreed that they sometimes do science-related tasks at home that are not for school work, the rest did not. In indicating their reasons for choosing this subject, 63% indicated that they feel that they had to and only 32% of the group agreed that taking science could help the learners in the future. In addition, 62% of learners indicated that they took science because their parents insisted on it.

In terms of how they themselves perceived science as a subject as well as their performance in it, only 50% indicated that they were good in science, while 60% of the whole group agreed that science was not a boring subject. In relation to the amount of time they spent on Physical Science, outside class time: 48% spent less than 1 hour per day; 30% spent 1-2 hours; only 2% spent more than 4 hours while 20% admitted that they spent no time at all on science outside class time.

The learners were then asked about how they perceived their understanding of the research topic, electricity and magnetism. All of the learners indicated that they had covered this topic already during the research year with 70% indicating that they do enjoy this section of work. They did, however, indicate that they have a low understanding of both current electricity (74%) and electromagnetism (90%).

In order to establish the learners' skills in practical work, they answered questions with regard to the frequency of practical work as well as how it was done. Although they tended to differ in their responses, the majority of the learners indicated that they did not do practical work very regularly, with 34% saying only once a year and 42% saying once or twice a month. The discrepancy in their responses can be explained in the context of the fact that they have different teachers. This practical work was said to be done in groups and the last experiment was done more than a month ago, an experiment which was a CASS (continuous assessment) requirement. Lack of equipment and insufficient time were the main reasons given for not doing practical work regularly.

With specific reference to practical work on E&M itself, all the learners concurred that they had not done practical work on either current electricity or electromagnetism and 86% of them indicated that they were interested in doing practical work in these sections. A very small (30%) percentage of the learners indicated that they had physically worked with some of the possible apparatus used in E&M like cells, wires, light bulbs, electromagnets, etc.

The majority of the practical activities that were done during this research made use of the TRAC program which is computer based practical activities. The learners' computer skills were therefore of interest to the researcher. The specific skills asked included understanding of the basic components of a computer or laptop; use of a keyboard; use of a mouse to move a cursor; starting or shutting down a computer; use of icons to open programs; ability to click and drag, etc. On average, more than 50% of the learners indicated that they were quite comfortable.

Finally, in order to determine the possible impact of other interventions on the topic, the learners were asked to indicate if they attended any other interventions like extra classes, only 2% did E&M in other interventions. This small percentage of learners also indicated, however, that they did no practical work during these interventions.

The research sessions took place during the study hour, which was part of the daily proceedings at the school. When conducted within the study hour, the sessions were better attended with learners to a maximum of 47 learners out of 61. The attendance, however, changed dramatically when the school cancelled the study hour sessions without informing the researcher. This meant that learners could choose to go home after school

and not stay behind for the research sessions. As a result of this the numbers of learners fluctuated between 23 and 47. The number of learners reflected upon in these results, are learners who would have attended both tests (pre and post) as well as the practical intervention in between. These learners stayed after school to take part in these sessions.

### **3.4.2. Data Collection**

The participants were a group of grade 11 learners from a Western Cape school who received instruction from their educator on the topics being researched prior to the data collection. The E&M topics (concepts) that were researched are as follows:

- basics of current electricity;
- Ohm's Law;
- series and parallel circuits;
- effective and internal resistance;
- magnetic field associated with current and
- current associated with a magnetic field

This research was carried out in various steps: pre-intervention questionnaire, pre-test, practical activities based intervention, post-test and post-intervention questionnaire.

Firstly, in order to establish the details of the research group, a pre-questionnaire was administered (Appendix T). The questionnaire evaluated matters like the learners' current attitudes, demographics, perceptions of science in general and E&M, frequency and nature of practical, computer skills and other issues related to this research.

Secondly, the learners would write a pre-test to determine their current knowledge of a particular E&M topic after being taught this topic by their teacher only theoretically. These tests consisted of a mixed bag of questions, i.e. open-ended (long questions) as well as closed (multiple choice) questions. The majority of the questions however, were long questions, where learners were given an opportunity to show their working out and reasoning. In the cases of the multiple choice questions the learners were requested to indicate whether or not they were sure of their answer.

Thirdly, practical activities based intervention then took place. Here the learners worked in groups of between three to five learners depending on the number of learners present on a

given day. Half of the practical activities were done only manually i.e. experiment and data collected manually. The other half were done making use of the TRAC practical activities – this included a manual execution of the actual practical activity but the data collection and (small amount of) analysis done making use of the TRAC Vernier soft and hardware.

Due to time constraints and the difficulty at times with which the learners performed the practical activities, some activities spanned over two sessions. In addition, some practical activities were divided into more than one part, for example series and parallel circuits. The details of how each experiment was executed are spelled out in Chapter 4. During these practical sessions, qualitative data in the form of observations was also collected. This is also reflected on in the data analysis chapter (section 3.5).

Fourth, in order to determine the effect of the practical activities on the learners' knowledge of the concept at hand, the learners wrote a post-test on that concept. This took place very soon after the practical activity, on the same or the next day. The post tests were fairly similar to the pre-tests but they were not identical. Here too were a couple of multiple choice questions but the majority of the questions were long questions.

On the last day of the research process, a post intervention questionnaire was also administered to explore the learners' experiences of the practical activities, and to also discover areas of improvement for the TRAC program itself as the proponents of a practical activities based approach.

The collected quantitative data was then recorded and analysed using Excel. In order to compliment the quantitative data, most of the qualitative data was coded and then quantitized. The rest of the qualitative (exact difficulties and misconceptions, challenges within the experiments, etc.) data, however, was consolidated and included in the data analysis of each of the concepts researched.

### **3.5. DATA ANALYSIS**

#### **3.5.1. Data Analysis Stages Utilized**

In analysing the quantitative and qualitative data within this study, some of the following strategies as recommended by Onwuegbuzie and Teddlie, (2003:375), have been applied: data reduction, data display, data transformation, and data integration.

### 3.5.1.1. Data reduction

In order to “sharpen, sort, focus, discard and organise”, the collected data “in such a way that final conclusions can be drawn and verified” (Miles & Huberman, 1994:11; Onwuegbuzie & Teddlie, 2003:373), the data collected was reduced. The qualitative data (questionnaires, learner difficulties and misconceptions from tests) was reduced by coding the responses, summarizing the sections where they wrote explanations and then clustering those responses under certain codes. The quantitative data was reduced by scaling the learner performances using the following codes as utilized by the department of education (DBE, 2011:150).

**Table 3.1. Performance Levels Indicator**

Rating Code	Rating	Marks (%)
8	Scored 100%	100%
7	Outstanding achievement	80-99
6	Meritorious achievement	70-79
5	Substantial achievement	60-69
4	Adequate achievement	50-59
3	Moderate achievement	40-49
2	Elementary achievement	30-39
1	Not achieved	1-29
0	Scored zero	0

For the sake of greater clarity however, a level 8 has been added to indicate the presence of 100% (which according to the DoE would be level 7) and level 0 (which according to the DoE is level 1) to indicate cases where learners obtained none correct.

### 3.5.1.2. Data Display

The data collected in this data is displayed in three forms – tables, bar graphs, as well as numerically within the text. The learner test scores provided quantitative data, which was tabulated and is shown in Appendix A to G. This quantitative data after being analysed on Microsoft Excel was displayed in the form of bar graphs which provided with a more

simplified version of the results collected. The rest of the data remains displayed as percentages within the text.

### **3.5.1.3. Data Transformation**

The dominant data in this study was quantitative data, with a smaller portion being the qualitative data. The data transformation stage was an important stage in the analysis of this data and it took place in various steps.

Step one was the quantitative analysis of quantitative data. This analysis was done making use of descriptive statistics to compute the levels of learner understanding in the pre-test, compared the to the post-test. The main statistic feature that was utilised is the t-test, which was utilised in order to determine that the difference obtained between two sets of data (pre-test and post-test) was statistically significant. In this case the two sets of data represent “before treatment and after treatment observations on the same” (Boudah, 2011:293) research group.

To be specific, the type of t-test utilized in this study was the t-test: Paired Two Sample for Means. The paired test is the one used “when there is a natural pairing of observations in the samples, such as when a sample group is tested twice — before and after an experiment” (Microsoft, 2012). This was the case with the data in this study, i.e. the same sample was tested twice, before and after the practical activity to determine the effectiveness of practical activities in addressing learner difficulties in E&M.

Step 2 involved the qualitative analysis of the quantitative data (qualitizing) and later a quantitative analysis of the qualitized data. In order to answer the research question about the exact difficulties (and later misconceptions) experienced by the learners, the actual responses (questions) in the transcripts were given various codes, thereby allowing the researcher to be able to list the exact difficulties experienced by the learners. This was the qualitization of the quantitative data. Because the difficulties were coded, they could be entered on a spread sheet and therefore calculations done that gave percentage prevalence of the various difficulties and misconceptions i.e. the quantitization of the qualitized data.

Step three was the qualitative analysis of the qualitative data. The qualitative data referred to here are the learner responses to the questionnaires as well as the observations schedules from the practical activities. This was done in order to determine the learner attitudes and behaviour towards science as well as to establish their level of scientific knowledge, prevalence of practical work and challenges faced during the practical sessions.

The final step was then the quantization of the questionnaire qualitative data. The responses were given various codes which were then recorded on a spread sheet to get an indication of the percentage of learners who responded in a certain way.

#### **3.5.1.4. Data Integrations**

Both the qualitative and quantitative data from the learners' transcripts and test scores were then integrated into a coherent whole in which the overall performances per test were displayed. In other words, once the learner performance in the individual tests (pre and post) was displayed, the exact difficulties in that particular test were displayed as well as how prevalent (on percentage form) those difficulties were.

After each pre and post test results had been analysed as described in the preceding paragraph, an analysis of how the difficulty has changed between the pre and post-test was then done. This analysis was displayed in the form of a table and a bar graph.

### **3.5.2. Interpretation of Data**

#### **3.5.2.1. Quantitative Data Interpretation**

After the data had been transformed, recorded and analysed as stipulated in the steps described under Data Transformation (section 3.5.1.3), the data was then interpreted. For the first step - the quantitative analysis of quantitative data – the quantitative data was represented graphically. These differences in the height of the bars on the bar graphs gave an indication of the differences between the means of the pre and post-test scores.

In order to establish the statistical significance of the percentage increase for each test, descriptive statistics and t-tests were then utilized. The specific statistics for each of the

tests have been recorded in the data analysis chapter (Chapter 4). To begin with, the null hypothesis, i.e. a “claim of no difference” (Gerstman, 2003:6.1) was formulated:

$H_0$ : there is no significant difference between the two sets of scores and they come from the same population.

A t-test was then performed in order to test the null hypothesis, in order to accept or reject it. Table 3.2 is an example of some of the data that can be obtained on Excel when performing the t-test:

**Table 3.2: t-Test for Example: Pre- and Post-Test 1**

t-Test: Paired Two Sample for Means		
	<i>Variable 1</i>	<i>Variable 2</i>
Mean	35.26681	58.44042553
Variance	391.104	242.3775346
Observations	47	47
Pearson Correlation	0.649906	
Hypothesized Mean Difference	0	
Df	46	
t Stat	-10.4016	
P(T<=t) one-tail	5.73E-14	
t Critical one-tail	1.67866	
P(T<=t) two-tail	1.15E-13	
t Critical two-tail	2.012896	

The null hypothesis is then accepted or rejected according to the following table:

**Table 3.3: Null Hypothesis Analysis**

<b>If</b>	<b>Then</b>
Test statistic (t) > critical value (t Crit) (two tail)	Reject the null hypothesis
T < t Crit	Accept the null hypothesis
P value < a	Reject the null hypothesis
P value > a	Accept the null hypothesis

Table 3.3 illustrates that if the “calculated t-value>critical t-value and  $p \leq 0.05$ ”, “this indicates that there is significant statistical evidence in support of rejecting the null hypothesis. In other words, the means of the two samples are significantly different. There is less than or equal to a 5% probability that we could obtain this result by chance, which is an acceptable level of error for ecological experiments”.

On the other hand, Table 3.3 also illustrates that if the “calculated t-value  $\leq$  critical t-value and  $p > 0.05$ , then there is no significant statistical evidence in support of rejecting the null hypothesis. In other words, the means of the two samples are not significantly different. There is greater than a 5% probability that we could obtain this result by chance, which exceeds the acceptable level of error for ecological experiments.

Explaining the use of the phrase “significant”, Gerstman (2003:6.1) suggested the following conventions:

- when p value  $> 0.10$ , the observed difference is “not significant”
- when p value  $\leq 0.10$ , the observed difference is “marginally significant”
- when p value is  $\leq 0.05$ , the observed difference is “significant”
- when p value is  $\leq 0.01$ , the observed difference is “highly significant”

Gerstman (2003:6.1) further cautiously explained that “significant” in this case means that the observed data is unlikely due to chance and adds that “significant” does not mean important or meaningful.

Using the above conventions, from an analysis such as the one in Fig 3.3 for example, it would then be concluded that since the t statistic  $>$  t critical(two tail) ( $10.40 > 2.01$ ) and p value  $<$   $\alpha$  ( $1.15 \times 10^{-3} < 0.05$ ), there is highly significant statistical evidence in support of rejecting the null hypothesis. In other words, there is less than or equal to a 5% probability that this result could be obtained by chance. The 5% probability is the acceptable level of error for ecological experiments (Cohen, *et al.*, 2011:145-150). Therefore, it can be concluded the practical activities approach was successful at addressing learner difficulties in this topic, at a 95% confidence level.

Another piece of statistical information that shed more light to the quantitative data was the Pearson Correlation. According to Gerstman (2003:14.1), “correlation quantifies the extent to which two quantitative variables, X and Y, “go together.” Gerstman (2003) differentiates between positive and negative correlation, explaining that when high values of X are associated with high values of Y, a positive correlation exists. When high values of X are associated with low values of Y, a negative correlation exists (Gerstman, 2003:14.1).

Gerstman (2003:14.5) suggested Pearson's correlation coefficient ( $r$ ) could be interpreted as shown in table 3.4. where the sign of the the correlation coefficient determines whether the correlation is positive or negative. The strength of the correlation is then determined by the magnitude of the coefficient.

**Table 3.4 Pearson's Correlation Interpretation** (Gerstman, 2003:14.5)

<b>Pearson Correlation (<math>r</math>) value</b>	<b>Meaning</b>
$0 < r < 0.3$	Weak Correlation
$0.3 < r < 0.7$	Moderate Correlation
$r > 0.7$	Strong Correlation

Gerstman (2003:14.5) was however quick to admit that the information given in Table 3.3. is only a guideline as "there are no hard and fast rules". Again using the data example on Table 3.2, there was a moderate positive correlation between the pre-test and post-test scores. This further strengthened the rejection of the null hypothesis that the difference is purely by chance.

### **3.5.2.2. Qualitative Data Interpretation**

The qualitative data in the form of learner transcripts – where the qualitative data was quantitized in order to get a clear indication of the prevalence of a particular difficulty or misconception, was then given in the form of a table, similar to table 3.5.

**Table 3.5 An Example of Quantitized Qualitative Data**

Pre-Test					Post-Test				
LEVELS	Description (%)	No. of learners	% Learners		LEVELS	Description (%)	No. of Learners	% Learners	
0	0	10	21.3	FAIL	0	0	1	2.128	FAIL
1	1-29	29	61.7	83	1	1-29	5	10.64	12.768
2	30-39	0	0	30-59	2	30-39	11	23.4	30-59
3	40-49	4	8.5	8.5	3	40-49	0	0	51.06
4	50-59	0	0		4	50-59	13	27.66	
5	60-69	0	0	60%	5	60-69	6	12.77	60%
6	70-79	4	8.5		6	70-79	0	0	
7	80-99	0	0		7	80-99	10	21.28	
8	100	0	0	8.5	8	100	1	2.128	36.178

Table 3.5, for example, illustrates a comparison of learner performance on knowledge of the basic components of an electric circuit, between the pre-test and the post-test. A decrease in percentage of learners obtaining levels zero and one from the pre-test to the post-test, gives an indication of the possible effect of the practical activity on increasing learner knowledge of these components. Similarly an increase in the percentage of passing learners (levels three to eight) also gives the same indication. This data was also presented graphically in the form of a bar graph.

The final sample of qualitative data was the one obtained from the pre-intervention and post-intervention questionnaires. Its analysis was mainly through the use of percentages and bar graphs and could only be interpreted in terms of the prevalence of that particular item being questioned. Most of this data was useful in the analysis of the research sample itself.

### 3.5.3. Legitimation (Validity) of the Data

Legitimation involves assessing the trustworthiness of both the qualitative and quantitative data and subsequent interpretations (Johnson & Onwuegbuzie, 2004:22). "Legitimation" is a term preferred by Onwuegbuzie and Johnson (2006:55) in mixed research studies to replace the term "validity". By validity, Onwuegbuzie and Johnson (2006:48) refer to the extent in which a research study, its parts, conclusions drawn and applications, made can be of high, low or medium quality.

### 3.5.3.1. Mixed Research Legitimation Types

Onwuegbuzie & Johnson (2006:56) offered a new typology of legitimation types in mixed methods, containing nine legitimation types. These legitimation types, most of which the researcher strived to implement, are

“sample intergration, inside-outside, weakness minimization, sequential, conversion, paradigmatic mixing, commensurability, multiple validities, political” (Onwuegbuzie & Johnson, 2006:75).

*Sample intergration legitimation* applies to situations in which a researcher wishes to make statistical generalizations from the sample participants to a larger population (Onwuegbuzie & Johnson, 2006:56). In this research study, this was achieved by having exactly the same individuals taking part in both the quantitative and qualitative components of the study. This made it easy to construct meta-inferences (intergrated mixed inference by pulling together the inferences made from the qualitative and quantitative data. Therefore the quality of these meta-inferences was quite reasonable.

*Inside-out legitimation* refers to the degree in which the researcher accurately presents and utilizes the insider’s view (“emic” viewpoint) and the outsider’s (“etic” viewpoint) view when making meta-inferences by combining inferences from the qualitative and quantitative phases of the study (Onwuegbuzie & Johnson, 2006:58). The “emic” viewpoint is the point of the insider, in this case the researcher and the etic viewpoint is that of an objective outsider. In this study the researcher strived to achieve this legitimation by making use of peer review as well as the help of the research supervisor.

*Weakness minimization legitimation* is the extent to which the weakness from one approach is compensated by the strengths from another. This is one type of legitimation in which mixed research is in an optimal position to maximize due to the fact that the researcher is able to systematically design a study that combined two or more methods (Onwuegbuzie & Johnson, 2006:58) from the beginning.

The authors added that the researcher needs to consciously and carefully assess the extent to which the weaknesses of one approach are compensated by another and then plan the study to achieve that. The one area where this legitimation was applied extensively in this study was in the pre-test and post-test scores data. The quantitative data only answered the first part of the hypothesis – the effect of practical work on learner

performance in E&M – but could not crystallize the actual difficulties. The crystallization of the difficulties was then obtained by the qualitative analysis of the tests. This qualitative analysis on the other hand also could not quantify the extent of the difficulties and was thus quantitized to achieve that.

*Conversion Legitimation* is a measure of the extent to which the data conversion techniques lead to interpretable data and high inference quality (Onwuegbuzie & Johnson, 2006:58). In the case of this research the conversion techniques utilized were quantitization (questionnaire qualitative data and qualitative data from the learner transcripts) and qualitization (learner transcripts). This made it possible to draw stronger inferences especially pertaining to the extent of learner difficulties in E&M.

*Multiple validities* refers to the extent to which addressing legitimation of the quantitative and qualitative components of the study results from the use of quantitative, qualitative and mixed validity types, yielding high quality meta-inferences (Onwuegbuzie & Johnson, 2006:59). The authors explain that for example when addressing legitimation of the quantitative component, the relevant quantitative validities are addressed and the same applied when addressing legitimation of the qualitative component of the study. Then during intergration and to allow stronger meta-inferences, the relevant mixed legitimation types are addressed and achieved.

### **3.5.3.2. Qualitative Validity**

In trying to achieve multiple validities as well, the qualitative component of this study was validated by making use of Onwuegbuzie and Leech (2007:239) strategies (24 in total) which they believe would “assess the truth value of qualitative research”. The qualitative validity strategies or techniques used in this research are as follows:

“prolonged engagement, triangulation, leaving an audit trail, weighting the evidence, checking for representativeness of sources of data, checking for researcher effects/clarifying researcher bias, making contrasts/comparisons, theoretical sampling, checking the meaning of outliers, ruling out spurious relations, replicating a finding, following up surprises, peer debriefing, rich and thick description, assessing rival explanations, negative case analysis, and effect sizes” (Onwuegbuzie & Leech, 2007:239).

Some of the strategies of Onwuegbuzie and Leech (2007:239) for assessing validity in qualitative research, also apply to quantitative research and were thus utilized in this study.

These were:

replication, researcher bias, external evaluation (peer debriefing), representativeness, theoretical sampling triangulation, suitable generalizability (Cohen, *et al.*, 2011:183).

As far as quantitative research is concerned, the validities that best suited the quantitative data in this study were Graziano & Michael's (2009:162) four validity types: statistical, construct, external and internal validity.

*Statistical validity* is when statistical procedures are used to test the null hypothesis, as was the case in this study, the question of whether the results are due to chance variations or are due to the independent variable needs to be addressed (Graziano & Michael, 2009:162). The authors argued that the first step in testing the effects of the independent variable is to reject the null hypothesis, thus reaching some conclusion. Thus, they submitted that statistical validity addressed the question of whether these conclusions are reasonable or not. The pre- and post-tests which were used as a measure to assess the dependant variable are a fairly reliable tool to use and therefore increase the degree of validity of these statistics.

*Construct validity* is the degree to which the theory behind the research study provides the best explanation for the results observed (Graziano & Michael, 2009:163). The authors elaborate that this validity refers to how well the study's results support the theory or constructs behind the research and whether the theory supported by the findings provided the best available explanation of the results. This validity was addressed in a number of ways during this study. First the theoretical base for this study – the ability of practical work to improve learner knowledge in science - is reasonably strong, with the rival theories mostly not disputing practical work's ability to do so, but rather disputing failures in how practical work is implemented.

With regards with construct validity, Jackson (2009:72) suggested that one of the ways of accomplishing construct validity is to “correlate performance on the test with performance on an established test or with people who have different levels of the trait the test claims to measure”.

*External validity* refers to the degree to which researchers are able to generalize the results of a study to other participants, conditions, times and places (Graziano & Michael,

2009:163). Generalization, according to the authors, is the process of inferring something about a population based on findings from a sample. In this case, the research sample, though learners from the same school, was to a certain extent randomly selected and that contributes to the strength of the generalizations. However, due to ethical principles, one could only use the data obtained from the participants who signed consent but even that group had the option to choose not to attend.

*Internal validity* “involves the very heart of experimentation: demonstrating causality” (Graziano & Michael, 2009:164). It concerns the question of whether or not the independent variable and not some extraneous variable is responsible for the change in the independent variable. All the possible measures were taken during this study to control all the other variables that could also contribute to the change in the dependant variable. The only two variable that could not be kept constant were the teacher as well as the number of learners available during the testing and the intervention sessions. The participant school’s science learners were taught by two teachers and due to ethical consideration, the researcher could not only work with one group and not the other. The other ethical consideration issue was the attendance levels which fluctuated due to the fact that the learners had a choice of staying or not, for the program. The latter has been accounted for in that the data being analysed is only for th learners who would have attended all the phases (pre-test, practical activity and post-test).

Although a researcher can never be in a position to say that the collected data and methods utilized were hundred percent correct, enough caution and care was employed in this study to ensure that the data collected and the interpretations made are valuable and relevant to the debate about learner difficulties in E&M and how practical activities can assist with these difficulties. However, like with any other work of this kind, limitations exist.

### **3.6. LIMITATIONS AND POTENTIAL PROBLEMS**

There were a number of challenges which the researcher experienced during the data collection stage of this research, and these have led to the following limitations to the perfection of the data collected. These limitations include

- sample population
- participant attendance

- research process time – changes in arrangements made
- learners' language proficiency
- faulty equipment

The agreement reached when the participating school agreed to take part was that all the grade 11 learners (61 in total) would take place in this study. Therefore the maximum number that one could get was 61 participants, which is considered low especially in quantitative research when it comes to confidence levels and intervals. In addition, the researcher was not able to achieve 100 percent attendance (i.e. all 61 participants) in any of the six phases of the research. In fact the attendance numbers were as shown in Table 3.6.

**Table 3.6 Participants Attendance**

<b>Session 1 (Pre-test, practical activity(ies), post-test</b>	<b>Sample Size</b>	<b>Percentage Attendance</b>
1	47	77.1
2	41	67.2
3	29	47.5
4	31	50.8
5	24	39.3
6	23	37.7

The size of the samples in some of the sessions would therefore compromise the statistical analysis of the data collected. However, the data collected still provides enough information for reasonable conclusions and diagnosis of learner difficulties that could contribute to the current body of knowledge or utilised as a foundation for future research.

When the school management agreed to take part in the research, it was established that the research process would take place during the study period already allocated within the school's time-table. This was the case for the first two sessions of the intervention, hence the decent attendance number. The study periods were, however, done away with, which meant that the learners could choose not to come to the intervention sessions and some indeed did not attend. The main reason they gave was scholar transport and being hungry.

The remaining learners, at times in spite of being hungry, did give their best during the sessions.

When it came to the questionnaires as well as the tests, there were occasions where the learners did not seem to understand what was being asked and thus provided irrelevant answers. The researcher did however, explain questions perceived as difficult to understand but could not be responsible for cases when learners did not understand but also did not ask. All the data collection tools were in English which was the second language to all the participants.

Lastly, in the fifth session, the researcher experienced some challenges with faulty equipment and computers that were freezing, with no back-up provision being made. This led to two stations being unused and thus increased the numbers in the rest of the groups. Although this was not evident upon observation, it might have demotivated the participants a bit.

### **3.7. ETHICAL CONSIDERATIONS**

The following considerations have been made:

- endorsement by the DoE and the school
- learner inclusion
- learner anonymity during analysis

Meetings with the DoE, school management were held to communicate the research purpose and to obtain written consent from the department of education (Appendix V) and the school (Appendix W). In addition, the school also wrote letters to the parents to obtain their consent for their children to participate, these letters had to be translated to isiXhosa, the home language of the participants (Appendix X). Additionally, the learners signed two consent forms as stipulated by the University of Stellenbosch (SU): SU consent (Appendix Y) and Minor Consent (Appendix Z).

In addition to the consent, the school was given the option to include all their grade 11 science learners in this study, they indeed took that option. This meant that no grade 11 Physical Science learners were excluded from the program due to structuring by the researcher. Learners who would have been excluded would have done so by choice.

Also, during the analysis of the data, learners were given student numbers in order to protect their rights to privacy and to ensure that their confidentiality was protected.

### **3.8. CONCLUSION**

This chapter has been a detailed look at how this research was executed. This was done first by outlining research method chosen – mixed methods and the rationale for choosing mixed methods as well as all the detail pertaining to mixed methods. In addition to that, the data collection techniques utilized – pre-test and post-tests, questionnaires and observations schedules - were discussed as well as why they were utilized. The process of how the data was analysed and the mixed methods data analysis stages used were explained. This analysis also included the discussion on the validity of the data and research instruments. Lastly, the limitations of this study and the ethical considerations made were discussed. The results obtained using the methods discussed in this chapter will be documented and analysed in the following chapter.

## CHAPTER 4: DATA COLLECTION AND ANALYSIS

### 4.1. INTRODUCTION

This chapter reports on the results obtained after embarking on the research process as described in Chapter 3. Firstly, a summary of the results obtained from all the tests is given, accompanied with a preliminary observation based on this summary. Secondly, a detailed analysis on each and every topic as covered by the tests is given as follows:

- the learner performances on each pre and post-test,
- a brief analysis based on the null hypothesis,
- a detailed list of difficulties in the pre-test,
- the practical intervention,
- a detailed list of difficulties in the post-test
- a comparison in performance between the pre- and post-tests, in terms of difficulties

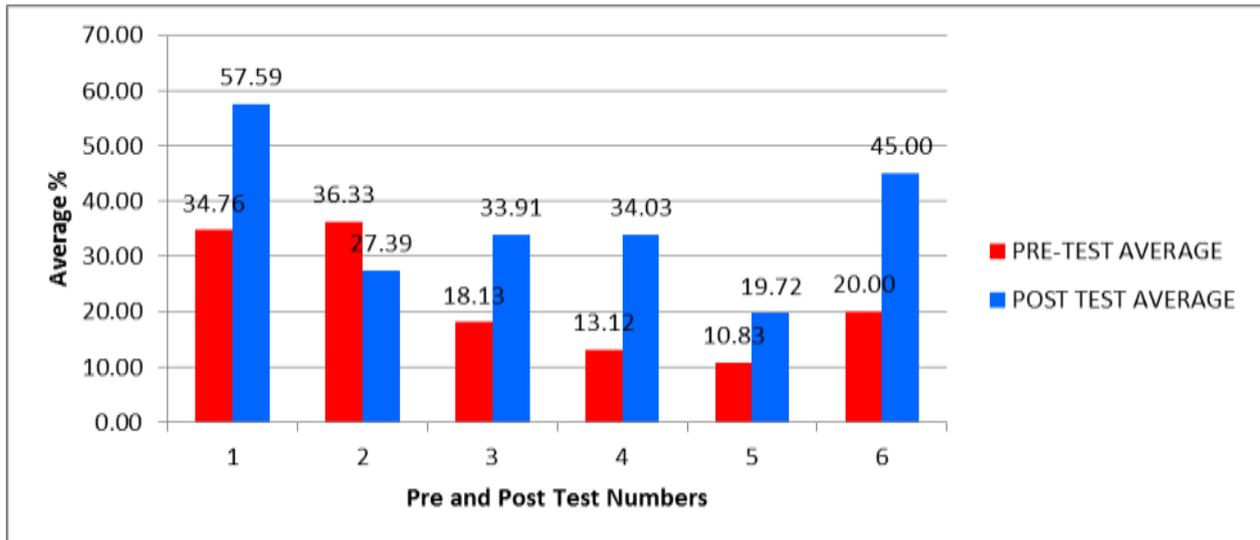
Thirdly, an analysis of test scores for the learners who attended all the sessions is done. This is then compared to the trend observed in tests one to five. Finally, this chapter also takes a look at the difficulties experienced by learners in the module E&M and indicates the prevalence of these misconceptions in the pre-test as well as in the post-tests, to document the effect of practical activities in addressing misconceptions.

It is however important to note that, due to circumstances beyond the control of the researcher, the size of the sample kept decreasing as a result of deteriorating learner attendance. This therefore affects the generalizability of the data, in particular the quantitative data. It also affects the observed tendencies which are reflected as percentages due to the totals getting less as you progress from test 1 to test 5. However, due to the fact that this is a mixed methods study, the weakness of the one type of data (quantitative) is to a certain extent compensated for by the qualitative data. Therefore, there is still a lot of value to be gained from the results discussed in this chapter.

### 4.2. SUMMARY OF FINDINGS

#### 4.2.1. Summary of all the test results

In order to provide the bigger picture, the summary of all the test results is shown in Fig 4.1.



**Fig 4.1: Pre and Post-test Averages - All Tests**

The titles of each test are as follows:

- Test 1 – Basic of current electricity
- Test 2 – Resistance and Ohm's Law
- Test 3 – Emf and internal resistance
- Test 4 – Series and parallel circuits
- Test 5 – Magnetic field associated with current
- Test 6 – Current associated with magnetic field

The general trend, as illustrated in Fig 4.1 shows an increase in the averages of the post-tests compared to the pre-tests, with the exception of Test 2, which actually showed a decline. One can therefore reach a preliminary conclusion that the practical activities based intervention which took place after the pre-test, played a role in increasing learner knowledge on the section of Electricity and Magnetism. A closer look at the individual tests performances will provide a much clearer picture in detailing this assertion.

#### **4.2.2. Analysis of learners test scores**

Pre and post-testing of the learners to determine their conceptual difficulties in E&M, as well as to measure the effect of the practical activities based approach in addressing learner difficulties in E&M, revealed that indeed the learners were struggling to grasp a lot of the concepts in this module. These results will be discussed for each of the E&M topics that were covered during this research.

For the purpose of discussion and uniformity, the performance indicators as prescribed by the Department of Basic Education (DBE, 2011:150), shown in Table 4.1 will be utilised.

**Table 4.1: Performance Levels Indicators**

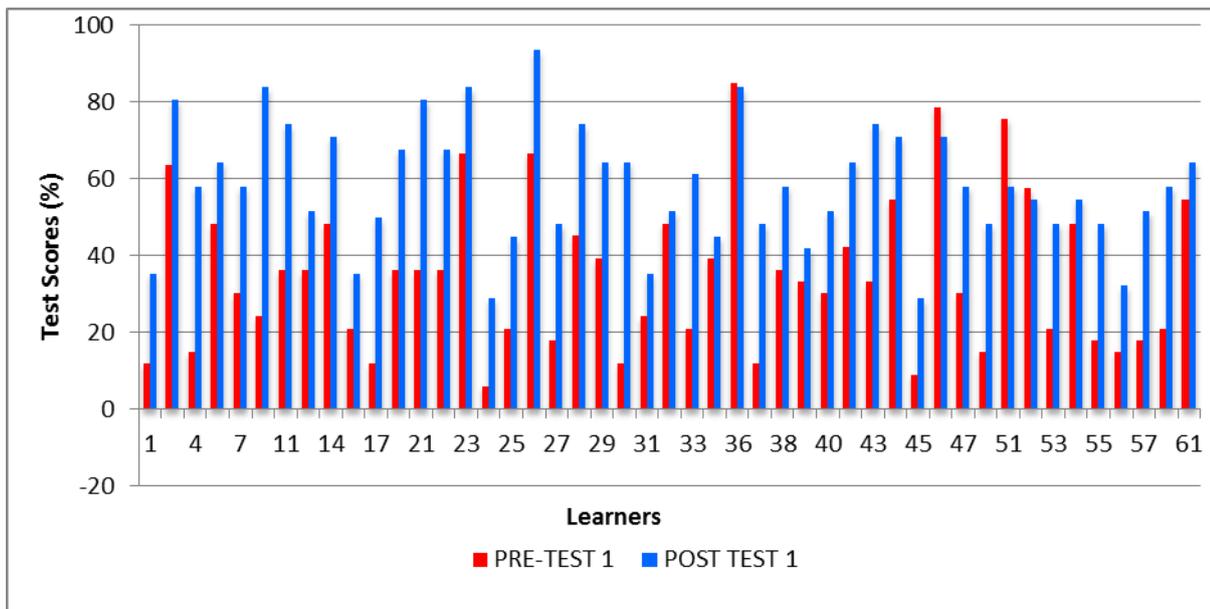
<b>Rating Code</b>	<b>Rating</b>	<b>Marks (%)</b>
<b>8</b>	<b>Scored 100%</b>	<b>100</b>
7	Outstanding achievement	80-99
6	Meritorious achievement	70-79
5	Substantial achievement	60-69
4	Adequate achievement	50-59
3	Moderate achievement	40-49
2	Elementary achievement	30-39
1	Not achieved	1-29
0	Scored zero	0

### **4.3. BASICS OF CURRENT ELECTRICITY**

#### **4.3.1. Pre and post-test 1 scores**

The number of learners whose pre-test scores was analysed was 47. The tests (Appendix H) consisted of questions which required the learners to provide the meaning of the various components of a basic electric circuit, namely: battery; connectors; resistor; ammeter; voltmeter; galvanometer and switch. They were also required to provide labels to a provided circuit diagram and to also draw the symbols of these circuit components. The last question asked learners to define, provide names and symbols of units for the foundational concepts in current electricity like current; potential difference; resistance and emf.

Learner performance in pre- and post-test 1, focusing on the basics of current electricity is shown in Fig 4.2.



**Fig 4.2: Pre- and Post-Test 1 Scores – Basics of Current Electricity**

***H<sub>0</sub>: there is no significant difference between the two sets of scores and that they come from the same population.***

The effectiveness of the intervention in terms of learner performance is measured by the increase in learner test scores between the pre- and post-test. With the exception of four learners (8.51%) whose performance decreased, 91.14% of the learners showed an increase in the post test.

A paired t-test was then performed to determine if the practical activities based intervention was effective in improving learner understanding of basic current electricity. The mean difference in test scores ( $M = 23.17$ ,  $SD = 15.27$ ,  $N = 47$ ) was significantly different than 0,  $t = 10.40$  ( $df = 46$ ) and  $p = 1.15 \times 10^{-13}$  (two-tailed). This provides sufficient evidence that the intervention was effective in improving grade 11 learners' knowledge of basic current electricity.

In addition, since the t statistic > t critical (two tail) ( $10.40 > 2.01$ ) and p value <  $\alpha$  ( $1.15 \times 10^{-13} < 0.05$ ), there is highly significant statistical evidence in support of rejecting the null hypothesis. The confidence interval for this sample, at a 95% confidence level, is slightly more than 5% (the probability value that is the acceptable level of error for ecological experiments (Cohen, *et al.*, 2011:145-150)).

In other words, there is less than or equal to a 5% probability that this result could be obtained by chance. Therefore it can be concluded the practical activities approach was successful at addressing learner difficulties in this topic, at a 95% confidence level.

Also, looking at the Pearson Correlation value ( $r = 0.65$ ), to determine the correlation between the pre-test and post-test scores, there was a moderate positive correlation between the pre-test and post-test scores. This further strengthened the rejection of the null hypothesis that the mean difference was purely by chance.

#### 4.3.2. Learner difficulties detected from the Pre-test 1

In Question 1.1 in the Basics of Current Electricity pre-test (Appendix H), the learners were required to *define the circuit components* and by implication *include the function of each*. The circuit components were batteries; connectors; resistors; ammeter; voltmeter; galvanometer and switch.

The levels of learner performance on the whole question revealed the difficulties listed below:

- A large majority (83%) of the learners obtained less than 30% for this question with 21.3% of this majority obtaining zero out of 7.
- Only 17% of the learners actually obtained more than 30% for this question, with only 8.5% scoring more than 60%.
- None (0%) of these learners obtained all 7 questions on the components correct.
- In terms of the individual questions, question 1.1.3 (labelling the resistors/appliances) was incorrectly answered by all of them. The possible explanation to this was that perhaps the question was not clearly asked.

The information and analysis clearly indicated that a large majority of the learners struggle to define and / or to provide the function of the circuit components. Their inability to define and to provide functions of these led to learners continually struggling with current electricity because they lacked the basic understanding of what each of those components does in the circuit.

Question 1.2, which asked learners to *provide labels to a drawn circuit diagram*, was very well answered, however. The components they were to label included a battery, voltmeter, ammeter, resistor and connectors.

- A notable 23.4% of the learners obtained all five questions correct.
- Another 38.3% of the learners obtained 4 out of 5, only getting the last question incorrect (this might be because the question was not clear to them..)
- In total, approximately 87.2% of the learners obtained more than 60% in this question.

This implied that a lot of the learners were able to get the correct answer on the symbols of the components when asked simply to label, but struggled with defining them, as required in Question 1.1. However, a circuit component that seemed more difficult for learners to identify was the resistor, which in the circuit diagram was illustrated by a small rectangular block. For some reason, approximately 30% of the learners were not able to identify that.

In question 2.1, the learners were this time assessed on their *ability to draw circuit diagrams with more than one circuit component connected in series or in parallel*. The question required learners to draw fully labelled diagrams of cells in series (2.1.1); cells in parallel (2.1.2) and resistors in series (2.1.3) and resistors (2.1.4) in parallel. To that was added one more question where they had to draw a complete circuit diagram consisting of 3 cells in series, an ammeter and two resistors in parallel as well as a voltmeter connected to one of the resistors.

Here again, it was quite evident that the learners were experiencing difficulties:

- A total of 68.1% obtained less than 30% for this question with an astounding 48.9% of learners scoring zero for all four of the questions.
- On the part of the series and parallel diagrams, only 17% got all four questions correctly answered and in total only 25.5% of learners scored above 60%.

The complete circuit diagram (2.1.5) was even more poorly answered:

- When the less than 30% level is totalled, 40.3% of the learners failed this question with 27.6% of learners obtained zero out of the 5 marks given.
- Only 8.5% of the learners could draw the complete circuit diagram correctly
- The total percentage of learners who obtained 60% or more for this question is 38.3%.

Current electricity terms like current, *potential difference*, *resistance* and *emf* form the foundation of learner understanding to this section of work. To assess the learners' understanding of these terms, they were asked to *define the terms, provide the symbol used for each of these terms as well as the names and symbols of the units of these terms* (2.2). The learners' performance gave reason for concern:

- Not even one learner obtained full marks for this question, while on the other hand 21.3% of learners got none of the terms and their units correct.
- Adding to this number (21.3%), the number of learners who obtained between 1 and 29%, the percentage of learners who failed this question is 72.4%.
- The remainder mainly scored between 40 and 59% with only 3 learners scoring greater than 60%. This was clearly a huge area of concern as these terms are the foundation for greater understanding in the entire Electricity and Magnetism module.

McDermott and Shafer (1992a:996), summarized this observation as the tendency of students to confuse the concepts of current, potential difference, power and resistance. They referred to this tendency as “failure to distinguish among related concepts”.

#### 4.3.3. Practical Activities based intervention 1

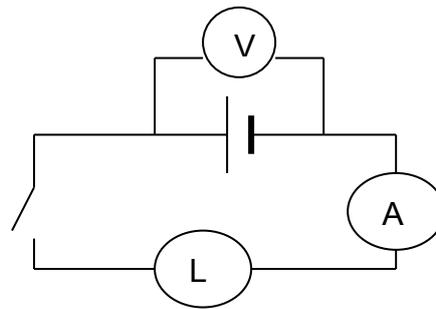
An experiment titled “a simple circuit” (Appendix N) was performed with the learners working in groups of between four to five learners per group. Following are some of the observations made during this experiment based session:

- This was their first practical session of this intervention and their second practical in the year (taking place in August), so the enthusiasm was quite high. The attendance was also high as this session occurred during their study session as instituted by the school.
- After explaining the instructions and aim of the experiment and providing the necessary equipment (cells; connecting wires; light bulbs and later, circuit board; batteries, voltmeter and ammeter), the learners began. In the first activity, the learners were asked: *“You are supplied only with a torch cell, a bulb and a single piece of wire. Make the bulb shine. How many different times can you make this happen? Draw the arrangement in the space below.”*

It was immediately clear that the learners were struggling to connect the circuit and to make the bulb glow but in the end after a lot of fiddling on their side, they actually got the bulb to glow, without much help from the facilitator (deliberately). The excitement in their eyes when they got the bulb to glow was however difficult to miss.

The task was made a bit more sophisticated now, where they were provided with a circuit board and asked to use the circuit board supplied to build the simple circuit shown in Fig 4.3.

109



**Fig 4.3: Practical Activity 1 Basic Circuit**

The very idea of using the circuit board was to the learners brand new. Most of them could not move but were encouraged to give it a try nonetheless, so they continued. It turned out that the learners could not recognise circuit components like the connectors, ammeters and voltmeters and therefore the researcher had to point these out to them. Their greatest struggle was to connect the voltmeter and the ammeter i.e. making the voltmeter part of the circuit to start with, let alone connecting the right terminals. Most of the learners connected the ammeter in parallel. In the end they had to be taken through the connections step by step until eventually the circuit was completed.

Once connected, then the functions of each of the components were explained individually as well as how the circuit works.

#### 4.3.4. Post-test 1 analysis

In Question 1.1 (excluding 1.1.3; 1.1.6 & 1.1.9) of the Basics of Current Electricity post-test (Appendix H), the learners were required to *define the circuit components including how to connect these in a circuit*.

- Only 12.7% of the learners scored less than 30% for this question with only one learner obtaining zero,
- Although only 1(2.1%) of the learners answered all these questions correctly, 36.2% obtained 60% or more for this question.
- The rest of the learners (51.1%) scored between 30 and 59%. The question asking the direction of the current (1.1.2) though was not very well answered, with 74.5% of them getting it wrong.

Question 1.2 which asked the learners to *draw circuit symbols for various components was again*, as in the pre-test quite well answered:

- Only 1 learner obtained zero out of the 7 marks allocated and a small percentage (6.4%) obtained between 1 and 29%.

- A large percentage of the learners (68.1%) obtained between 60 and 100% with 14.9% of this group obtaining full marks.
- The remainder (22.5%) obtained between 40 and 59%.

In question 2.1 – 2.2, the learners were once again assessed on their *ability to draw complete circuit diagrams from given descriptions*:

- A reflection on how they performed revealed that none of the learners got both questions (2.1 and 2.2 wrong), while only 14.8% of them obtained between 1 and 29% and 12.8% obtained between 30 and 39%.
- A significant 36.1% of them obtained above 60% and above in the question, with 8.5% of those obtaining full marks. The rest of them obtained between 40 and 59%.

Question 2.3.1 – 2.3.4 (*multiple choice*) combined with 1.1.3; 1.1.6 & 1.1.9 asked for *definitions and units of terms like current, potential difference, resistance and emf*, these terms form the foundation of learner understanding to this section of work:

- None of the learners obtained zero for this question, while only 21.3% of them failed this question.
- On the other hand, 29.5% of them scored higher than 60%, with 8.5% of them scoring full marks. The remainder of them scored between 40 and 59%.

#### **4.3.5. Sub-conclusion based on Pre and Post-test 1**

A closer look at learner performance in the assessed topics of the Basics of Current Electricity, there has generally been a significant improvement in learner performance. On the ability of the learners to *define the circuit components including how to connect these in a circuit*, the learners' improvement was as follows:

- Failure percentage (0-29%) decreased from 83% to 12.8%
- Percentage between 30 and 59% increased from 8.5% to 51.1%
- Percentage scoring 60% or higher increased from 8.5% to 36.1%

The learners' performance on the ability to label or *draw simple circuit diagrams* changed as follows:

- Failure percentage (0-29%) changed from 2.1% to 8.5%
- Percentage between 30 and 59% increased from 10.7% to 23.4%
- Percentage scoring 60% or higher decreased from 87.2% to 68.1%

Although, there seems to be a drop from the pre- to the post-test scores, the averages of the pre- and post-test (73.6 and 71.1% respectively), are almost the same. This implies that in general, this area was quite well understood by the learners.

The next question dealt with *drawing circuit diagrams illustrating series and parallel connections as well as complete and mixed circuit diagrams*. The learners' performance is illustrated below:

- Failure percentage (0-29%) decreased from 54.3% to 14.9%
- Percentage between 30 and 59% increased from 13.8% to 48.9%
- Percentage scoring 60% or higher increased from 31.9% to 36.2%

The last question covered the terms involved in current electricity and the changes in learner performance are as follows:

- Failure percentage (0-29%) decreased from 72.3% to 21.3%
- Percentage between 30 and 59% increased from 21.3% to 48.9%
- Percentage scoring 60% or higher increased from 6.4% to 29.8%

From the above analysis, it appears that as Toplis and Allen (2012:4) also cited, that the use of practical work to explain these concepts has somewhat aided in the learning of theory. In other words, the practical activities based learning experience was effective in remediating some of the learner difficulties and thus improving their performance in this area of the basics of current electricity. This means that if the learners get to see these components in real life and actually get to work with them and see them as part of the circuit, they are better able to understand this section.

#### 4.4. RESISTANCE AND OHM'S LAW

##### 4.4.1. Pre and Post-Test 2 results

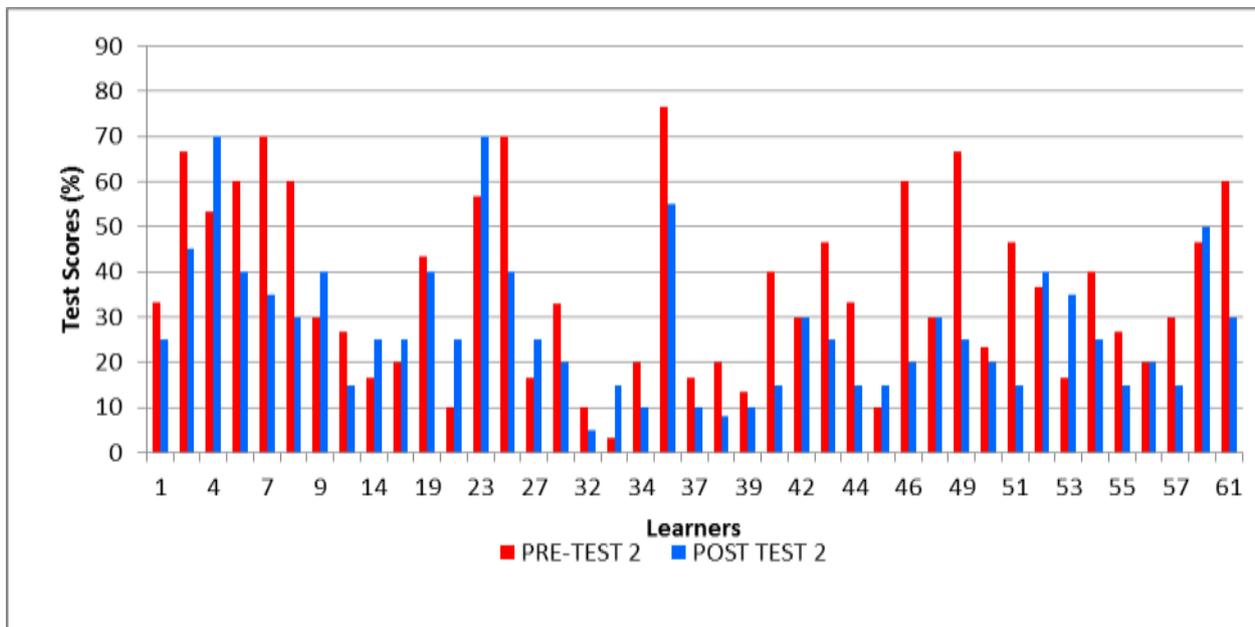


Fig 4.4: Pre and Post Test 2 Scores – Ohm's Law

The null hypothesis, applicable to all the sections examined, is as follows:

***H<sub>0</sub>: there is no significant difference between the two sets of scores and that they come from the same population.***

The effectiveness of the intervention in terms of learner performance is measured by the increase in learner test scores between the pre- and post-test. In this case, however, the majority of the learners showed an average decline with the exception of 34% of the learners whose performance actually increased, ranging from an increase of 3% to 16.7%. Another 9.8% of the learners obtained the same marks in both the pre-test and the post-test.

A paired t-test was performed to obtain the statistics in this regard. The mean difference in test scores ( $M = -8.94$ ,  $SD = 16.22$ ,  $N = 41$ ) was significantly different than 0,  $t = 3.53$  ( $df = 40$ ) and  $p = 0.001059$  (two-tailed). The learner performance in this test was contrary to the general trend in all the other tests in that the learner performance actually drops.

The main reason was the fact that in these tests (Appendix I), the Ohm's Law concept was asked making use of a graphs. Graphing and associated skills (gradients calculations) as well as other mathematical skills like subject of the formula, were not covered in much

detail by the researcher in the practical intervention as the assumption was made that this was a competence dealt with in Mathematics.

The Pearson Correlation value ( $r$ ) for these tests was 0.60, which implied that there was a moderate positive correlation between the pre-test and post-test scores.

#### 4.4.2. Learner difficulties detected from the Pre-test 2

Question 1.1 required the learners to demonstrate their ability to state *Ohm's Law* or at least illustrate that they understand what Ohm's Law is all about. Question 1.2 provided them with potential difference and current data and required them to *plot a graph* using this data. They were then asked questions from the graph they plotted. The questions included a calculation of the gradient, what the gradient of this graph represented and then to state whether or not Ohm's Law had been verified.

From the recorded data, 43.9% of the learners failed this question (1.1 and 1.2), with 4.9% of them obtaining zero for the entire question. In addition, only 9% of the learners obtained above 60% and this is only between 60 and 69%, no one greater than 70%.

When looking at the individual questions, one noticed the following:

- Question 1.1 (Ohm's Law Statement) – 53.7% could not state Ohm's Law (i.e. obtained zero for the question) and only 29.3% of the learners successfully stated the law.
- The most badly answered question (97.6% failure) is the one asking them what the gradient of a current vs. time graphs represented (Q1.2.3), followed by the actual calculation of the gradient from the graph (78.1%).

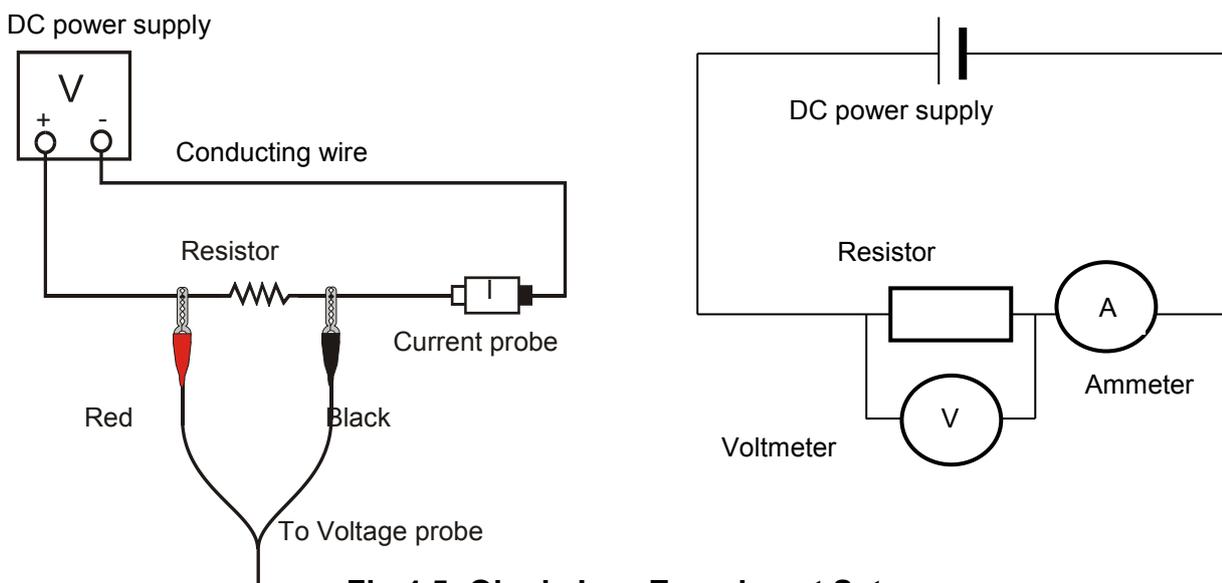
On average, Question 2 was answered better than question 1 in that the average for question 2 was 41.6% compared to 28.5% in question 1. In this question, the learners were asked to *calculate current ( $I$ ), potential difference ( $V$ ) and resistance ( $R$ )* given some of the information. In addition, learners were asked a question on *ohmic and non-ohmic conductors*. Their performance showed that 41.5% of the learners failed this question, with a substantial 19.5% of them obtaining zero. On the other hand, 41.5% of them obtained 60% or more in this question with 17.04% obtaining 80% or more. The remainder obtained between 30 and 59%.

A detailed analysis of this question revealed the following information pertaining to learner difficulties in this question:

- When learners are given information such that they must apply the Ohm's Law formula  $R = \frac{V}{I}$  exactly as it stands, i.e. ask learners to calculate R, they cope with it fairly easily. This is shown by their performance in question 2.1 where 29.2% of them failed the question by obtaining between 0 or 1 out of the 5 marks allocated to this question, while 63.4% of them obtained between 2 and 5 marks for this question. Once the question is asked in such a way as to require them to calculate V or I, a large number of them struggle. The problem here is the mathematical skills involved: making a certain variable the subject of the formula. In question 2.2 and 2.3 the percentage of learners who obtained zero out of the possible 4 marks is 51.2 and 63.4% respectively.
- Question 2.4 was also extremely badly answered, the learners (78.1% of them) seemed to have no clue as to what an Ohmic and / or a non-Ohmic conductor is.

#### 4.4.3. Practical activities based intervention: Ohm's law

The practical worksheet that was used is one of TRAC SA's standard worksheets on Ohm's Law (EM1 – Appendix O), the focus of which is shown in the Table 4.2 below. The learners were provided with the necessary equipment to set up the circuit diagram shown in Fig 4.5



**Fig 4.5: Ohm's Law Experiment Set-up**

This was one of the experiments where the learners were required to also use computers, i.e. the voltage and current probes were connected to a computer which then provided the learners with a table of results, from which they were asked to plot a graph. As this

experiment was the first one where the learners were utilizing a computer, the experiment went rather slow as they were struggling to familiarize themselves with the software. In fact, some learners were struggling with computer skills as well and this slowed them down quite significantly. The other challenge here was the presence of too many wires: the connecting wires, laptop cable, Lab Pro power, as well the cables connecting the voltage probe and current probes. Once they had neatened these up, working became a bit simpler.

The learners were asked to plot three current vs. potential difference graphs, for the two resistors and the light bulb. In addition, the concept of ohmic and non-ohmic conductors was discussed. The learners were also led to the discovery of the formula of Ohm's Law by dividing the potential difference by the current and comparing that to their given resistance. Another aspect of Ohm's Law that was addressed was the effect of temperature on this relationship, in particular as observed in the light bulb.

**Table 4.2: Ohm's Law Data**

	Potential Difference (V)	Current (A)	Constant ( $\frac{V}{I}$ )
<b>Resistor 1</b>  _____ $\Omega$			
<b>Average value</b>			
<b>Resistor 2</b>  _____ $\Omega$			
<b>Average value</b>			
<b>Light Bulb</b>			

#### 4.4.4. Post-test 2 analysis

In post-test 2 (Appendix B), question 1.2 to 1.5, the learners were asked using multiple choice questions to *calculate resistance; the relationships in Ohm's Law; ohmic and non-*

*ohmic conductors and about relationships between potential difference and current.* In addition, question 2.1 was included as it addressed a similar concept – asking the learners to *calculate potential difference, given current and resistance.* From the collected data, 56.1% of the learners failed the question, with 4.9% of them obtaining zero for the question. On the other hand, 12.2% of them obtained 70% and above for this question. The remainder obtained between 30 and 59%.

Question 2 of post-test 2 was again a question on *graphs*, with question 2.1 excluded here and accounted for in Question 1. A huge number of the learners (78%) failed this question, with 7.3% of them obtaining zero. On the other hand, only 2.4% obtained 60% or more, with in fact no learner obtaining 70% or more. The remainder obtained between 30 and 59%.

#### 4.4.5. Sub-conclusions

On the learners ability to perform Ohm's law calculations the questions to be compared is Question 2 in Pre-Test 2 and Question 1 (including Post-Test question 2.1) in the Post-Test 2 and the following is observed:

- Failure percentage (0-29%) increased from 41.5% to 78.1%
- Percentage between 30 and 59% decreased from 48.8% to 19.5%
- Percentage scoring 60% or higher decreased from 9.8% to 2.4%

On the learner's ability to plot graphs as well as answer questions on graphs pertaining to Ohm's Law, Pre-test question 1 is compared to Post-test Question 2 (with 2.1 excluded), the following is observed:

- Failure percentage (0-29%) increased from 41.5% to 56.1%
- Percentage between 30 and 59% decreased from 41.5% to 12.2%
- Percentage scoring 60% or higher increased from 17.1% to 31.7%

From the above data, it is evident that the concepts covered are still very challenging to the learners. These concepts involve a lot of mathematical abilities and the mathematical problems are deeply entrenched. The amount of time that was utilized during the practical intervention was clearly not enough to address these issues. In fact, the practical activity utilized in this case dwells more on the learners discovering the relationship between potential difference and current and later discovering that  $\frac{V}{I}$  gives you the resistance of the conductor.

Although the learners were helped with graph plotting as diagnosed in Pre-test 2, the focus was still on the discovering the relationship between potential difference and current and therefore reaching the conclusion of Ohm's Law. Not enough time was spent on the mathematical skills like making a certain variable the subject of the formula as well as extrapolating information from a graph such as gradients, etc. The effect of the mathematical skills involved in science on learners' performance in science is a topic worth exploring.

From the above observations it seems that the mathematical concepts embedded within Ohm's Law were not mastered by the participants prior to this study. Research also agrees that mathematical expressions and formulae make science difficult for the students (Chabay & Sherwood, 2006:329; Dori & Belcher, 2005:244; Bahar & Polat, 2007:1121), especially those students that are not good at Mathematics.

#### 4.5. EMF AND INTERNAL RESISTANCE

The number of learners whose pre-test scores will be analysed is 29. Learner performance in pre- and post-test 3, focusing on emf, resistance and internal resistance is shown in Fig 4.6.

##### 4.5.1. Pre and Post-test 3 results

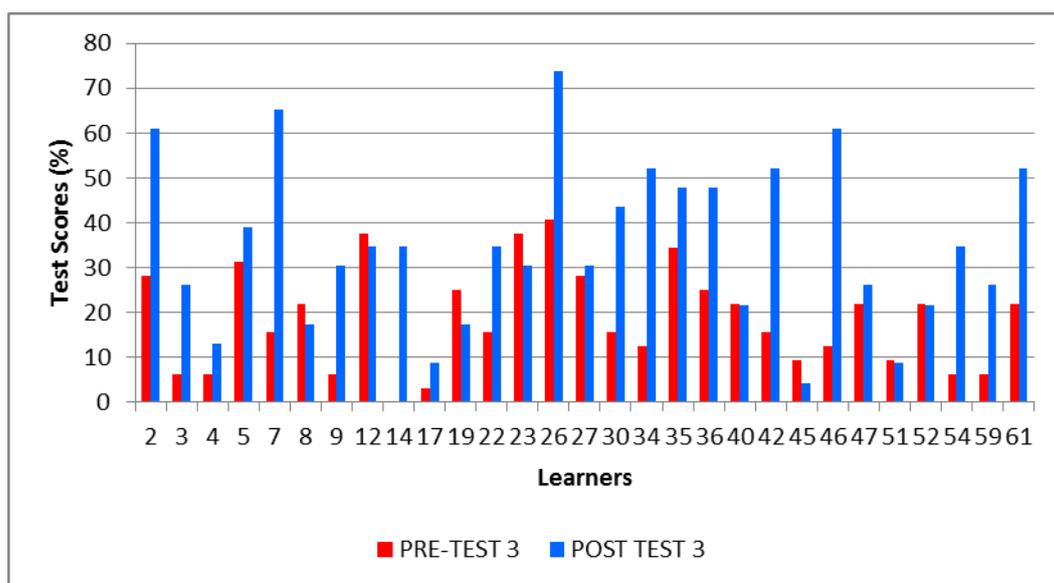


Fig 4.6: Fig 4.6: Pre and Post Test 3 Scores – Emf and internal resistance

***H<sub>0</sub>: there is no significant difference between the two sets of scores and that they come from the same population.***

This analysis is not done per question as the whole test covers one main concept – emf and internal resistance. The effectiveness of the intervention in terms of learner performance is measured by the increase in learner test scores between the pre- and post-test. With the exception of a few learners whose performance decreased, 91.3% of the learners showed an increase in the post test.

A paired t-test was then performed to determine if the practical activities based intervention was effective in improving learner understanding of emf and internal resistance. The mean difference in test scores ( $M = 16.54$ ,  $SD = 17.35$ ,  $N = 29$ ) was significantly different than 0,  $t = 5.13$  ( $df = 28$ ) and  $p = 1.92E-05$  (two-tailed). This provides evidence that the intervention is effective in improving grade 11 learners understanding of basic current electricity.

The 95% confidence interval about mean test score differences implies that the test score gain could range from 9.94 to 23.14 there is highly significant statistical evidence in support of rejecting the null hypothesis. The confidence interval for this sample, at a 95% confidence level, is slightly more than 5%.

In other words, there is less than or equal to a 5% probability that this result could be obtained by chance. Therefore it can be concluded the practical activities approach was successful at addressing learner difficulties in this topic, at a 95% confidence level.

Also, looking at the Pearson Correlation value ( $r = 0.38$ ), to determine the correlation between the pre-test and post-test scores, there was a moderate positive correlation between the pre-test and post-test scores. This further strengthened the rejection of the null hypothesis that the mean difference was purely by chance.

#### **4.5.2. Learner difficulties detected from the Pre-test 3**

Eight of the 29 learners (27.6%) showed a decrease in their performance ranging from 0.14 to 7.61%. This means that in some of the learners (though a minority), the difficulties were still evident even after the practical intervention. The remainder of the learners, however, (72.4%), showed an increase in the post test.

A paired t-test was performed to determine if the practical activities based intervention was effective in improving learner understanding of emf, resistance and internal resistance. The mean difference in test scores ( $M = 16.54$ ,  $SD = 17.35$ ,  $N = 29$ ) was significantly different than 0,  $t = 5.13$  ( $df = 28$ ) and  $p = 1.92E-05$  (two-tailed). This provides sufficient evidence that the intervention is effective in improving grade 11 learners understanding of emf and internal resistance, thereby rejecting the null hypothesis.

In addition, since the t statistic  $>$  t critical (two tail) ( $5.13 > 2.02$ ) and p value  $<$   $\alpha$  ( $1.92 \times 10^{-5} < 0.05$ ), there is highly significant statistical evidence in support of rejecting the null hypothesis. Due to the smaller sample size, the confidence interval for this sample, at a 90% confidence level, is slightly more than 10%. Therefore it can be concluded the practical activities approach was successful at addressing learner difficulties in this topic, 90% of the time.

Also, looking at the Pearson Correlation value ( $r = 0.38$ ), to determine the correlation between the pre-test and post-test scores, there was a moderate positive correlation between the pre-test and post-test scores. This further strengthened the rejection of the null hypothesis that the mean difference was purely by chance.

#### **4.5.3. Learner difficulties detected from the Pre-test 3**

Although the manifestations have differed, McDermott and Shafer, (1992a:998) have also noted that students did not have an adequate understanding of the concept of resistance, enough to apply it correctly. Question 1 of the Pre-test 3 (Appendix J) deals with the learners' understanding of *resistance, factors affecting resistance; how they affect it; and the units of resistance*.

- The only sub-question in which the learners did better is question 1.4 where they were asked the name and symbol of the unit of resistance. The rest of question 1 was very poorly answered. It seemed that the learners had very little knowledge of the factors affecting the resistance of a conductor and how these affect the resistance.
- A large majority of them (96%) scored zero for question 1.1. and 1.2, while on average 77.6% of the learners answered question 1.3 incorrectly.

In question 2 of Pre-Test 3, the learners were asked to demonstrate their understanding of *internal resistance and the emf* of a battery. They were also asked to calculate internal resistance, emf and resistance as well as providing reading to voltmeters when a switch is open or closed.

- A detailed look at the results shows that the learners could not describe internal resistance and emf. In fact, none of the learners could describe emf and only 62.1% could describe internal resistance.
- In terms of calculating internal resistance (2.3 and 2.4.3), on average 44.9% of the learners scored zero out of the possible 7 or 8 marks allocated to this question. In addition, 75.9% of them did not know that when a switch is closed, the voltmeter connected across the battery reads the emf of that battery and that the voltmeter connected across the resistor reads zero if the switch is open.

#### **4.5.4. Practical activities based intervention: emf and internal resistance**

The practical intervention in this case was divided into two parts:

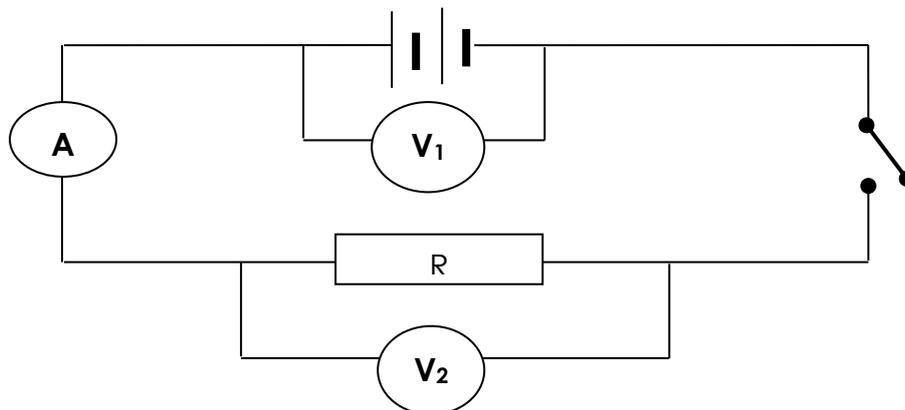
- Part I – factors affecting the resistance of a conductor and
- Part II – emf and internal resistance

Part I of this intervention was done as a scientific investigation where the following steps were followed:

- investigative question
- hypothesis
- variables
- apparatus
- method
- results
- conclusion and discussion

where the groups each had to investigate the effect of each of the factors (length, thickness, temperature and type of material used). The learners were quite comfortable in performing the experiment, after they initially had to be refreshed on how to use the circuit boards.

In Part II, the learners constructed the following circuit:



**Fig 4.7: Experimental set-up – emf and internal resistance**

They were then asked to read the voltmeters and ammeters when the switch was open and when the switch was closed. Given the resistance of  $R$ , they actually were able to discover the Emf formula:  **$\text{Emf} = I(R+r)$** .

#### 4.5.5. Post-test 3 Analysis

Post-Test 3 question 1 (1.1 and 1.2) was multiple choice, on factors affecting resistance and demonstrating their understanding of internal resistance. Interestingly 52% of the learners answered 1.1 correctly and 41% of them answered 1.2 correctly.

Question 2.1 asked learners for the “lost” voltage given the emf and the external voltage, 55.2% of the learners answered correctly. In continuation with 2.1 they were asked to calculate current (2.2) and 69% of them passed this question, obtaining between two and four out of the possible four marks. With the above information, they were then asked to calculate internal resistance and 55.1% of them also obtained between two and four out of four marks.

Question 2.4.1 (voltmeter reading across the battery when switch is open) was the worst performed question in this test, with 86% of learners scoring zero for this question. In addition, the voltmeter readings when the switch is open or closed, the learners also did not do so well, 58.6% failing. For the last question on effective and internal resistance (2.4.3), approximately half of them (51.2%) got the question incorrectly, i.e. zero out of the possible 5 marks allocated.

#### 4.5.6. Sub-conclusions

The comparison in this test will not be broken down question by question but the whole test will be analysed. Observations of learner performance in both tests, the following is observed:

- Failure percentage (0-29%) decreased from 82.7% to 37.9%
- Percentage between 30 and 59% decreased from 17.2% to 48.3%
- Percentage scoring 60% or higher increased from 0 to 13.8%

A detailed examination of the concepts within these tests revealed general improvements in learner understanding except for a couple of concepts. On learners' ability to describe internal resistance, there was a slight improvement in that the percentage of learners obtaining 30% or more increased from 37.9% to 41% and on calculating internal resistance, this improvement was from 25.9% to 48.1% on average.

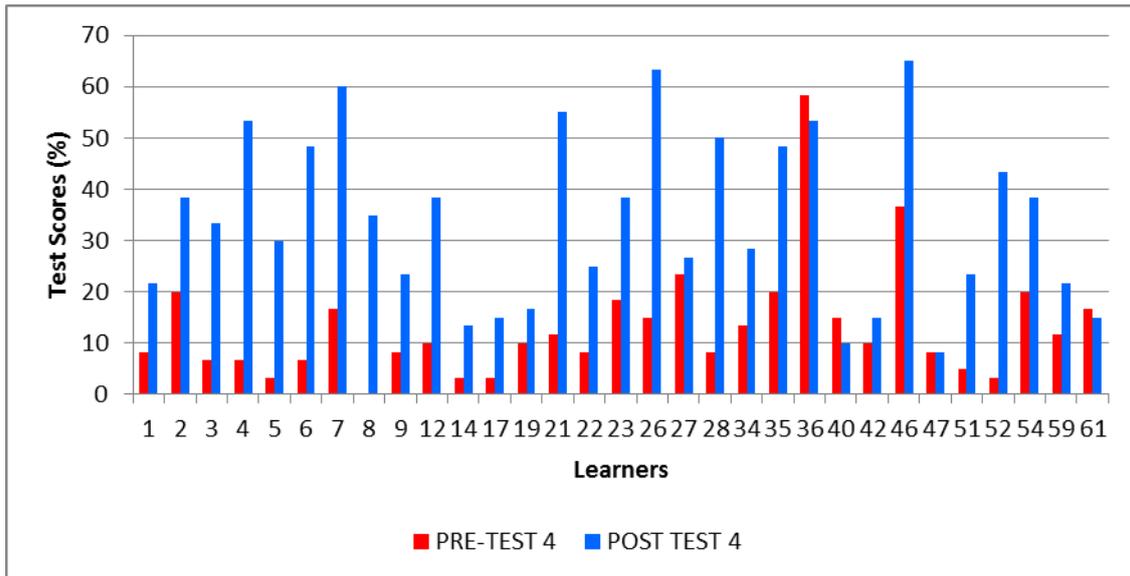
Areas which showed a concern, however, were the concept of emf (voltmeter across battery when switch is open) and the ability to give voltmeter readings with the switch open or closed. These concepts, however, are dealt with again in the section on series and parallel circuits.

From the above analysis, it can be concluded that the practical activities based learning experience was effective in remediating learner difficulties and thus improving their performance in this area of emf, resistance and internal resistance.

#### 4.6. SERIES AND PARALLEL CIRCUITS

The number of learners whose pre-test scores will be analysed is 31. The learner performance in pre- and post-test 4, focusing on series and parallel circuits is shown in Fig 4.6.

#### 4.6.1. Pre and Post-test 4 results



**Fig 4.8: Pre and Post test 4 scores – series and parallel Circuits**

***H<sub>0</sub>: there is no significant difference between the two sets of scores and that they come from the same population.***

The effectiveness of the intervention in terms of learner performance is measured by the increase in learner test scores between the pre- and post-test. Three of the 31 learners (9.7%) showed a decrease in their performance ranging from 1.67 to 5% and one learner showed no change. The remainder of the learners (87.1%) showed an increase in the post tests.

A paired t-test was performed to determine if the practical activities based intervention was effective in improving learner understanding of series and parallel circuits. The mean difference in test scores ( $M = 20.91$ ,  $SD = 15.94$ ,  $N = 31$ ) was significantly different than 0,  $t = 7.31$  ( $df = 30$ ) and  $p = 3.9E-08$  (two-tailed). This provides evidence that the intervention is effective in improving grade 11 learners understanding of series and parallel circuits.

In addition, since the t statistic > t critical (two tail) ( $7.31 > 2.02$ ) and p value <  $\alpha$  ( $3.9 \times 10^{-8} < 0.05$ ), there is highly significant statistical evidence in support of rejecting the null hypothesis. Due to the smaller sample size, the confidence interval for this sample, at a 90% confidence level, is 10%. Therefore it can be concluded the practical activities approach was successful at addressing learner difficulties in this topic, 90% of the time.

Also, looking at the Pearson Correlation value ( $r = 0.40$ ), to determine the correlation between the pre-test and post-test scores, there was a moderate positive correlation between the pre-test and post-test scores. This further strengthened the rejection of the null hypothesis that the mean difference was purely by chance.

#### 4.6.2. Learner difficulties detected from the Pre-test 4

Question 1 of Pre-test 4 dealt with *series connection of resistors, the potential difference of resistors in series, current in a series circuit, the effect of increasing resistors in series on potential difference and total current as well as explanations to these effects*. The average performance of the learners in this question of 16.7% indicates that the learners were clearly experiencing difficulties with these concepts. A detailed question-by-question analysis revealed the following:

- The learners could not provide the potential difference across individual resistors in series, given the potential difference across the battery in the absence of internal resistance – 74% of them obtained zero for question 1.1.1. An explanation to this question seemed beyond their ability to answer – 94% obtaining zero for question 1.1.2.
- In addition, a large number of learners (65%) were not able to answer the question about current in a series circuit (1.1.3). Here too the 65% scored zero points.
- A similar trend, for both potential difference and current, was observed in the case of increasing the number of resistors in series.

Question 2 of the pre-test dealt with a parallel connection of resistors: *the potential difference of resistors in parallel, the current in a parallel circuit, the effect of increasing resistors in parallel on the potential difference and total current as well as explanations to these effects*. The average performance of the learners in this question of 9.51% indicates that the learners were clearly experiencing even greater difficulties with this concept. A detailed question-by-question analysis revealed the following:

- The learners could not provide the potential difference across individual resistors in parallel, given the potential difference across the battery in the absence of internal resistance – 87.1% of them obtained zero for question 2.1.1. The explanation was just as badly given as in question 1 – 96.8% obtaining zero for question 2.1.2.
- Also, in question 2.1.3, a large number of the learners (83.9%) were not able to answer the question about current in a parallel circuit. The 83% is the number of learners who scored zero points.
- A similar trend, for both potential difference and current, was observed in the case of increasing the number of resistors in parallel, with more than 80% of learners on average obtaining zero for questions 2.2.3 to 2.2.5 of Pre-test 4.

Question 3 was a mixed circuit question and it was also as badly answered, with learners having difficulties with the following:

- Calculating the total current in the circuit – 51.6% scoring zero points.
- Calculating the total resistance of parallel resistors and therefore the effective resistance in a mixed circuit – 85.6% on average obtaining zero.
- Calculating the potential difference across the battery given the total current in the circuit and the effective resistance of the circuit – 74% obtained zero.
- They also did not seem to know that the potential difference of parallel resistors is the same – 74% scored zero.
- 84% of the learners scored zero for the question that asked them for current in each of three identical resistors in parallel given the total current in the circuit.

Researchers have explained the above observations in two ways. Firstly, the tendency to reason sequentially rather than holistically (McDermott & Shafer, 1992a:1001). Students tended to think of a circuit as consisting of separate individual entities that could be analysed independently of one another. Explaining this sequential reasoning, Driver, Squires, Rushworth and Wood-Robinson (1994:120) added that students tend to think that “something from the battery travels around the circuit” meeting the circuit components in sequence. Secondly, students tend to exhibit a lack of a conceptual model for predicting and explaining the behaviour of simple dc circuits (McDermott & Shafer, 1992a:1001).

#### **4.6.3. Practical activities based intervention: series and parallel circuits**

An experiment dealing with series and parallel connections was done with the learners, see Appendix P. This was divided into three sections:

- Part I: Series and parallel connections of cells and light bulbs – here the focus was just on the learners’ ability to build these circuits in order for them to visualize them when dealing with such questions.
- Part II: The series circuit– potential difference and current
- Part III: Parallel circuit - potential difference and current

##### *Part I: Series and parallel connections: cells and resistors*

The learners were required to construct the circuits described below, using the circuit board given and then draw the corresponding circuit diagrams:

1. Two cells in series
2. Two cells in parallel
3. Two bulbs in series

4. Two bulbs in parallel
5. Two cells in series, connected to two bulbs in series and a switch (open), an ammeter in series and a voltmeter across one bulb.
6. Two cells in parallel, connected to two bulbs in parallel and a switch (open), an ammeter in series and a voltmeter across the cells.
7. Two cells in series connected to two bulbs in parallel, a switch, an ammeter in series and a voltmeter across the one bulb.

With lots of going back and forth the learners in their groups succeeded in constructing the above and observations were also discussed and explained. It is important to note that in this part, no computers were used but actual voltmeters and ammeters and light bulbs instead of resistors.

*Part II and III: Series and parallel connections: cells and resistors*

These parts then made use of computers, i.e. voltage probes and current probes to investigate series and parallel connections of resistors.

The learners were first required to construct a series circuit, this time first with two equal resistors of a small resistance, then two different resistors, and then two equal resistors of a higher resistance. They were then to read potential difference, current as well as calculate the effective resistance for these connections of resistors, recording the results in the Table 4.3.

**Table 4.3: Series Circuit Typical Data Table**

Part II: Resistors in series							
	R <sub>1</sub>	R <sub>2</sub>	I	V <sub>T</sub>	V <sub>1</sub>	V <sub>2</sub>	R <sub>eff</sub>
	( $\Omega$ )	( $\Omega$ )	(A)	(V)	(V)	(V)	( $\Omega$ )
1	10	10					
2	10	15					
3	15	15					

On the following day, the learners were required to construct a parallel circuit, first with two equal resistors of a small resistance, then two different resistors, and then two unequal resistors of a higher resistance. They were to read potential difference, current as well as calculate the effective resistance for these connections of resistors, recording their results as shown in Table 4.4.

**Table 4.4: Parallel Circuit Typical Data Table**

Part II: Resistors in parallel									
	R <sub>1</sub> (Ω)	R <sub>2</sub> (Ω)	I <sub>1</sub> (A)	I <sub>2</sub> (A)	I <sub>T</sub> (A)	V <sub>T</sub> (V)	V <sub>1</sub> (V)	V <sub>2</sub> (V)	R <sub>eq</sub> (Ω)
1	10	10							
2	10	15							
3	15	15							

Again, in both Parts I and II, the learners struggled with constructing the circuits especially with the parallel circuit (part II) as well as with connecting the voltage and current probes. Ultimately, however, they did manage to get the correct construction and readings as they were not allowed to move on unless they had the correct circuit connection.

#### 4.6.4. Post-test Analysis

The performance of the learners in the post test was much better than in the pre-test. Question 1 of the post-test also dealt with the series circuit, asking learners to draw a series circuit, calculate the total resistance for resistors in series, given the potential difference for each of the different resistors, to calculate the total current in the series circuit as well as provide the current in each resistor. The average percentage of this question was 50.6% and

- only 6.5% of the learners failed question 1.1 – constructing a series circuit,
- only 22.5% failed the question on calculating total resistance for resistors in series (1.2)
- However, the question on potential difference across each resistor, question 1.3 was still very badly answered (97% obtaining zero).
- Although on average 55% of the learners passed the question about current in a series circuit, it is still quite concerning that over 40% of them scored zero for these questions.

Question 2, which dealt with a parallel circuit, also showed an improvement compared to question 3 of the pre-test, although the following areas still give reason for concern:

- 90% of the learners scored zero for the question on potential difference across the parallel resistors (2.2.3) and 74% of them could not provide the correct value for the current on each of the parallel resistors (2.2.4).

Question 3, which dealt with a mixed circuit, also showed an improvement in comparison to the pre-test. Here too, there are areas of concern, interestingly similar (one of them at least) to the challenges in the parallel circuit:

- 74% of the learners scored zero for the question asking them to calculate the effective resistance of the mixed circuit (3.2). A lot of them simply treated the three resistors as if they are all in parallel.
- Another difficulty for learners was calculating the potential difference across the parallel combination (3.4), with 84% of them getting zero for this question.

#### 4.6.5. Sub-conclusions

When one looks at the averages of Pre-test 4 and Post-test 4, there is an obvious improvement, which illustrates that the practical work did help to remediate some of the difficulties experienced. A question-by-question look also agrees with the above assertion.

In Question 1 – series circuit, the following was observed:

- Failure percentage (0-29%) decreased from 83.9% to 19.4%
- Percentage between 30 and 59% increased from 16.1% to 35.5%
- Percentage scoring 60% or higher increased from 0% to 45.2%

In Question 2 – parallel circuit, the following was observed:

- Failure percentage (0-29%) decreased from 90.3% to 48.4%
- Percentage between 30 and 59% increased from 9.7% to 48.4%
- Percentage scoring 60% or higher increased from 0% to 3.3%

In Question 3 – mixed circuit, the following was observed:

- Failure percentage (0-29%) decreased from 87.1% to 67.8%
- Percentage between 30 and 59% increased from 6.5% to 19.4%
- Percentage scoring 60% or higher increased from 6.5% to 12.9%

Although the above statistics show a positive trend, the percentage of failure (less than 30%) is still quite concerning, especially in the case of the mixed circuit and the parallel circuit. This means that the difficulties diagnosed have not been completely addressed by the practical activity.

## 4.7. MAGNETIC FIELD ASSOCIATED WITH CURRENT

The number of learners whose test scores will be analysed is 24. It is important to note in this section that the learners were hardly taught this section by their teacher as it is not directly examinable in grade 12. This determined the level of their knowledge prior to the pre-test and that level determined the level to which an improvement (where applicable) would climb to.

Learner performance in pre- and post-test 5, focusing on the magnetic field associated with current is shown in Fig 4.9.

### 4.7.1. Pre and Post-test 5 results

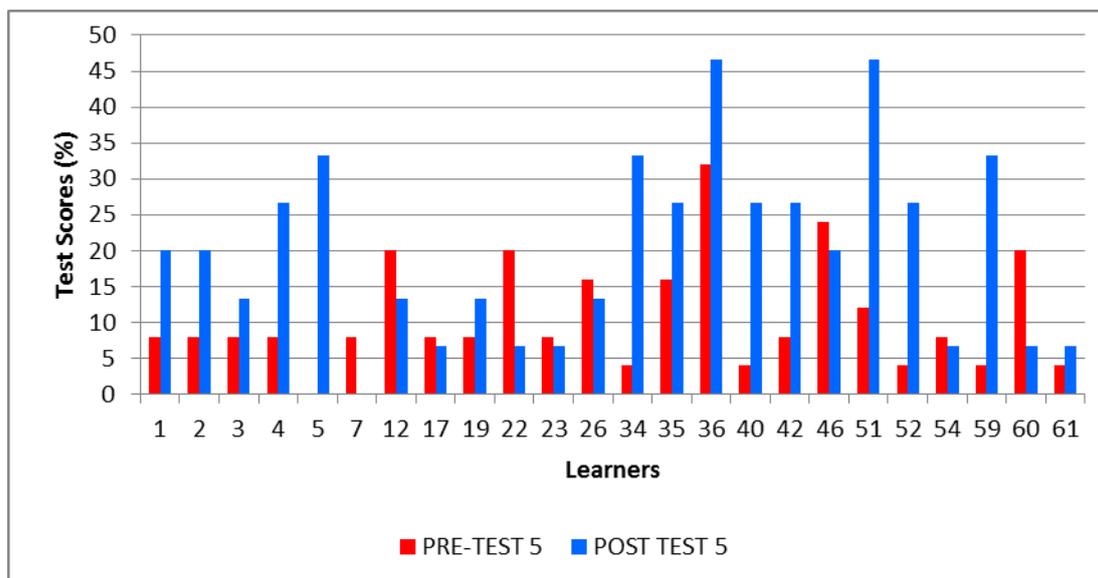


Fig 4.9: Pre and Post test 5 scores – Magnetic field associated with current

***H<sub>0</sub>: there is no significant difference between the two sets of scores and that they come from the same population.***

Nine of the 24 learners (37.5%) showed a decrease in their performance ranging from 1.3 to 13.3%. However, the remainder of the learners (62.5%) showed an increase.

A paired t-test was performed to determine if the practical activities based intervention was effective in improving learner understanding of the magnetic field associated with current. The mean difference in test scores (M= 9.17, SD = 14.62, N=24) was significantly

different than 0,  $t = 3.07$  ( $df=23$ ) and  $p = 0.005389$  (two-tailed). This provided evidence that the intervention was effective in improving grade 11 learners understanding of the magnetic field associated with current.

In addition, since the  $t$  statistic  $>$   $t$  critical (two tail) ( $3.07 > 2.07$ ) and  $p$  value  $<$   $\alpha$  ( $5.39 \times 10^{-3} < 0.05$ ), there is highly significant statistical evidence in support of rejecting the null hypothesis. Due to the much smaller sample size, the confidence interval for this sample, at a 90% confidence level, is slightly greater than 10%.

Therefore it can be concluded the practical activities approach was successful at addressing learner difficulties in this topic, 90% of the time.

Also, looking at the Pearson Correlation value ( $r = 0.06$ ), to determine the correlation between the pre-test and post-test scores, there was a rather weak but positive correlation between the pre-test and post-test scores. The null hypothesis could still be rejected.

#### **4.7.2. Learner difficulties detected in Pre-test 5**

As mentioned above, it was difficult to tell whether these difficulties were as a result of lack of knowledge due to the topic being uncovered by the educator or lack of understanding. Nevertheless, below are the difficulties that have been diagnosed from the pre-test.

Question 1 of Pre-test 5 (Appendix L) assessed the learners understanding of the *nature of an induced magnetic field around a current-carrying conductor, the Right Hand Rule, the symbols for the direction of the current as well as the direction of the induced magnetic field given the direction of the current*. This question was very badly answered except for Question 1.2 which asked learners to state the Right Hand Rule; at least 42% of the learners passed this question. In the remainder of the question, none of the learners obtained the correct answers for question 1.1 and 1.4, on the nature of the induced magnetic field and its direction given the direction of the current. On the question of the direction of current represented by a dot or a cross (1.3), 88% of learners answered that question incorrectly.

Question 2 required the learners to describe how to *make an electromagnet*, mentioning ways to make it stronger. In addition, they were given a solenoid attached to a battery, then asked to *describe the rule used to determine its polarity and using this rule to indicate*

*the polarity of this solenoid.* Lastly, they were asked to distinguish between *soft and hard magnets* as well as classify steel and iron as either soft or hard magnets.

Again here, the learners performed very badly except for the question on classifying steel and iron as either soft or hard magnets (2.4.2), where 70.8% of learners passed this question getting either 1 (66.7%) or both questions (4.17%) correct. This, however, is highly likely due to guess work because in the previous question where the learners were asked to distinguish between soft and hard magnets, all the learners obtained zero for this question. In the remainder of the questions, a huge number of them, 80% on average, scored zero.

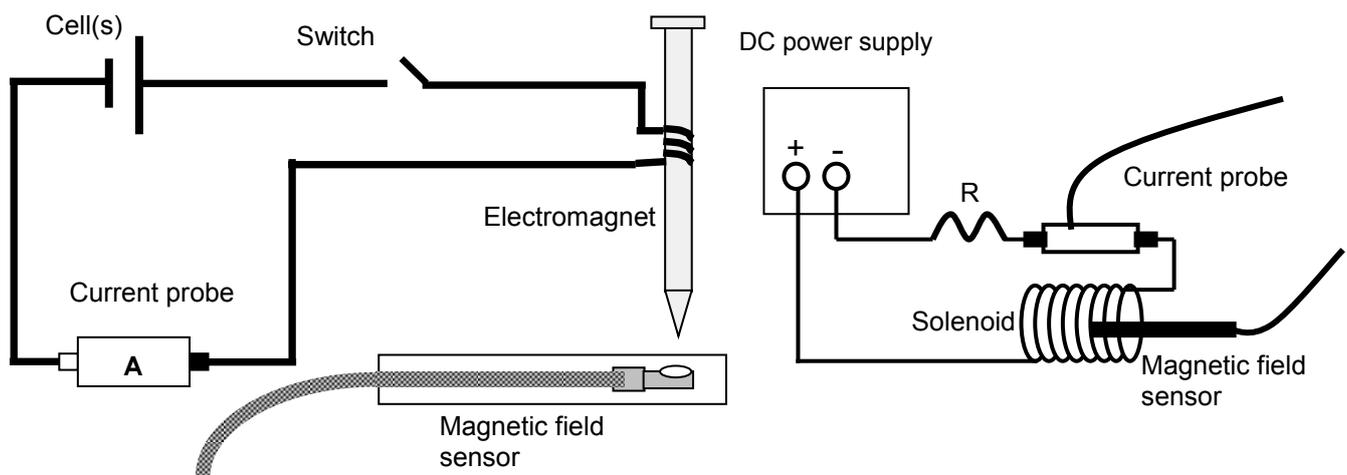
#### **4.7.3. Practical activities based intervention: magnetic field associated with current**

This session began with challenges, first within the school and then with equipment as well. The research intervention sessions took place during the study sessions instituted by the school but at times the school cancelled the sessions without communicating with the researcher and at such times, fewer learners attended and even the ones that did attend did not always pay full attention as some were worried about missing the scholar transport. The intervention did take place nonetheless but this time there were challenges with three of the laptops to be utilized, which brought down the number of groups to three, making the group sizes rather big.

The experiments session took place in two parts – part I: making an electromagnet using an iron nail, a copper wire and connecting this to a direct current (DC) source. The current was then switched on, then the nail was brought to the paper clips and then switched on and off a couple of times observing what happened. A discussion explaining these observations took place during which the factors that could strengthen this electromagnet were discovered.

Using the experimental set-up shown in Fig 4.8, part II investigated the effect of these factors on an electromagnet using the electromagnet made in part 1. This was done by allowing current to flow through the electromagnet, then bringing it to a magnetic field sensor which gave readings of magnetic field strength shown on the laptop screen. The various factors were individually investigated and graphs plotted for the number of turns

vs. magnetic field strength and current vs. magnetic field strength.



**Fig 4.10: Experimental set-up – magnetic field associated with current**

#### 4.7.4. Post-test 5 analysis

Question 1 of Post-test 5 consisted of multiple choice questions assessing the learners' ability to indicate the *direction of the induced magnetic field* given the direction of the current (1.1, 1.2 & 1.3); the direction of the current given the direction of the induced magnetic field; and one question on the function of a soft iron in a current carrying conductor. Although there was a slight improvement in comparison to the pre-test the performance of the learners was still quite unsatisfactory, with on average more than 80% of learners scoring zero for this question. The only exception was the question on the function of the soft iron in a current carrying conductor (1.6) which was better answered (67% correct).

Question 2 also showed a similar trend as described above where although there were areas that showed improvement some concepts like electromagnets diagrams and its polarity were still not clearly understood. A concept that seemed better understood, however, was the current-carrying loop – its polarity and the direction of the induced magnetic field in this case.

#### 4.7.5. Sub-conclusions

The slight improvement of 9.2% on average between the pre-test and the post-test lead to the conclusion that the practical activities based intervention involved in this case, did have

some positive effect in improving the learners understanding of the concepts of a magnetic field associated with a current-carrying conductor. This is especially true considering the technical glitches that accompanied the experiments session.

On the concept of the induced magnetic field around a current-carrying straight conductor, question 1.1 to 1.4 in the pre-test and question 1.1 to 1.5 in the post-test, the following has been observed:

- Failure percentage (0-29%) decreased from 87.5% to 83.3%
- Percentage between 30 and 59% increased from 8.3% to 16.7%
- Percentage scoring 60% or higher decreased from 4.2 to 0%

On the concept of electromagnets and loops and the induced magnetic field around them, pre-test question 2 and post-test question 1.6 and question 2, the following has been observed:

- Failure percentage (0-29%) decreased from 100% to 58.3%
- Percentage between 30 and 59% increased from 0 to 37.5%
- Percentage scoring 60% or higher decreased from 0 to 4.2%

#### **4.8. CURRENT ASSOCIATED WITH MAGNETIC FIELD**

The number of learners whose pre-test scores will be analysed is 23. Here too the challenge of smaller numbers was as a result of the study sessions being cancelled and therefore learners voluntarily remained behind, in which case most chose not to stay. It would also be important to note that this section of work was covered by the teacher during the same week as the research intervention, and this is an exception. The rest of the content being researched would have been done a while (two to three weeks) ago. Learner performance in pre- and post-test 6, focusing on the current associated with the magnetic field is shown in Fig 4.9.

#### 4.8.1. Pre and Post-test 6 results

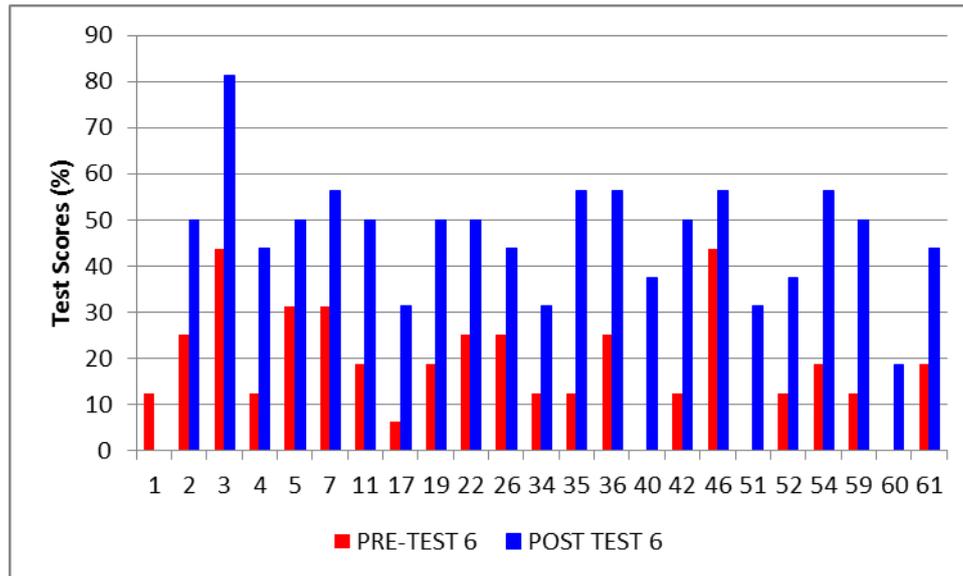


Fig 4.11: Pre and Post test 6 scores – Current associated with magnetic field

***H<sub>0</sub>: there is no significant difference between the two sets of scores and that they come from the same population.***

Only one of the 23 learners showed a decrease in their performance – a decrease of 12.5%. The remainder of the learners, however, showed an increase in the post test.

A paired t-test was performed to determine if the practical activities based intervention was effective in improving learner understanding of the current associated with a magnetic field. The mean difference in test scores ( $M = 26.63$ ,  $SD = 11.65$ ,  $N = 23$ ) was significantly different than 0,  $t = 10.96$  ( $df = 22$ ) and  $p = 2.209E-10$  (two-tailed). This provided evidence that the intervention was effective in improving grade 11 learners understanding of this topic.

In addition, since the t statistic  $>$  t critical (two tail) ( $10.96 > 2.07$ ) and p value  $<$   $\alpha$  ( $2.20 \times 10^{-10} < 0.05$ ), there is highly significant statistical evidence in support of rejecting the null hypothesis. Due to the smaller sample size, the confidence interval for this sample, at a 90% confidence level, is 10%. Therefore it can be concluded the practical activities approach was successful at addressing learner difficulties in this topic, 90% of the time.

Also, looking at the Pearson Correlation value ( $r = 0.68$ ), to determine the correlation between the pre-test and post-test scores, there was a moderate positive correlation

between the pre-test and post-test scores. This further strengthened the rejection of the null hypothesis that the mean difference was purely by chance.

#### **4.8.2. Learner difficulties as detected in the pre-test 6**

Question 1 of the pre-test (Appendix M) asked the learners to identify *electromagnetic induction* from a diagram based description; describe the *nature of the induced current* and mention ways of increasing the induced current. They were also asked to define the term "*magnetic flux*" as well as state *Faraday's Law of electromagnetic induction*.

The general performance was not good, especially for the questions on electromagnetic induction and alternating current (1.1 and 1.2). Most of learners (74%) were, however, able to mention the factors affecting the induced current (1.3).

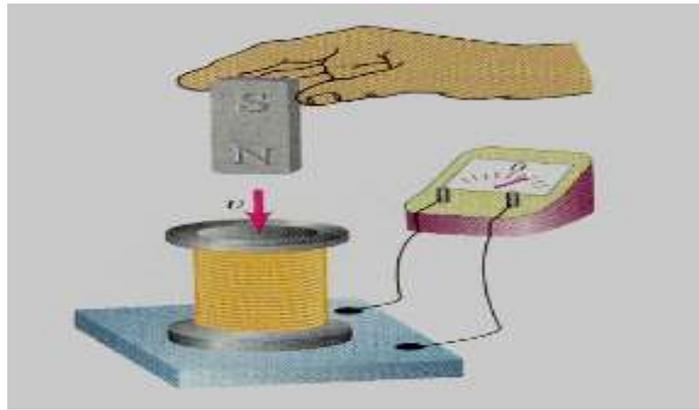
In terms of the definition of magnetic flux and Faraday's Law (1.4 and 1.5), here too the learners demonstrated very poor understanding with more than 70% of them getting the questions wrong, although in the case of Faraday's law there were a bit more learners (26%) who had some idea of the Law.

Question 2 focused on *mutual Induction* and ways of strengthening this phenomenon. The learner also did not do too well, especially for the question that asked them to name and define mutual induction as shown in a given diagram (2.1). Question 2.2, with naming of the factors to strengthen mutual induction, was slightly better answered in that 43.5% of the learners could state at least one of the factors.

#### **4.8.3. Practical activities based intervention: magnetic field associated with current**

The experiment was divided into two parts, Part I – Electromagnetic induction and Part II – mutual induction.

Part I – the set-up was as shown in Fig 4.12, the coil was first connected to a Galvanometer to illustrate the alternating nature of the induced current and then later connected to a current probe and to a computer generating a current vs. time graph.



**Fig 4.12: Experimental set-up – electromagnetic induction**

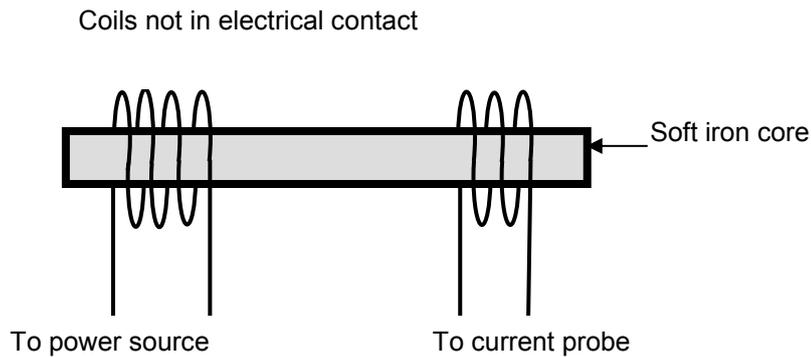
The learners then investigated the factors affecting this induced current and how these factors affected the induced current, recorded their observations Table 4.5.

Table 4.5: Typical Data Table for Electromagnetic Induction

Factors influencing strength of the induced current			
Factor	Symbol		Current (Stronger / Weaker)
Speed with which magnet moves.	Longer $\Delta t$	Slow	
	Shorter $\Delta t$	Fast	
Strength of magnet	Weaker $\Phi = BA$	Weak	
	Stronger $\Phi = BA$	Strong	
Number of turns in coil (depending on the available coil).	Less N	240	
	More N	360	

From the above data, they were then able to conclude on how each factor affects the induced current and eventually the equation for Faraday's Law was deduced.

In Part II, the learners dealt with mutual induction, first using a DC source in the primary coil and switching that current on and off, observing what happens to the current in the secondary coil, and later replacing the DC source with an alternating current (AC) source with no need to switch on and off this time. A set-up similar to the one shown in Fig 4.13 was utilised.



**Fig 4.13: Mutual induction set-up**

The learners then had to record their observations as well as explain these observations. An explanation of these observations and the terminology involved was also given by the facilitator.

#### **4.8.4. Post-test 6 analysis**

Question 1 of the post-test (Appendix M) dealt with both electromagnetic and mutual induction and in general the learners performed better, with the exception of question 1.1 and 1.3 (requirements for obtaining current in mutual induction and conditions for induction of current in the secondary coil during mutual induction), where there was still a large number of learners (67.5 on average) obtaining zero.

Question 2 was a calculation using Faraday's Law and the equation for calculating magnetic flux. Only 2 learners passed the Faraday's Law calculation (2.1.1), but the magnetic flux one (2.1.2) was better answered.

#### **4.8.5. Sub-conclusions**

This analysis will not be broken down question-by-question as both questions had aspects of both electromagnetic and mutual induction and also because the concepts are quite similar. In general, learner performance in the post test, as shown by an average increase of 26.6%, was much better than in the pre-test.

Comparison of the pre-test and post-test revealed the following changes in performance:

- Failure percentage (0-29%) decreased from 78.3% to 8.7%

- Percentage between 30 and 59% increased from 21.7 to 82.6%
- Percentage scoring 60% or higher decreased from 0 to 8.7%

The difficulties in test 5 and test 6 have been related to the abstractness experienced in E&M. Dori and Belcher (2005:249) submitted two causes contribute to these:

- firstly, that humans “are simply not equipped to gauge magnetism”. For example, although current electricity could be indirectly observed (e.g. light bulb glowing) or felt by electric shocks, there was almost no sensual indication of magnetic fields.
- secondly, electromagnetism is in a realm of Physics that is not covered by any of the five human senses. This poses a greatest challenge when students are trying to make electromagnetic concepts concrete. Therefore, “visual imagery” could help make the abstract concepts encountered in electromagnetism more concrete.

#### **4.9. LEARNER MISCONCEPTIONS AND PRACTICAL WORK**

In this section, will be listed some of the common E&M misconceptions as found in existing literature, then examine their prevalence in the learners’ pre and post-tests. That way, the extent to which the practical activities based approach addressed learner difficulties caused by these misconceptions will be observed. Each misconception will be stated, its prevalence in the pre and post-tests mentioned and then conclusions based on those results will be made.

*Misconception 1: Batteries of the same type always supply a fixed amount of current regardless of what is in the circuit (Grayson, 2004:1131).* This misconception is attributed to lack of an appropriate conceptual model for electric current.

##### **Prevalence:**

In Pre-test 4, this concept was tested, where question 1.2.3 and 2.2.3 (Appendix K) required the learners to state what happens to the total current when an additional resistor is added in the circuit of the same battery, in series and parallel respectively. This misconception was prevalent in 41.9% of the learners with explanations such as this one given:

Learner 24: *“stays the same, because they are supplied with the same electricity from the battery and they are identical”*

This response was given for the series component in this question, where the one circuit had two resistors and the other three, both in series.

In Post-test 4, this misconception seemed to have been reduced, with the exception of only one learner. This can be attributed to the effectiveness of practical work in addressing this misconception as the learners, during the experiments, could clearly see that although you have the same battery, if you change the number of resistors, the current changes.

*Misconception 2: Current emanates from the battery*, i.e. current ‘coming out’ of the battery is less than the current ‘going into’ the battery (Sengupta & Wilensky, 2009:26). The authors attributed the misconception to careless use of language, breaking this misconception into two parts: first, that the circuit elements (resistors, light bulbs, etc.) actually hinder the flow of current, i.e. offer resistance. Secondly, current needs effort to overcome this resistance offered by the circuit.

## **Prevalence**

In the research sample, responding to a question on Pre-Test 1 (Appendix H), asking learners to define a battery, 11.8% of the learners exhibited this misconception. Typical answers included the following:

Learner 23: *“It’s an object where charges are coming from”*

Learner 48: *“....where electrical current flow into...”*

On Post-Test 1, this misconception was still prevalent in 4 of the 51 learners (7.8%), with interestingly learner 48 still getting it wrong in stating the function of the battery as *“providing current flow through the wires to the light bulb”*.

One of the learners (Learner 22) also showed signs of this confusion of terms in Post-test 1, indicating that *“the maximum amount of energy a battery can supply”* is current and that he was sure of his answer.

*Misconception 3: A bulb closest to the end of the battery, from which learners think current flows, is the brightest and the other bulbs glow dimmer and dimmer as the current gets used up in the process of passing through successive bulbs* (Grayson, 2004:1128; McDermott & Shafer, 1992a:997). An alternative name for this conception is called sequential reasoning where students believe that changes made in preceding circuit elements (like bulbs; resistor and switches) cannot affect the elements following (Smaill, *et al.*, 2012:29). Using the words of Engelhardt and Beichner (2004:98), Smaill *et al.*, (2012) attributed this misconception to the belief that current travels around a circuit and “is influenced by each elements as it is encountered and a change made at a particular point does not affect that point until it reached that point”.

### Prevalence

The misconception was prevalent in 32.3% of the learners in Pre-Test 4, particularly for the series circuit (1.1.2-1.1.4 and 1.2.4-1.2.5) and to a smaller extent in the parallel circuit (2.1.3-2.1.4). The following typical answers gave an indication of the learners’ reasoning to question 1.2.4 asking them about the current that goes through each resistor (R).

Learner 26: *“is because when it gets to R2 carried nothing...delivered everything in R1.”*

Learner 5: *“because when it gets to V1 it left many electrons and when it gets to V2 and V3 small electrons.”*

Learner 31: *“the current that flow through the three resistors, in R3 there is less than R2, which is less than R1.”*

Learner 27: *“R1 has more current than R2 and R3 because the current start there and it have that ‘umf’ of power then after it goes slow.”*

Learner 19: *“R1 is the highest resistance and R2 middle and R3 lowest”* – this despite being told in the question that the resistors are identical.

Another response, this time in relation to resistors in parallel (question 2.1.3):

Learner 3: *“In a parallel circuit, the current of first resistor is more than the other.”*

This misconception was also reduced in the sample’s post-test 4 with the exception of 1 learner, who, in response to question 1.4 and 1.5 (Appendix K), could calculate the total current in the circuit. When asked for the current in each of the series resistors gave the first resistor more current and the second one a bit less.

*Misconception 4: A ‘blind reliance on Ohm’s Law’* (Smaill, *et al.*, 2012) For example, students thinking that when **current doubles, potential difference also doubles due to**

$V=IR$ , not recognizing that potential difference is a property of the battery (Smaill, *et al.*, 2012:31). This also manifested itself in students' inability to recognise that potential difference is an independent variable.

### **Prevalence**

This misconception in the sample manifested itself in learners plotting potential difference on the y-axis, when given a set of potential difference and current data. They did this so that in the next calculation, when asked to calculate the gradient of the graph, their answer ( $V/I$ ) would give them resistance, instead of the inverse of the resistance. This was prevalent in 39% of the learners in Pre-test 2, while in Post-test 2 the prevalence decreased down to only 7.3%. This means that the practical activity done was to a certain extent successful in reducing this misconception in most of the learners, although they were still experiencing difficulties differentiating between dependant and independent variables.

The misconceptions found from the literature dealing specifically with electromagnetism could not be clearly extracted from the two tests (tests 5 and 6) as the tests were not structured in a manner that required a lot of explanations. Therefore the discussion on misconceptions will not include those related with electromagnets, electromagnetic and mutual induction.

## **4.10. HOW THE PRACTICAL ACTIVITIES-BASED APPROACH ENHANCES LEARNING**

In order to answer the question of how this approach enhances learning in general and on E&M, the learners were given a questionnaire at the conclusion of the whole research intervention. The main questions were about their thoughts on these sessions; their perceived understanding of E&M after these interventions; value of the computers; areas of improvement; rating of these sessions, worksheets, time and facilitator and any other experiences they might have had.

In the words of the learners, the practical sessions on E&M provided them with "better understanding" of the work as well as a "hands and eyes-on" experience that provided them "an opportunity to connect theory and practical". Others enjoyed "seeing and

enjoying the exciting part of science” and the fact that they have also gained knowledge and confidence on how to do practical work.

All of them, therefore felt that practical work on E&M was absolutely necessary for “better and increased understanding” as well as “helping their attitude” towards science in general. As a result of these experiences, all the learners felt that they were now able to successfully answer relevant questions on E&M as evidenced by the improvements in the post-tests.

Asked about which section they found easy overall, interestingly most of the learners seemed to have found the current electricity section easier and the electromagnetism section more difficult. On areas of improvement, almost all the learners indicated the need for “more time” and “smaller groups”. To use the words of Learner 3: “experiments must be regular and fit within the time-table”.

The use of computers was also mentioned as something that added value to this experience. In this regard, the learners mentioned things like “computer skills”; “clearer info”; “better display of data”; “graphs” and “experiments made easy” as benefits associated with the use of computers for these practical’s.

#### **4.11. SUMMARY**

This chapter contains the detailed of the results collected during this study in the form of learner individual scores. It also detailed the E&M difficulties as well as some of the current electricity misconceptions that were diagnosed from the learner manuscripts. The analysis of each set of test results also gave a brief indication of the effect of the practical intervention in between.

Out of the six E&M pre- and post-tests written, five post-tests (Test one and Tests three to six) showed an improvement of moderate to high statistical significance. Test two, however, showed a declined that is associated with Mathematical skills and this has been explained in details in this chapter.

The number of learner difficulties as extracted from the learner transcripts tended to be very high in the pre-test but was in most cases significantly reduced after the practical intervention, as illustrated by the post-tests. The same could also be said about the current

electricity misconceptions diagnosed in the pre-tests. Although these were not wiped out between the pre and the post-tests, there was also a general reduction in the prevalence of misconceptions between pre-tests and post-tests.

#### **4.12. CONCLUSION**

From the data given, analysed and interpreted above, the value of practical activities in the teaching and learning of E&M has been revealed. It is indeed clear that the learners experienced a lot of difficulties learning some of the concepts involved in E&M. Some of these difficulties, however, can be remediated simply by allowing the learners to learn the concepts practically instead of only theoretically. This was evidenced by the overall results which showed improvements in five of the six post-tests.

It can also be further argued that the use of practical work in the teaching of E&M can also aid in the reduction of the number of misconceptions that learners hold in this regard, with special reference to current electricity. Although, not a lot of resources were utilised in researching this component, the available data discussed above supports this assertion.

Also the value added to the learners' attitudes towards the subject; their better understanding of E&M; increased interest in science in general; knowledge on how to do experiments – are some of the additional benefits to allowing the learners to learn using practical work.

The following and final chapter will go into more detail expatiating and expanding on the above conclusions as well as making recommendations on the effectiveness of practical work in the teaching and learning of science.

The level of learner's prior knowledge had an influence on the percentage improvement after the intervention. In cases where the content was hardly covered by the educator, the level of knowledge of the learners was extremely low. This meant that at times although the intervention showed an increase, the average increase still fell below the accepted pass mark for Physical Science in South Africa (30%). Also, the amount of time available for the intervention was a factor as the study sessions were cancelled, making it challenging for the learners to remain long after school is finished.

## CHAPTER 5: CONCLUSION

### 5.1. INTRODUCTION

As explained in Chapter 3, this mixed methods study was aimed at diagnosing the conceptual difficulties experienced by Grade 11 learners in the module Electricity and Magnetism (E&M). In addition, the research also extracted some of the common learner misconceptions in the current electricity component of E&M. This diagnosis was followed by an investigation of the use of a practical-activities based approach in assisting learners with these difficulties.

As a mixed methods study, this research utilized a variety of data collection techniques, to incorporate qualitative and quantitative data. Specifically, the study employed a mixed methods approach in which the qualitative research method is embedded within the quantitative method, with the mixing of these methods taking place at the data collection analysis phases of the study.

The main purposes for choosing the mixed methods approach were:

1. To seek complementarity within the collected data in order to elaborate, enhance, illustrate and clarify the results from the quantitative data with the detailed analysis of the qualitative data (Johnson & Onwuegbuzie, 2004:22).
2. For development purposes to “expand the breadth and range” (Johnson & Onwuegbuzie, 2004:22) of the different data collection tools used.

The quantitative data provided an answer to the main research question of whether or not the use of practical activities was effective in addressing learner difficulties in Physical Science. The qualitative data, on the other hand, provided an in-depth platform of investigation on the specific difficulties and misconception that the learners were dealing with prior to the practical intervention and to what extent these still existed after the intervention.

The qualitative data included observations, pre- and post-intervention questionnaires as well as the actual contents of the learner transcripts. This qualitative data was quantitized by encoding the various responses to the questionnaires and tests, thereby allowing the researcher to express the observed trends in percentage form. The main technique, however, was still the use of pre- and post-tests providing quantitative data.

This chapter will provide a summary of the findings and how they relate to the literature reviewed; discuss and make recommendations based on this research as well as the literature reviewed. The limitations of this study and implications for possible beneficiaries of the knowledge gained will also be highlighted. A final conclusion will then be made.

## **5.2. SUMMARY OF FINDINGS**

The hypothesis made in Chapter one of this study alluded to the presence of conceptual learner difficulties and misconceptions in the module of E&M and it proposes a practical activities based approach as a possible remedy for some of these difficulties and misconceptions. The following research findings will therefore provide an indication of the extent to which this hypothesis was proven correct:

Firstly, based on how poorly they were doing in the pre-tests as well as the qualitative analysis of the actual difficulties as extracted from the learner transcripts, these Grade 11 learners clearly experienced a lot of difficulties in the module E&M.

Secondly, as extracted from the learners transcripts, these learners exhibited many of the commonly known misconceptions as recorded in literature, especially in the current electricity component of the study,.

Thirdly, upon exposure to the practical activities, although the misconceptions were not completely wiped out, there was a notable decline in the difficulties as well as the prevalence of the misconceptions.

Fourthly, with the exception of one test out of six, there was a general improvement of test scores between the pre-tests and the post-tests. Due to the size of the sample however, the statistical significance of the improvement is very low. However, this improvement can loosely be attributed, to the practical activities-based intervention that took place between the pre-test and the post-test. The decline in the one test can be attributed to the lack of mathematical skills exhibited by the learners. This will be discussed further in the section on questions and limitations for further research (5.7).

## **5.2. DISCUSSION OF FINDINGS**

### **5.2.1. Researcher's Reflection & Relationship with Previous studies**

Making use of the qualitative aspects of this study, it has been established that the module E&M still poses challenges to learners, and some of these challenges manifest themselves in the form of misconceptions. Research by McDermott and Shafer (1992a) together with other researchers, (Bagno & Eylon, 1997; Bahar & Polat, 2007; Grayson, 2004; Mauk & Hingley, 2005; Maloney, et al., 2001; Planinic, 2006; Sengupta & Wilensky, 2009), indicated a large range of these difficulties and misconceptions in the module E&M. This research proves that these difficulties and misconceptions are not peculiar to the current research group but could be prevalent with science learners in general.

On the basis of the quantitative data on the other hand, although it indicates patterns that accept the hypothesis, it is difficult to be generalize the conclusion as the data is compromised by the small sample size. Although there is enough research (Millar, 2004; Hofstein & Lunetta, 2003; DoE, 2003; Wellington, 1994; Toplis & Allen, 2012; Woodley, 2009) advocating for the use and importance of practical activities, more still needs to be done to firmly establish this section of the hypothesis on a statistically significant sample.

### **5.2.2. Explanations of Unanticipated Findings**

The learner performance in Test 2 was contrary to the general trend in all the other tests in that the learner performance actually drops. The main reason was the fact that in these tests, the Ohm's Law concept was asked making use of graphs. Graphing and associated skills (gradients calculations) as well as other mathematical skills like subject of the formula, were not covered in much detail by the researcher in the practical intervention as the assumption was made that this was a competence dealt with in Mathematics.

Although steps should have been taken to ensure that the level of mathematical skills assessed was uniform in both the pre and post-test, this anomaly was not surprising. Research (Chabay & Sherwood, 2006:329; Dori & Belcher, 2005:244; Bahar & Polat, 2007:1121) has also shown that mathematical expressions and formulae can make science difficult for students especially those that are not good at Mathematics. This therefore opens up an area for further research into the impact of mathematical skills on learners performance in Physical Science.

### 5.3. RECOMMENDATIONS ON THE USE OF PRACTICAL WORK – FROM LITERATURE AND THIS STUDY

Some of the reasons given by the students as given to them by their teachers for not doing practical work were that it is time-consuming, lack of equipment and lack of competence on the teachers' side. Indeed practical work is not something that a teacher can decide spare of the moment and be able to successfully do, it requires proper preparation. In this section, recommendations will be made based on the researcher's experiences while working on this research study as well as those made by other researchers.

Firstly, thorough planning – before and after the practical session – is invaluable. This allows the teacher enough time to collect the equipment necessary as well as get an indication of what the practical entails, and whether or not it can be completed in the time available. Should the time envisaged not be available in one period, the teacher is able to arrange accordingly, prior to even beginning the practical activity. There is nothing as disorganizing to the teacher and the learners as running out of time, in the middle of a practical activity, with no alternative plan. However, if the teacher knew before the practical activity started, he is able to plan how much will be achieved in the one lesson and what will happen with the rest. Bradley, *et al.* (1998:1406), supported the above notion, adding that practical activities have to be appropriately designed and managed by the teacher. If that did not happen, the enthusiasm of both teachers and learners quickly declines, because they see no value in it.

Secondly, to increase effectiveness, practical activities must have clear objective and outcomes and these must be communicated to the learners so that they also know why they are doing this activity (2009:49). Otherwise the learners enjoy the session but have no idea where the lesson is going and very little learning usually takes place in that regard. On the other hand, when outcomes are clearly stipulated, verbally and on paper for example, the learners are able to measure their progress as they proceed through the practical.

Properly executed practical sessions can stimulate and engage students' learning at different levels, challenging students mentally and physically in ways that other science experiences cannot (SCORE, 2009:2). In addition to clear and properly communicated objectives and outcomes, it is also important to consolidate these outcomes for the whole

class at the end of the lesson. This consolidation usually helps in cases where not every learner has achieved all the outcomes. It is therefore important to make sure that one practical activity does not have too many outcomes, it can get cumbersome and learners end up losing track of what is to be done.

While in this study, enough care was taken to ensure that the learners remained on task with the outcomes and objectives, it was necessary to continuously remind them throughout the activity, especially in cases on long practical activities.

Thirdly, the practical activities should rather be short and address only one main idea if it is possible (2004:13). When the practical activity is too long, chances are that the knowledge gained as the activity progresses depends on the knowledge of the initial concepts in that activity. If that initial knowledge was not properly grasped by the learners they might end up not grasping the rest of the activity. On the other hand, if the activity covers one main idea per practical activity, it allows enough time for the learners to grasp the concept involved. An example of this is an experiment on series and parallel circuits, which when done as one activity, might end up creating confusion between the main concepts of potential difference and current, instead of clearer understanding of concepts.

Fourthly, the value of back ground knowledge on a learner's ability to grasp the concepts being taught, as well as understand the outcomes of the activity, cannot be underestimated. When learners already know something about the topic, they tend to be more curious and motivated to learn more about the concept, especially when done practically.

Lastly, research by Felder (1996:2), suggested strategies to make active learning even easier, these can certainly be applicable to practical work as it is a form of active learning.

The strategies are as follows:

- Set the stage i.e. explain to the class what you are going to do and why
- Provide coaching on the skills the students might be lacking
- Get feedback and be responsive to it – as much as it is feasible
- Be patient – frustration might be only for a few weeks

#### 5.4. LIMITATIONS OF THIS RESEARCH STUDY

The main limitation of this study – a small sample size - was due to the deteriorating conditions for the intervention. Others include the role of language, poor mathematical skills of the learners, time constraints for the practical activity and time lapse between the intervention and the post-test.

It was impossible during this study to ensure that the conditions under which the practical activity took place were always favourable. In fact, the conditions for the first three sessions were much better while deteriorating conditions in the last three tests affected the number of learners attending and thus the strength of the data. These deteriorating conditions refer to the decreasing number of learners in attendance due to cancellation of allocated time, which resulted in reshuffling the group members and group sizes. In addition, when the school had cancelled the allocated time, the learners who remained for the practical activity are also anxious about scholar transport and being hungry. Therefore, one cannot determine for sure that they were paying full attention to the practical activity.

The large majority (94%) of the learners were Xhosa-speaking and had English as the medium of instruction during these practical sessions. The use of English during these practical sessions was new to them, as they had indicated that their teachers actually taught them in a mixture of English and isiXhosa. It is therefore difficult to determine the full impact of lack of understanding of some concepts due to language issues.

Physical Science is commonly known for its reliance on mathematical skills in order to fully grasp some of the Physical Science concepts. Although this limitation was glaring in Test 2, it is difficult to determine its impact on the other five tests.

Another limitation was the issue of time. Firstly, the school involved dictated the amount of time available for the intervention and therefore the long activities had to be broken down. These meant that the learners might have forgotten what was done in the first part of the practical and only remember the recent concept. Secondly, the time lapse between the between the assessment and the intervention i.e. it was difficult to determine how much of the knowledge gain was as a result of the intervention or the freshness of the content in the learners' minds?

These participants (learners) also came from two different groups, taught by two different teachers. One group also did Computer Applications Technology (CAT) as a subject and the other did not. Therefore the difference in their pre-knowledge as well as their computer skills required in the practical activities could not be controlled due to the reasons aforementioned.

## **5.5. CONTRIBUTIONS OF THIS RESEARCH**

There are a number of entities that could benefit from a study such as this once. The first is the Department of Basic Education (subject advisors, school principals, educators). Knowledge gained from this study could be helpful to the designers of work schemes and decision makers in the allocation of time to be spent on each subject. Knowledge of the difficulties experienced in particular topics might help the DBE in structuring content such that enough time is given to areas with misconceptions and difficulties. Teachers too could benefit from knowledge of which areas to study carefully.

Knowledge gained from this research will go a long way in assisting learners themselves to prevent some of these difficulties in this module but as well as those that are generic to other modules in the Physical Science curriculum.

Researchers in the field of science education could also benefit from some of the results, observations and recommendations made in this study.

Intervention programs such as TRAC South Africa (Technology Research Activity Centres), in their quest to improve Physical Science performance is, also stand to benefit from some of the recommendations and findings of this study. For example, TRAC SA could be able to refine and redesign their practical worksheets as well as the delivery of their sessions, making use of some of the information gained from this study.

## **5.6. QUESTIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH**

The researcher in this study did strive to address as many issues as possible, relating to the difficulties experienced by learners in E&M as well as how a practical activities approach could reduce these difficulties. However, there are still more questions that would need to be answered by future research, namely:

1. What is the value of Mathematics and mathematical skills in learners' understanding of Physical Science concepts? This question is asked also in the context of a lot of anecdotal evidence that the pass rate of Physical Science learners who take Mathematical Literacy is much lower than those Physical Science learners taking pure Mathematics.
2. What role does language play in second language speakers' ability to grasp the science concepts taught in English? Does the switching between English and their home language help learners understand better, or does it hinder them?
3. What role does the teacher play in the facilitation of practical work? In other words, how important is the teacher's ability to use practical work effectively in science teaching, to the learners ability to benefit from the practical activity. Is it possible that teachers' inadequacy or incompetence in practical work could hamper the learners' understanding of science concepts?

Hofstein and Lunetta (1982:213) expounding on the above suggested that future research must be done on specific conditions and strategies of laboratory work, on their effects on a range of learning outcomes, and on their interactions. This should include important variables in the laboratory environment, namely:

- teacher attitudes and behaviour;
- content and nature of laboratory activities;
- instructional goals;
- social variables or learning environment;
- management (temporal placement of activities in curriculum; method of student evaluation; time allotted to activities; method of grouping students; and availability of space and materials) (Hofstein & Lunetta, 1982:213).

In terms of investigating students' characteristics pertaining to practical work, Hofstein and Lunetta (1982:213) added that the variables to be investigated should include factors like:

- student behaviour;
- intellectual development;
- conceptual understanding;
- skill level (inquiry and problem-solving skills; mathematical skills; reading skills; and manipulative skills);
- attitudes toward a variety of relevant issues (interest and curiosity).

How would their recommendation improve practical work?

## 5.7. FINAL CONCLUSION

While it is crucial to acknowledge that the results reported here are from a generally smaller sample, they nonetheless provide valuable insights and indicators into the difficulties experienced by learners in E&M as well as the misconceptions harboured, especially among disadvantaged schools characterized by poor resources. It is acknowledged, however, that schools from similar areas have produced good results in spite of the poor resources, which implies that practical activities alone will not solve the poor performance challenge in Physical Science. While this study may not be generalizable in terms of whether or not learner would pass, it is definitely generalizable in terms of the difficulties and misconceptions experienced by learners as this finding is also supported by research. Unfortunately, the size of the sample makes it difficult to generalize the quantitative data.

Evidently, the collected data has shown that, firstly, learners clearly experience difficulties and misconceptions in E&M. Secondly, with the exception of the Mathematics skills lacking, the average performance of learners before the practical intervention was much lower than their average performance after the practical intervention. In addition, the prevalence of these difficulties and misconceptions showed a decline in the post-tests compared to the pre-tests. This study therefore suggests that this improvement in learner performance and decline in difficulties and misconceptions, at least in part, was a result of the use of practical activities.

It is important for the science teacher to note that the success of practical work is neither immediate nor automatic, one might face awkwardness, frustration, student resistance and hostility. This is because anything new and important involves a learning curve that may be particularly steep to the teacher and the students at first. Students whose teachers have spoon-fed them from early on might be quite resistant to practical work (Felder, 1996:1). However, this is too important a tool not to utilize.

Although there is a large range of other interventions that have been shown by researchers to also enhance learner understanding in Physical Science, these cannot be a substitute for practical work. Such activities like simulations, the use of ICT, models and

modelling, concept substitutions, peer instructions and others, have an important role to play in supporting practical work in developing and increasing learners' scientific knowledge.

In conclusion, while in the South African context, the pass rate of Grade 12 learners in Physical Science, is continuing to show a steady increase in terms of learners obtaining 30% or more, “only 20% of pupils writing matric Mathematics and Physical Science achieve more than 50%” (SAIRR, 2013:1). In addition, the number of learners enrolling for this subject is continuously decreasing from 220 882 in 2009 to 179 194 in 2013 (DBE, 2012:5). This, in a country that is hoping to increase the number of students going into scarce skills careers still reflects a huge challenge for this country. Therefore, any resource that could assist in making a difference with this subject should surely be embraced, providing the necessary resources. A practical activities based approach to the teaching of Physical Science is such a resource.

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**APPENDIX A: TEST 1 SCORES**

<b>TEST 1: Basic of Current Electricity</b>			
<b>Student Number</b>	<b>PRE-TEST 1</b>	<b>POST TEST 1</b>	<b>% Change</b>
1	12.12	35.48	23.36
2	63.64	80.65	17.01
4	15.15	58.07	42.92
5	48.49	64.52	16.03
7	30.3	58.07	27.77
9	24.24	83.87	59.63
11	36.36	74.19	37.83
12	36.36	51.62	15.26
14	48.49	70.97	22.48
15	21.21	35.48	14.27
17	12.12	50	37.88
19	36.36	67.74	31.38
21	36.36	80.65	44.29
22	36.36	67.74	31.38
23	66.67	83.87	17.2
24	6.06	29.03	22.97
25	21.21	45.16	23.95
26	66.67	93.55	26.88
27	18.18	48.39	30.21
28	45.45	74.19	28.74
29	39.39	64.52	25.13
30	12.12	64.52	52.4
31	24.24	35.48	11.24
32	48.49	51.61	3.12
33	21.21	61.29	40.08
34	39.39	45.16	5.77
36	84.85	83.87	-0.98
37	12.12	48.38	36.26
38	36.36	58.06	21.7
39	33.33	41.94	8.61
40	30.3	51.61	21.31
42	42.42	64.52	22.1
43	33.33	74.19	40.86
44	54.55	70.97	16.42
45	9.09	29.03	19.94
46	78.79	70.87	-7.92
47	30.3	58.07	27.77
50	15.15	48.39	33.24
51	75.76	58.06	-17.7
52	57.58	54.84	-2.74
53	21.21	48.39	27.18
54	48.49	54.84	6.35
55	18.18	48.39	30.21
56	15.15	32.26	17.11
57	18.18	51.61	33.43
59	21.21	58.07	36.86
61	54.55	64.52	9.97
	<b>35.27</b>	<b>58.44</b>	<b>23.17</b>

**APPENDIX B: TEST 2 SCORES**

<b>TEST 2: Resistance and Ohm's Law</b>			
<b>Student Number</b>	<b>PRE-TEST 2</b>	<b>POST TEST 2</b>	<b>% Change</b>
1	33.33	25	-8.33
2	66.7	45	-21.7
4	53.33	70	16.67
5	60	40	-20
7	70	35	-35
8	60	30	-30
9	30	40	10
12	26.67	15	-11.67
14	16.67	25	8.33
17	20	25	5
19	43.33	40	-3.33
22	10	25	15
23	56.67	70	13.33
26	70	40	-30
27	16.67	25	8.33
30	33	20	-13
32	10	5	-5
33	3.33	15	11.67
34	20	10	-10
36	76.66	55	-21.66
37	16.67	10	-6.67
38	20	8	-12
39	13.33	10	-3.33
40	40	15	-25
42	30	30	0
43	46.67	25	-21.67
44	33.33	15	-18.33
45	10	15	5
46	60	20	-40
47	30	30	0
49	66.67	25	-41.67
50	23.33	20	-3.33
51	46.67	15	-31.67
52	36.67	40	3.33
53	16.7	35	18.3
54	40	25	-15
55	26.67	15	-11.67
56	20	20	0
57	30	15	-15
59	46.67	50	3.33
61	60	30	-30
	<b>36.33</b>	<b>27.39</b>	<b>-8.94</b>

**APPENDIX C: TEST 3 SCORES**

<b>TEST 3: Emf &amp; Internal Resistance</b>			
<b>Student Number</b>	<b>PRE-TEST 3</b>	<b>POST TEST 3</b>	<b>% Change</b>
2	28.13	60.87	32.74
3	6.25	26.09	19.84
4	6.25	13.04	6.79
5	31.25	39.13	7.88
7	15.63	65.22	49.59
8	21.88	17.39	-4.49
9	6.25	30.43	24.18
12	37.5	34.78	-2.72
14	0	34.78	34.78
17	3.13	8.69	5.56
19	25	17.39	-7.61
22	15.63	34.78	19.15
23	37.5	30.43	-7.07
26	40.63	73.9	33.27
27	28.13	30.43	2.3
30	15.63	43.48	27.85
34	12.5	52.17	39.67
35	34.38	47.83	13.45
36	25	47.83	22.83
40	21.88	21.74	-0.14
42	15.63	52.17	36.54
45	9.38	4.35	-5.03
46	12.5	60.87	48.37
47	21.88	26.09	4.21
51	9.38	8.7	-0.68
52	21.88	21.74	-0.14
54	6.25	34.78	28.53
59	6.25	26.08	19.83
61	21.88	52.17	30.29
	<b>18.53</b>	<b>35.08</b>	<b>16.54</b>

**APPENDIX D: TEST 4 SCORES**

<b>TEST 4: Series and parallel circuits</b>			
<b>Student No.</b>	<b>PRE-TEST 4</b>	<b>POST TEST 4</b>	<b>% Change</b>
1	8.33	21.67	13.34
2	20	38.33	18.33
3	6.67	33.33	26.66
4	6.67	53.33	46.66
5	3.33	30	26.67
6	6.67	48.33	41.66
7	16.67	60	43.33
8	0	35	35
9	8.33	23.3	14.97
12	10	38.33	28.33
14	3.33	13.33	10
17	3.33	15	11.67
19	10	16.67	6.67
21	11.67	55	43.33
22	8.33	25	16.67
23	18.33	38.33	20
26	15	63.33	48.33
27	23.33	26.67	3.34
28	8.33	50	41.67
34	13.33	28.33	15
35	20	48.33	28.33
36	58.33	53.33	-5
40	15	10	-5
42	10	15	5
46	36.67	65	28.33
47	8.33	8.33	0
51	5	23.3	18.3
52	3.33	43.33	40
54	20	38.33	18.33
59	11.67	21.67	10
61	16.67	15	-1.67
	<b>13.12</b>	<b>34.03</b>	<b>20.91</b>

**APPENDIX E: TEST 5 SCORES**

<b>TEST 5: Field associated with Current</b>			
<b>Student No.</b>	<b>PRE-TEST 5</b>	<b>POST TEST 5</b>	<b>% Change</b>
1	8	20	12
2	8	20	12
3	8	13.33	5.33
4	8	26.67	18.67
5	0	33.33	33.33
7	8	0	-8
12	20	13.33	-6.67
17	8	6.67	-1.33
19	8	13.33	5.33
22	20	6.67	-13.33
23	8	6.67	-1.33
26	16	13.33	-2.67
34	4	33.33	29.33
35	16	26.67	10.67
36	32	46.67	14.67
40	4	26.67	22.67
42	8	26.67	18.67
46	24	20	-4
51	12	46.67	34.67
52	4	26.67	22.67
54	8	6.67	-1.33
59	4	33.33	29.33
60	20	6.67	-13.33
61	4	6.67	2.67
	<b>10.83</b>	<b>20</b>	<b>9.17</b>

**APPENDIX F: TEST 6 SCORES**

<b>TEST 6: Current associated with Field</b>			
<b>Student No.</b>	<b>PRE-TEST 6</b>	<b>POST TEST 6</b>	<b>% Change</b>
1	12.5	0	-12.5
2	25	50	25
3	43.75	81.25	37.5
4	12.5	43.75	31.25
5	31.25	50	18.75
7	31.25	56.25	25
11	18.75	50	31.25
17	6.25	31.25	25
19	18.75	50	31.25
22	25	50	25
26	25	43.75	18.75
34	12.5	31.25	18.75
35	12.5	56.25	43.75
36	25	56.25	31.25
40	0	37.5	37.5
42	12.5	50	37.5
46	43.75	56.25	12.5
51	0	31.25	31.25
52	12.5	37.5	25
54	18.75	56.25	37.5
59	12.5	50	37.5
60	0	18.75	18.75
61	18.75	43.75	25
	<b>18.21</b>	<b>44.84</b>	<b>26.63</b>

### APPENDIX G: TEST SCORES 1 – 6 PARTICIPANTS IN ALL

#	Pre- & Post-test 1			Pre- & Post-test 2			Pre- & Post-test 3			Pre- & Post-test 4			Pre- & Post-test 5			Pre- & Post-test 6		
	Pre	Post	% Change	Pre	Post	% Change	Pre	Post	% Change	Pre	Post	% Change	Pre	Post	% Change	Pre	Post	% Change
	<b>100</b>	<b>100</b>		<b>100</b>	<b>100</b>		<b>100</b>	<b>100</b>		<b>100</b>	<b>100</b>		<b>100</b>	<b>100</b>		<b>100</b>	<b>100</b>	
1	12.12	35.48	23.36	33.33	25	-8.33	0	21.74	21.74	8.33	21.67	13.34	8	20	12	12.5	0	-12.5
2	63.64	80.65	17.01	70	45	-25	28.13	60.87	32.74	20	38.33	18.33	8	20	12	25	50	25
4	15.15	58.07	42.92	53.33	70	16.67	6.25	13.04	6.79	6.67	53.33	46.66	8	26.67	18.67	12.5	43.75	31.25
5	48.49	64.52	16.03	66.67	40	-26.67	31.25	39.13	7.88	3.33	30	26.67	0	33.33	33.33	31.25	50	18.75
7	30.3	58.07	27.77	76.67	35	-41.67	15.63	65.22	49.59	16.67	60	43.33	8	0	-8	31.25	56.25	25
12	36.36	51.62	15.26	26.67	15	-11.67	37.5	34.78	-2.72	10	38.33	28.33	20	13.33	-6.67	25	43.75	18.75
17	12.12	50	37.88	20	25	5	3.13	8.69	5.56	3.33	15	11.67	8	6.67	-1.33	6.25	31.25	25
19	36.36	67.74	31.38	43.33	40	-3.33	25	17.39	-7.61	10	16.67	6.67	8	13.33	5.33	18.75	50	31.25
22	36.36	67.74	31.38	10	25	15	15.63	34.78	19.15	8.33	25	16.67	20	6.67	-13.33	25	50	25
23	66.67	83.87	17.2	56.67	70	13.33	37.5	30.43	-7.07	18.33	38.33	20	8	6.67	-1.33	56.25	50	-6.25
26	66.67	93.55	26.88	70	40	-30	40.63	73.9	33.27	15	63.33	48.33	16	13.33	-2.67	25	43.75	18.75
34	39.39	45.16	5.77	20	10	-10	12.5	52.17	39.67	13.33	28.33	15	4	26.67	22.67	12.5	31.25	18.75
36	84.85	83.87	-0.98	76.66	55	-21.66	25	47.83	22.83	58.33	53.33	-5	32	46.67	14.67	25	56.25	31.25
40	30.3	51.61	21.31	40	15	-25	21.88	21.74	-0.14	15	10	-5	4	26.67	22.67	0	37.5	37.5
42	42.42	64.52	22.1	36.67	30	-6.67	15.63	52.17	36.54	10	15	5	8	26.67	18.67	12.5	50	37.5
46	78.79	70.87	-7.92	60	20	-40	12.5	60.87	48.37	36.67	65	28.33	24	20	-4	43.75	56.25	12.5
51	75.76	58.06	-17.7	46.67	15	-31.67	9.38	8.7	-0.68	5	23.3	18.3	12	46.67	34.67	0	31.25	31.25
52	57.58	54.84	-2.74	36.67	40	3.33	21.88	21.74	-0.14	3.33	43.33	40	4	26.67	22.67	12.5	37.5	25
54	48.49	54.84	6.35	40	25	-15	6.25	34.78	28.53	20	38.33	18.33	8	6.67	-1.33	18.75	56.25	37.5
59	21.21	58.07	36.86	46.67	50	3.33	6.25	26.08	19.83	11.67	21.67	10	4	33.33	29.33	12.5	50	37.5
61	54.55	64.52	9.97	60	30	-30	21.88	52.17	30.29	16.67	15	-1.67	4	6.67	2.67	18.75	43.75	25
<b>AVG</b>	<b>45.59</b>	<b>62.74</b>	<b>17.14</b>	<b>47.14</b>	<b>34.28</b>	<b>-12.85</b>	<b>18.75</b>	<b>37.05</b>	<b>18.30</b>	<b>14.76</b>	<b>33.96</b>	<b>19.20</b>	<b>10.28</b>	<b>20.31</b>	<b>10.03</b>	<b>20.23</b>	<b>43.75</b>	<b>23.51</b>

## APPENDIX H: PRE- AND POST-TEST 1

### Pre-test 1: Basics of Current Electricity

Name: \_\_\_\_\_

#### Instructions

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

#### Indication of Prior Knowledge

Have you received any formal teaching on this topic? Please indicate (√).

Yes

No

If yes, when did this take place? Please indicate (√).

This week 

Tick(√)

A week ago 

--

A month ago 

--

Last term 

--

Last semester 

--

Last year 

--

If not, why not? Please indicate (√).

I was absent on the day 

Tick(√)

The topic has not yet been covered by teacher. 

--

Other (specify in the space below):  
 .....

#### Question 1

1.1. Define the following terms (your understanding of these), include function:

1.1.1. Battery

.....  
 .....

1.1.2. Connectors (or connecting wires)

.....  
.....

1.1.3. Resistors or appliances

.....  
.....

1.1.4. Ammeter

.....  
.....

1.1.5. Voltmeter

.....  
.....

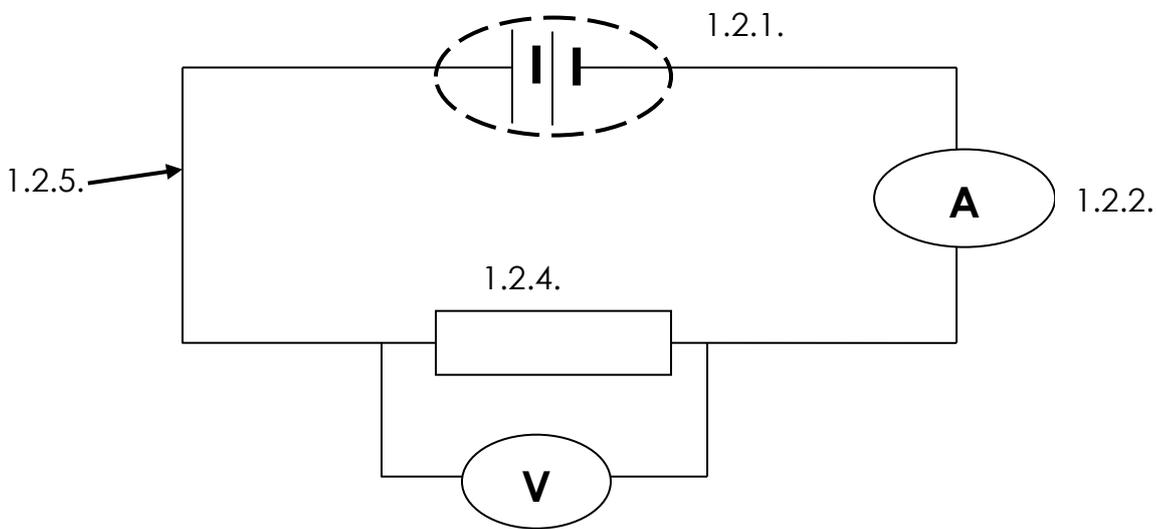
1.1.6. Galvanometer

.....  
.....

1.1.7. Switch

.....  
.....

1.2. Label the following circuit components



1.2.1. ....

1.2.2. ....

1.2.3. ....

1.2.4. ....

1.2.5. ....

**Question 2**

2.1. Draw fully labelled circuit diagrams for the following connections in the space provided:

2.1.1. Two cells in series

2.1.2. Two cells in parallel

2.1.3. Three resistors in series

2.1.4. Three resistors in parallel

2.1.5. A complete circuit with 3 cells in series, an ammeter and two resistors  $R_1$  and  $R_2$  connected in parallel and a voltmeter connected to  $R_2$ . An open switch.

2.2. Define the following terms, include symbol and units

2.2.1. Current

Definition:

.....  
.....

Symbol: .....

Unit name and Symbol: .....

2.2.2. Potential difference

Definition:

.....  
.....

Symbol: .....

Unit name and Symbol: .....

2.2.3. Resistance

Definition:

.....  
.....

Symbol: .....

Unit name and Symbol: .....

2.2.4. Emf

Definition:

.....  
.....

Symbol: .....

Unit name and Symbol: .....

.....oOo.....

**Post-Test 1: Basics of Current Electricity**

Name: \_\_\_\_\_

**Instructions**

- 1. Answer all questions on the question paper.
- 2. Calculators may be used where necessary.

**Indication of Prior Knowledge**

Have you attended the practical session on this topic? Please indicate (✓).

Yes

No

If yes, when did this session take place? Please indicate (✓).

This week 

Tick(✓)

A week ago

A month ago

Last term

Last semester

Last year

If no, why not? Please indicate (✓).

I was absent on the day 

Tick(✓)

Other (specify in the space below):  
.....

**Question 1**

1.1. Fill in the answers in the spaces provided.

1.1.1. What is the function of a battery in a circuit?

.....  
.....

1.1.2. Which way does electric current flow in conventional current?

.....

1.1.3. What unit is current measured in?  
.....

1.1.4. What type of meter measures current?  
.....

1.1.5. Is the meter which measures current connected in series or parallel?  
.....

1.1.6. What unit is potential difference measured in?  
.....

1.1.7. What type of meter measures potential difference?  
.....

1.1.8. Is the meter which measures potential difference connected in series or parallel?  
.....

1.1.9. What unit is resistance measured in?  
.....

1.2. In the space provided, draw the circuit symbol for the following circuit components:

1.2.1. battery (label the positive and negative terminal)

1.2.2. connectors

1.2.3. resistor

1.2.4. voltmeter

1.2.5. ammeter

1.2.6. open switch

1.2.7. closed switch

## **Question 2**

2.1. Draw a circuit diagram consisting of **two cells in series; three resistors  $R_1, R_2$  and  $R_3$  in parallel; an ammeter in series in the circuit, a voltmeter to  $R_3$  and an open switch.**

2.2. Draw a circuit diagram consisting of the following components:

- Two cells in parallel
- An ammeter in series in the circuit
- Two resistors ( $R_1$  and  $R_2$ ) in parallel to each other and another resistor  $R_3$  in series in the circuit.
- Voltmeter  $V_2$  connected to  $R_3$
- Voltmeter  $V_1$  connected to the battery

2.3. Choose the most correct answer and write only the letter.

2.3.1. The work done in moving a unit positive charge across two points in an electric circuit is a measure of \_\_\_\_\_.

- A. Current
- B. Potential difference
- C. Resistance
- D. Power

Answer: .....

How sure are you of your answer?

Unsure

Sure

2.3.2. Current is defined as

- A. the rate of flow of charges.
- B. the amount of work done to move a positive point charge.
- C. the rate at which energy is converted by an appliance.
- D. all of the above.

Answer: .....

How sure are you of your answer?

Unsure

Sure

2.3.3. The maximum amount of energy a battery can supply it its

- A. voltage
- B. emf
- C. potential difference
- D. current

Answer: .....

How sure are you of your answer?

Unsure

Sure

2.3.4. The value  $20\Omega$  is a measure of the \_\_\_\_\_ of the conductor.

- A. Current
- B. voltage
- C. resistance
- D. power

Answer: .....

How sure are you of your answer?

Unsure

Sure

## Pre-Test 2: Resistance and Ohm's Law

Name: \_\_\_\_\_

### Instructions

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

### Indication of Prior Knowledge

Have you received any formal teaching on this topic? Please indicate (✓).

Yes

No

If your answer is **Yes**, when did this take place? Please indicate (✓).

This week 

Tick(✓)

A week ago

A month ago

Last term

Last semester

Last year

If your answer is **No**, what is the reason? Please indicate (✓).

I was absent on the day. 

Tick(✓)

The topic has not yet been covered by teacher.

Other (specify in the space below):  
.....

### Question 1

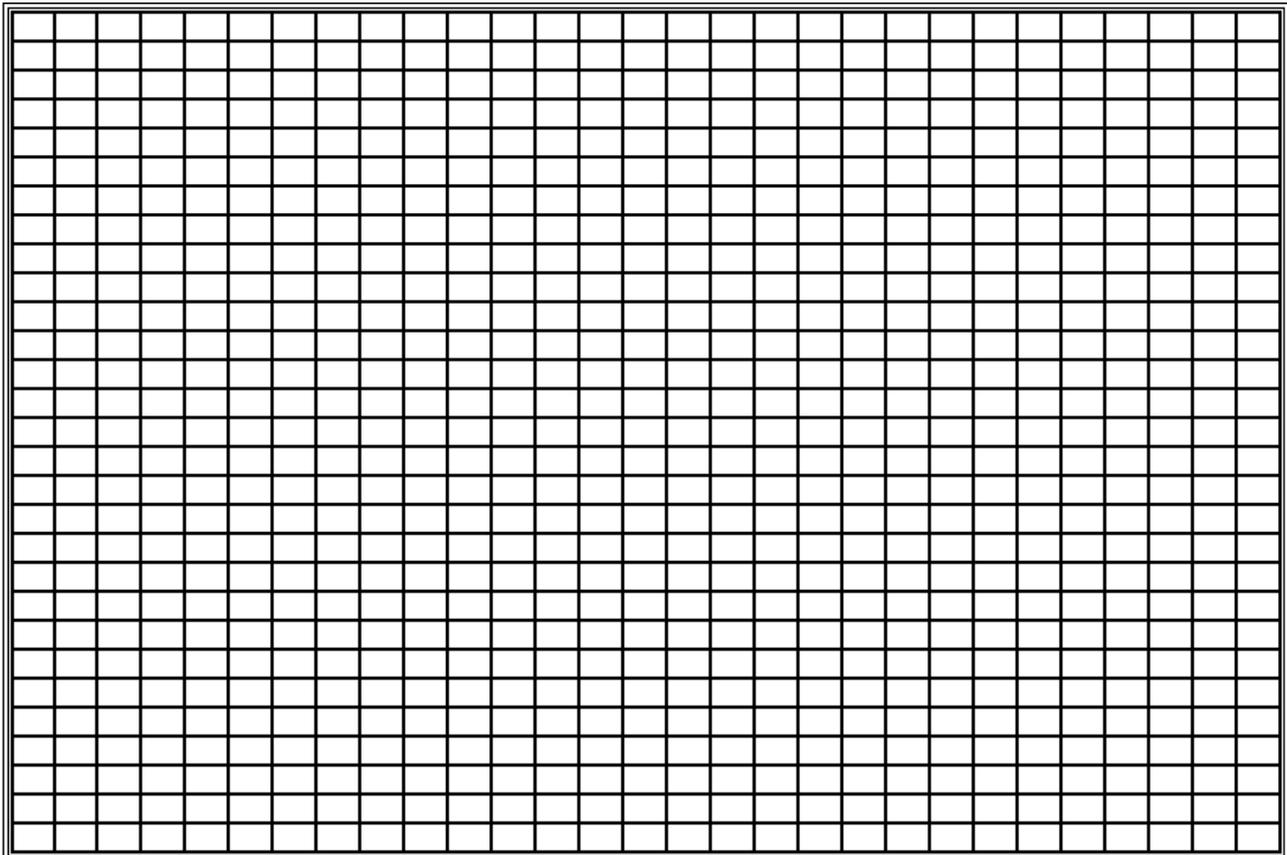
1.1. State Ohm's Law in words.

.....  
.....  
.....

1.2. Consider the following data which was obtained by a learner in an experiment in which he was trying to verify Ohm's Law:

Potential Difference (Volts)	Current (Amperes)
3	0.4
6	0.8
9	1.2
12	1.6

1.2.1. Using the above data, plot a graph of potential difference vs. current in the space provided below, showing all the necessary labels:



1.2.2. Calculate the gradient of this graph and show your working out on the graph and write the calculation in the space below:

.....  
.....  
.....  
.....

1.2.3. What does this gradient represent?

.....

1.2.4. Do these experiment results verify Ohm's Law? Explain.

.....  
.....  
.....

**Question 2**

2.1. Calculate the resistance of a resistor that has a potential difference of 8 V across it when a current of 2 A flows through it (Horner, Halliday, Blyth, Adams, & Wheaton, 2010:413).

.....  
.....  
.....

2.2. What current will flow through a resistor of 6 when there is a potential difference of 18 V across its ends (Horner, *et al.*, 2010)?

.....  
.....  
.....

2.3. What is the voltage across a 10 resistor when a current of 1,5 A flows through it (Horner, *et al.*, 2010)?

.....  
.....  
.....

2.4. Explain the difference between Ohmic and non-Ohmic conductors.

.....  
.....  
.....

.....o0o.....

**Post-Test 2: Resistance and Ohm's Law**

Name: \_\_\_\_\_

**Instructions**

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

**Indication of Prior Knowledge**

Have you attended the practical session on this topic? Please indicate (✓).

Yes

No

If yes, when did this session take place? Please indicate (✓).

- |               |                                  |
|---------------|----------------------------------|
| This week     | <input type="checkbox"/> Tick(✓) |
| A week ago    | <input type="checkbox"/>         |
| A month ago   | <input type="checkbox"/>         |
| Last term     | <input type="checkbox"/>         |
| Last semester | <input type="checkbox"/>         |
| Last year     | <input type="checkbox"/>         |

If no, why not? Please indicate (✓).

Tick(✓)

I was absent on the day

Other (specify in the space below):

.....

**Question 1**

1.1. Which of the following statements does NOT represent Ohm's law?

- A.  $R = \frac{I}{V}$
- B.  $R = \frac{V}{I}$
- C.  $V = \frac{I}{R}$
- D.  $I = VR$

Answer: .....

**How sure are you of your answer?**

Unsure

Sure

1.2. The resistance of an electric bulb drawing 1.2 A current at 6.0 V is \_\_\_\_\_.

- A. 0.5  $\Omega$
- B. 5  $\Omega$
- C. 0.2  $\Omega$
- D. 2  $\Omega$

Answer: .....

How sure are you of your answer?

Unsure

Sure

1.3. Ohm's law relates potential difference with \_\_\_\_\_.

- A. power
- B. energy
- C. current
- D. time

Answer: .....

How sure are you of your answer?

Unsure

Sure

1.4. Which of the following is an ohmic resistor?

- A. diode
- B. light bulb
- C. resistor
- D. graphite

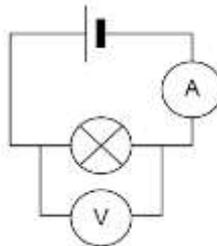
Answer: .....

How sure are you of your answer?

Unsure

Sure

1.5. Consider the closed circuit represented below (DBE, 2006:6):



How will the ammeter and voltmeter readings change, if the bulb burns out?

	Ammeter Reading	Voltmeter Reading
A	Increases	Increases
B	Becomes zero	Becomes zero
C	Does not change	Does not change
D	Becomes zero	Does not change

Answer: .....

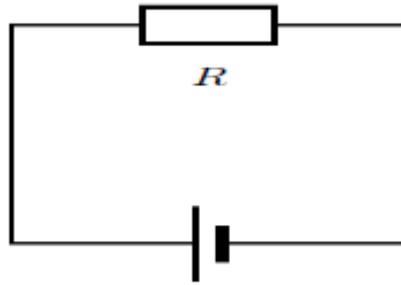
How sure are you of your answer?

Unsure

Sure

**Question 2**

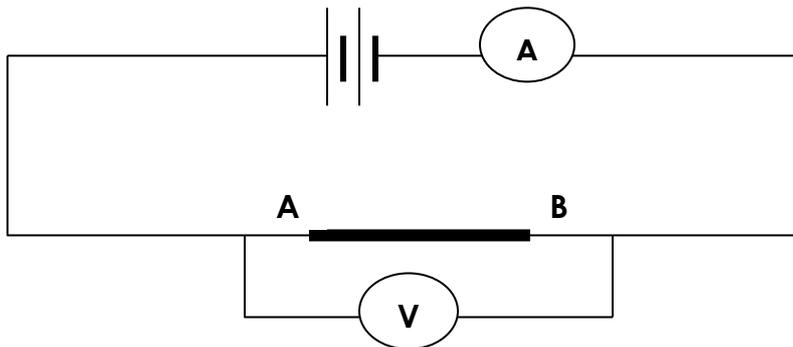
Consider the following circuit diagram:



2.1. The resistance of the above resistor is  $10\Omega$  and the current going through the resistor is 4 A. What is the potential difference (voltage) across the resistor?

.....  
 .....  
 .....

2.2. Sipho connected the circuit below to investigate whether a nichrome wire obeys Ohm's Law (Sunday Times, 2009: 7). He adjusts the current in the circuit and measures the potential difference across AB for every different value of current,  $I$ , i.e. the ammeter readings.



2.2.1. Explain which variable should be plotted on the x-axis and which variable on the y-axis.

.....  
 .....  
 .....

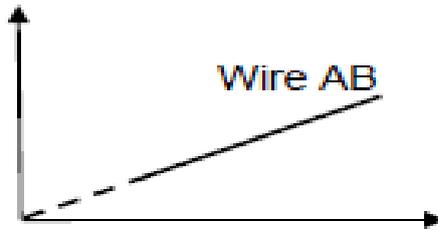
2.2.2. Which variable was controlled in this experiment and why?

.....  
 .....  
 .....

Sipho took the following readings:

Ammeter Reading	Voltmeter Reading
0.8	1
1.8	2.2
2.2	2.7
2.8	3.4

He then plots the following graph



2.2.3. What quantity does the slope of the graph represent?

.....

2.2.4. Use the raw data in the table to calculate the average value of slope of the graph.

.....  
.....  
.....  
.....

2.2.5. Was the nichrome wire used in Siphos experiment ohmic or non-ohmic? Explain.

.....  
.....  
.....

.....o0o.....

## APPENDIX J: PRE- AND POST-TEST 3

### Pre-test 3: Effective and Internal Resistance

Name: \_\_\_\_\_

#### Instructions

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

#### Indication of Prior Knowledge

Have you had any formal teaching on this topic? Please indicate (✓).

Yes

No

If yes, when did this session take place? Please indicate (✓).

This week 

Tick(✓)

A week ago 

--

A month ago 

--

Last term 

--

Last semester 

--

Last year 

--

If no, why not? Please indicate (✓).

I was absent on the day 

Tick(✓)

The topic has not yet been covered by teacher. 


Other (specify in the space below):  
.....

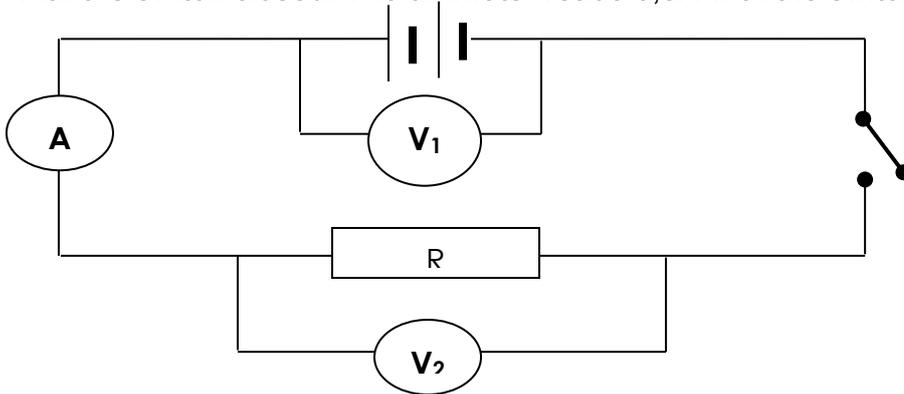
#### Question 1

- 1.1. List the 4 factors that affect the resistance of a conductor and how they each affect resistance.
- .....  
.....  
.....

- 1.2. Mention how each of the factors mentioned above affects the resistance.  
 .....  
 .....
- 1.3. One metre of wire has resistance of 10 ohms. What happens to the resistance of the wire if the wire is
- 1.3.1. halved:  
 .....
- 1.3.2. doubled:  
 .....
- 1.4. What is the unit of resistance called and what is its symbol?  
 .....

**Question 2**

- 2.1. Describe what is meant by the *internal resistance* of a battery.  
 .....  
 .....
- 2.2. Describe what is meant by the word “emf” of a battery.  
 .....  
 .....
- 2.3. What is the internal resistance of a battery if its emf is 6 V and the voltage drop across its terminals is 5,8 V when a current of 0,5 A flows in the circuit when it is connected across a load?  
 .....  
 .....
- 2.4. Consider the circuit below. The voltmeter  $V_1$  reads 6V when the switch is open and 5,5V with the switch closed. The ammeter reads 0,5A with the switch closed.



- 2.4.1. What is the emf of the battery?  
 .....
- 2.4.2. What is the reading on  $V_2$ , when the switch open and when it is closed?  
 $V_2$  (open switch):.....  $V_2$  (closed switch): .....
- 2.4.3. Calculate the resistance  $R$  as well as the internal resistance( $r$ ) of the battery.  
 .....  
 .....  
 .....o0o.....

**Post-Test 3: Effective and Internal Resistance**

Name: \_\_\_\_\_

**Instructions**

- 1. Answer all questions on the question paper.
- 2. Calculators may be used where necessary.

**Indication of Prior Knowledge**

Have you attended the practical session on this topic? Please indicate (✓).

Yes

No

If your answer is **Yes**, when did this take place? Please indicate (✓).

This week 

Tick(✓)

A week ago

A month ago

Last term

Last semester

Last year

If your answer is **No**, what is the reason? Please indicate (✓).

I was absent on the day. 

Tick(✓)

Other (specify in the space below):  
.....

**Question 1**

- 1.1. Which of the following factors does not affect the resistance of a conductor?
- A. thickness of the conductor
  - B. length of the conductor
  - C. potential difference across the conductor
  - D. the type of material used

Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.2. The number of volts measured between the terminals of a cell decreases when the cell supplies current because
- the cell is “running down”.
  - the cell has internal resistance.
  - the cell has a greater potential difference than the emf.
  - the circuit connected to the cell has a resistance that is too high.

Answer: .....

How sure are you of your answer?

Unsure

Sure

**Question 2**

The emf of a source of electrical energy is 9V. When it is connected to a resistor of 11Ω, the voltmeter connected across the resistance reads 8,8V.

2.1. What is the “lost” voltage in the circuit? .....

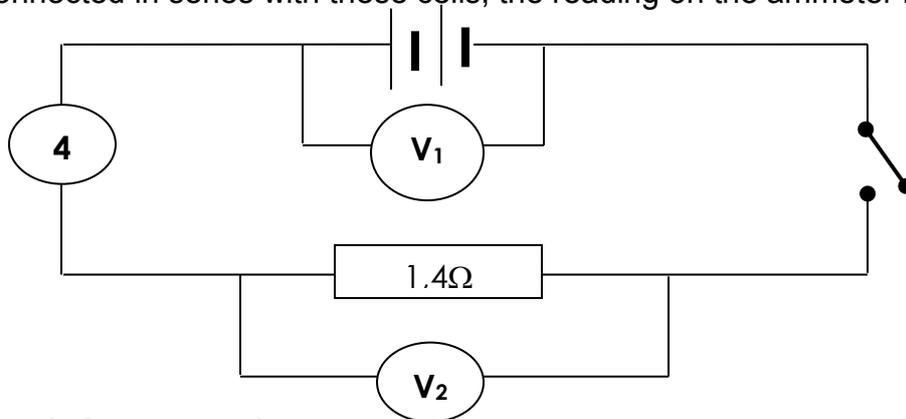
2.2. Calculate the current in the circuit.

.....  
 .....

2.3. Calculate the internal resistance of the battery.

.....  
 .....

2.4. The cells shown in the circuit below have an emf of 1,5V EACH. When a 1,4Ω resistor is connected in series with these cells, the reading on the ammeter is 4A.



2.4.1. What is the emf of the battery? .....

2.4.2. What is the reading on V<sub>1</sub> and V<sub>2</sub>, when the switch open and when it is closed?

V<sub>1</sub> (open switch):..... V<sub>1</sub> (closed switch): .....  
 V<sub>2</sub> (open switch):..... V<sub>2</sub> (closed switch): .....

2.4.3. Calculate the internal resistance of the battery.

.....  
 .....

## APPENDIX K: PRE- AND POST-TEST 4

### Pre-test 4: Series and Parallel Circuits

Name: \_\_\_\_\_

#### Instructions

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

#### Indication of Prior Knowledge

Have you had any formal teaching on this topic? Please indicate (✓).

Yes

No

If yes, when did this session take place? Please indicate (✓).

This week 

Tick(✓)

A week ago

A month ago

Last term

Last semester

Last year

If no, why not? Please indicate (✓).

I was absent on the day 

Tick(✓)

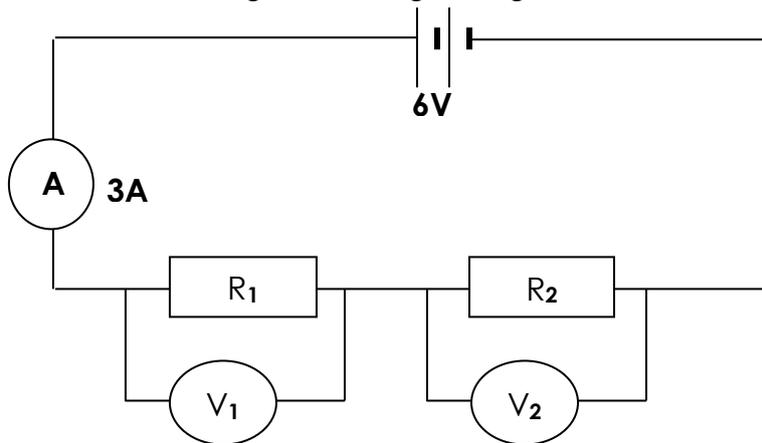
The topic has not yet been covered by teacher.

Other (specify in the space below):

.....

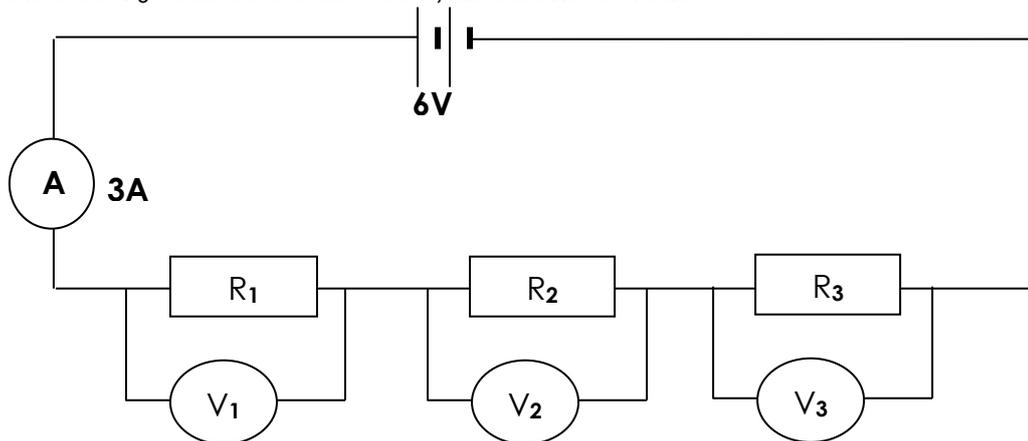
**Question 1**

Consider the following circuit diagram. Ignore internal resistance of the cells.



- 1.1. If the resistors  $R_1$  and  $R_2$  are identical:
- 1.1.1. What is the reading in  $V_1$  and  $V_2$  respectively?  
 $V_1$ : .....  
 $V_2$ : .....
- 1.1.2. Explain your answer to 1.1.1.  
 .....  
 .....
- 1.1.3. What is the value of the current that goes through  $R_1$  and  $R_2$  respectively?  
 Current in  $R_1$ : .....  
 Current in  $R_2$ : .....
- 1.1.4. Explain your answer to 1.1.3.

- 1.2. A third resistor  $R_3$  (identical to  $R_2$  and  $R_1$ ) is added in series in the above circuit with a voltmeter  $V_3$  connected across it, as shown below:



- If the resistors  $R_1$ ,  $R_2$  and  $R_3$  are identical:
- 1.2.1. What is the reading in  $V_1$ ,  $V_2$  and  $V_3$  respectively?  
 $V_1$ : .....  
 $V_2$ : .....  
 $V_3$ : .....
- 1.2.2. Explain your answer to 1.2.1.  
 .....  
 .....

1.2.3. With the inclusion of  $R_3$ , what happens to the total current in the circuit? Answer **INCREASE / DECREASE / STAYS THE SAME**. Explain.

.....  
 .....

1.2.4. Compare the current that goes through the three resistors.

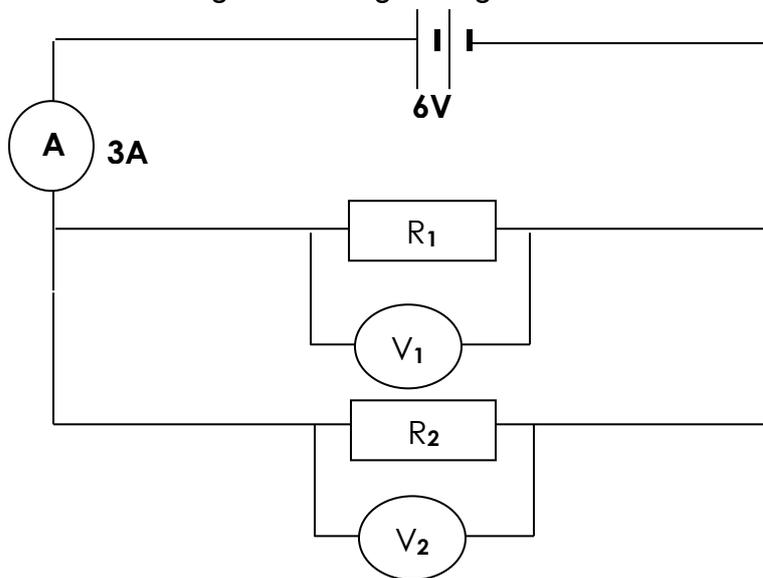
.....

1.2.5. Explain your answer to 1.2.4.

.....  
 .....

**Question 2**

Consider the following circuit diagram. Ignore internal resistance of the cells.



2.1. If the resistors  $R_1$  and  $R_2$  are identical:

2.1.1. What is the reading in  $V_1$  and  $V_2$  respectively?

$V_1$ : .....  
 $V_2$ : .....

2.1.2. Explain your answer to 2.1.1.

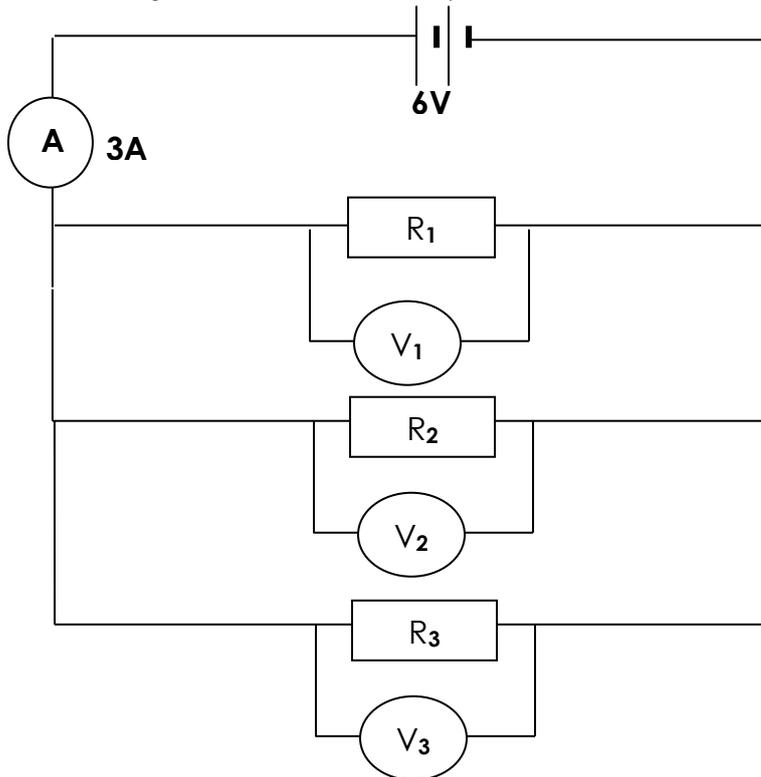
2.1.3. What is the value of the current that goes through  $R_1$  and  $R_2$  respectively?

Current in  $R_1$ : .....  
 Current in  $R_2$ : .....

2.1.4. Explain your answer to 2.1.3.

.....  
 .....

2.2. A third resistor  $R_3$  (identical to  $R_2$  and  $R_3$ ) is added in parallel in the above circuit with a voltmeter  $V_3$  connected across it, as shown below:



If the resistors  $R_1$ ,  $R_2$  and  $R_3$  are identical:

2.2.1. What is the reading in  $V_1$ ,  $V_2$  and  $V_3$  respectively?

- $V_1$ : .....
- $V_2$ : .....
- $V_3$ : .....

2.2.2. Explain your answer to 2.2.1.

.....  
 .....

2.2.3. What happens to the total current in the circuit? Answer **INCREASE / DECREASE / STAYS THE SAME**. Explain.

.....  
 .....

2.2.4. Compare the current that goes through the three resistors.

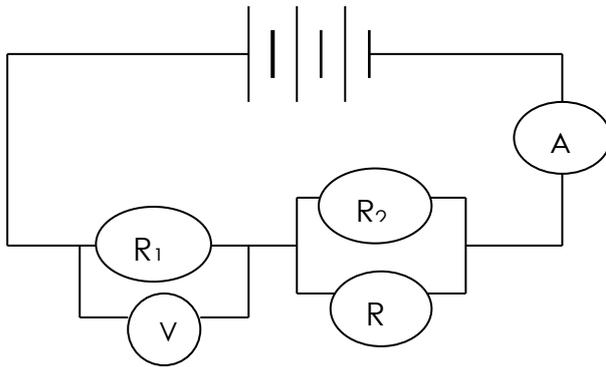
.....

2.2.5. Explain your answer to 2.2.4.

.....  
 .....

**Question 3**

The voltmeter reading in the circuit below is 9V.



$R_1 = 6\Omega$

$R_2 = 12\Omega$

$R_3 = 12\Omega$

Calculate

3.1. the ammeter reading

.....  
 .....

3.2. the effective resistance of the parallel combination

.....  
 .....

3.3. the total resistance of the circuit

.....  
 .....  
 .....

3.4. the potential difference across the battery

.....  
 .....

3.5. the potential difference across the parallel combination

.....  
 .....  
 .....

3.6. the current through  $R_1$ ,  $R_2$  and  $R_3$  respectively.

$R_1$ : .....

$R_2$ : .....

$R_3$ : .....

## Post-Test 4: Series and Parallel Circuits

Name: \_\_\_\_\_

### Instructions

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

### Indication of Prior Knowledge

Have you the practical session on this topic? Please indicate (✓).

Yes

No

If your answer is **Yes**, when did this take place? Please indicate (✓).

This week 

Tick(✓)

A week ago

A month ago

Last term

Last semester

Last year

If your answer is **No**, what is the reason? Please indicate (✓).

I was absent on the day. 

Tick(✓)

Other (specify in the space below):  
.....

### Question 1

Two resistors of  $14\Omega$  and  $6\Omega$  respectively, are connected in series and a potential difference of  $4,5V$  is connected across them.

- 1.1. Draw the circuit diagram.

1.2. Calculate the total resistance.

.....  
 .....

1.3. What is the potential difference across each resistor?

.....

1.4. Calculate the total current in the circuit.

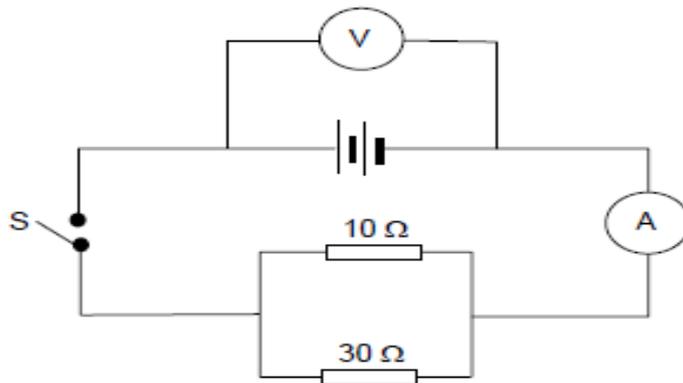
.....  
 .....

1.5. What is the current in each resistor?

.....  
 .....

**Question 2**

In the circuit represented below, the voltmeter reads 1,6V. Two resistors of 10Ω and 30Ω are connected in parallel and an ammeter is connected as shown.



2.1. When switch S is open, what is the reading on the ammeter?

.....

2.2. Switch S is now closed. Calculate the following:

2.2.1. the effective resistance of the circuit.

.....  
 .....

2.2.2. the reading on ammeter A.

.....  
 .....

2.2.3. the potential difference across the 10Ω and 30Ω resistors respectively.

$V_{10\Omega}$ : .....  
 $V_{30\Omega}$ : .....

2.2.4. The current in the 10Ω and 30Ω resistors respectively.

$I_{10\Omega}$ : .....  
 $I_{30\Omega}$ : .....

**Question 3**

A  $6\Omega$  resistor and a  $4\Omega$  are connected in parallel. This combination is then connected in series with a  $2,4\Omega$  resistor and a  $6V$  battery.

3.1. Draw the circuit diagram.

3.2. Calculate  
the effective resistance of the circuit.

.....  
.....

3.3. the current in the  $2,4\Omega$  resistor.

.....  
.....

3.4. the potential difference across the parallel combination of resistors.

.....  
.....

3.5. the current in the  $6\Omega$  resistor.

.....  
.....

.....o0o.....

## APPENDIX L: PRE- AND POST-TEST 5

### Pre-test 5: Magnetic Field associated with Current

Name: \_\_\_\_\_

#### Instructions

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

#### Indication of Prior Knowledge

Have you had any formal teaching on this topic? Please indicate (✓).

Yes

No

If yes, when did this session take place? Please indicate (✓).

This week  Tick(✓)

A week ago

A month ago

Last term

Last semester

Last year

If no, why not? Please indicate (✓).

I was absent on the day  Tick(✓)

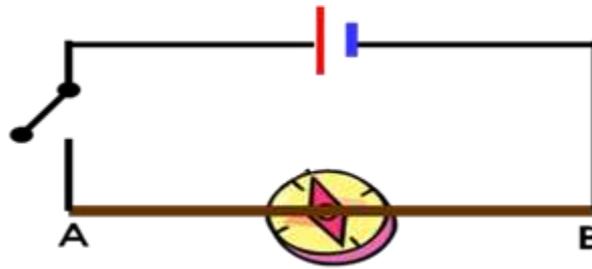
The topic has not yet been covered by teacher.

Other (specify in the space below):

.....

**Question 1**

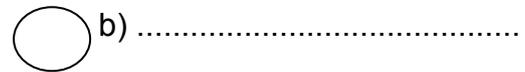
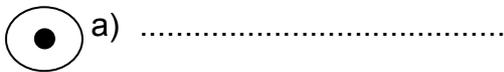
Consider the following diagram illustrating a compass needle placed under a conductor AB:



1.1. When switch S is closed, i.e. when there is current flowing through the conductor, the compass needle deflects (moves), which illustrates that a current-carrying conductor has a magnetic field around it. Describe the nature of this magnetic field.  
 .....

1.2. State the rule that can be used to determine the direction of this magnetic field.  
 .....  
 .....

1.3. The direction of the current in the conductor can be indicated by a cross or a dot. Next to each conductor, indicate what direction the cross or the dot represents



1.4. Using the rule described in 1.2, to indicate the direction of the induced magnetic field in 1.3a and 1.3b

a).....

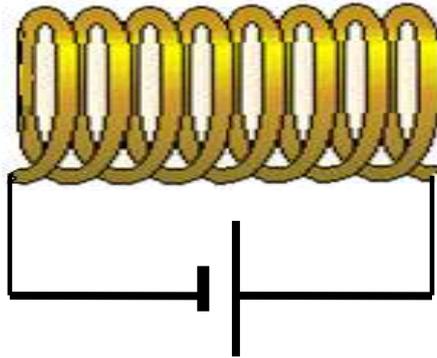
b).....

**Question 2**

2.1. Describe in point form how to make a simple electromagnet.  
 .....  
 .....  
 .....

2.2. Mention two ways in which the electromagnet can be made stronger.  
 .....  
 .....  
 .....

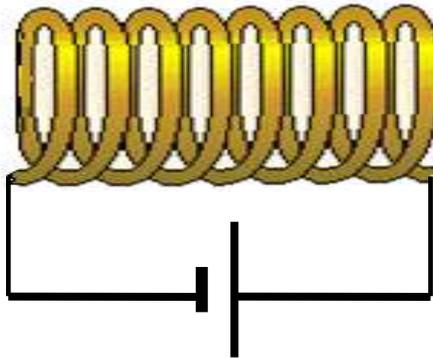
2.3. Consider the solenoid shown below:



2.3.1. Describe the rule that is used to determine the North pole of this magnet.

.....  
.....  
.....

2.3.2. Using the rule described in 2.3.1, indicate the North and South poles on the solenoid below:



2.4. Iron can be used for an electromagnet but steel cannot, it is used for a permanent magnet.

2.4.1. Distinguish between soft and hard magnets.

.....  
.....  
.....

2.4.2. State whether iron and steel are soft or hard magnets.

.....  
.....

**Post-Test 5: Magnetic Field associated with Current**

Name: \_\_\_\_\_

**Instructions**

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

**Indication of Prior Knowledge**

Have attended the practical session on this topic? Please indicate (✓).

Yes

No

If your answer is **Yes**, when did this take place? Please indicate (✓).

This week 

Tick(✓)

A week ago 

--

A month ago 

--

Last term 

--

Last semester 

--

Last year 

--

If your answer is **No**, what is the reason? Please indicate (✓).

I was absent on the day.

Tick(✓)

Other (specify in the space below):  
.....

**Question 1**

Choose the best answer

- 1.1. As an observer looks at it, an electric current in a coil flows clockwise. The direction of the induced magnetic field is
- A. to the left
  - B. to the right
  - C. towards the observer
  - D. away from the observer

**Answer:** .....

**How sure are you of your answer?**

Unsure

Sure

- 1.2. In order to achieve unlike magnetic poles at the ends of a horseshoe electromagnet, the coils around the limbs of the magnet must
- A. both carry current in clockwise circular directions.
  - B. both carry current in anti-clockwise circular directions.
  - C. carry the current in at the one coil and out at the other.
  - D. carry the current clockwise in one coil and anti-clockwise in the other.

Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.3. The direction of the induced magnetic field around a current carrying conductor carrying current as shown below, is



- A. towards the observer
- B. away from the observer
- C. clockwise
- D. anticlockwise.

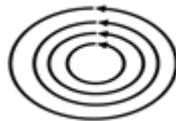
Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.4. The diagram below shows the direction of the induced magnetic field around a current carrying conductor. In which direction is the current flowing?



- A. towards the observer
- B. away from the observer
- C. clockwise
- D. anticlockwise.

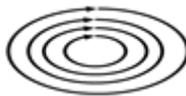
Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.5. The diagram below shows the direction of the induced magnetic field around a current carrying conductor. In which direction is the current flowing?



- A. towards the observer
- B. away from the observer
- C. clockwise
- D. anticlockwise.

Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.6. When a soft iron is placed in a current-carrying conductor, it

- A. reverses the current.
- B. increases the current.
- C. decreases the current.
- D. increases the magnetic field.

Answer: .....

How sure are you of your answer?

Unsure

Sure

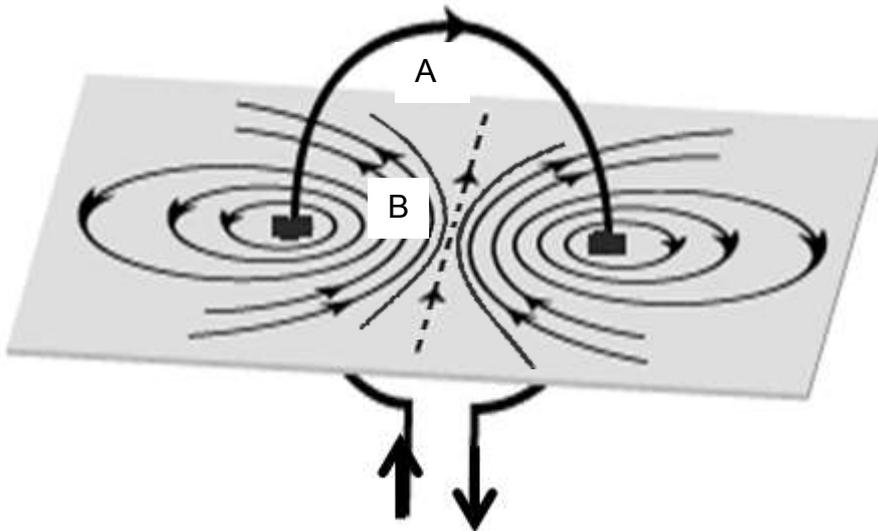
**Question 2**

2.1. List two uses of electromagnets.

.....  
 .....

2.2. Draw a labelled diagram of an electromagnet and show the poles of the electromagnet on your sketch.

2.3. A current-carrying loop has an induced magnetic field pattern as shown below.



2.3.1. Indicate which side (A or B) is North and which is South.

A: .....

B: .....

2.3.2. What is the direction of this induced magnetic field? North to South or South to North?

.....  
 .....o0o.....

## APPENDIX M: PRE- POST-TEST 6

### Pre-Test 6: Current Associated with a Magnetic Field

Name: \_\_\_\_\_

#### Instructions

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

#### Indication of Prior Knowledge

Have you had any formal teaching on this topic? Please indicate (✓).

Yes

No

If yes, when did this session take place? Please indicate (✓).

This week 

Tick(✓)

A week ago

A month ago

Last term

Last semester

Last year

If no, why not? Please indicate (✓).

I was absent on the day 

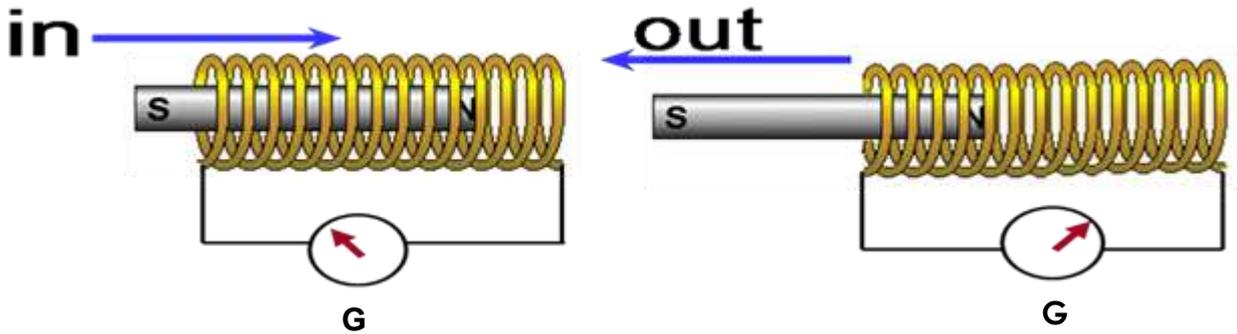
Tick(✓)

The topic has not yet been covered by teacher.

Other (specify in the space below):  
.....

**Question 1**

A magnet is moved into and out of a solenoid as shown in the diagram below:

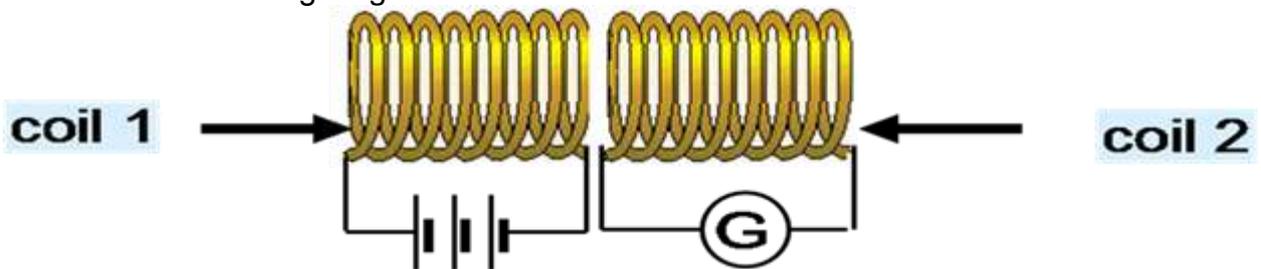


If the coil is connected to a closed circuit, an emf is induced in the circuit, therefore current flows in the circuit, as shown on the galvanometer, G.

- 1.1. What is this phenomenon called?  
.....
- 1.2. Describe the nature of the induced current.  
.....
- 1.3. Mention three ways in which the induced current can be increased.  
.....  
.....
- 1.4. Define the term magnetic flux.  
.....  
.....
- 1.5. State Faraday's Law of Electromagnetic Induction in words.  
.....  
.....

**Question 2**

Consider the following diagram:



When the current in coil 1 is switched on and off, a reading is seen on the galvanometer, which means that current flows in coil 2.

- 2.1. Name and define the phenomenon illustrated above.  
.....  
.....

2.2. Name three ways of strengthening the phenomenon shown above.

.....  
.....  
.....

2.3. A transformer is a device that makes use of this phenomenon to either increase and decrease the output voltage. What is the name given to Coil 1 and Coil 2 respectively.

Coil 1: .....

Coil 2: .....

**Question 3**

3.1. Name and describe the two types of transformers.

.....  
.....  
.....  
.....

3.2. The voltage produced by a power station is 25 000V. The transformer used to step this voltage up for the national grid has 200 turns on the primary and 3200 turns on the secondary coil. Calculate the voltage of the secondary coil.

.....  
.....  
.....  
.....

.....o0o.....

## Post-Test 6: Current Associated with a Magnetic Field

Name: \_\_\_\_\_

### Instructions

1. Answer all questions on the question paper.
2. Calculators may be used where necessary.

### Indication of Prior Knowledge

Have you attended the practical session on this topic? Please indicate (✓).

Yes

No

If your answer is **Yes**, when did this take place? Please indicate (✓).

This week 

Tick(✓)

A week ago 

--

A month ago 

--

Last term 

--

Last semester 

--

Last year 

--

If your answer is **No**, what is the reason? Please indicate (✓).

I was absent on the day. 

Tick(✓)

Other (specify in the space below):

.....

### Question 1

- 1.1. To obtain current in a coil by means of electromagnetic induction one needs
- A. a coil and a magnet
  - B. a coil, a magnet and a battery
  - C. a coil, a galvanometer and a magnet
  - D. a coil and a galvanometer

Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.2. A coil is situated in the magnetic field of a magnet. Current will be induced in the coil
- A. only when the magnet is moved.
  - B. only when the coil is moved.
  - C. if the coil and magnet are moved together.
  - D. if either the coil or the magnet is moved

Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.3. Current flowing in a primary coil can induce current in a secondary coil
- A. only when the current increases.
  - B. only when the current decreases.
  - C. only when the direction of the current is reversed.
  - D. as soon as there is any change at all in the current

Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.4. Two coils are placed next to each other. The one coil is connected to a battery and an open switch, the other is connected to a galvanometer. When the switch S is closed, the needle of the galvanometer moves to the right. If S is kept closed, the galvanometer needle will
- A. return to zero.
  - B. stay pointing to the right.
  - C. move over to the left.
  - D. move to and fro until the switch is opened.

Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.5. The ratio of the number of turns in the secondary coil to the number of turns in the primary coil of a transformer that changes 240V to 12V is
- A. 1:20
  - B. 20:1
  - C. 1:12
  - D. 12:1

Answer: .....

How sure are you of your answer?

Unsure

Sure

- 1.6. The following is an example of a step-down transformer
- A. 200 turns in the secondary coil and 50 turns in the primary coil.
  - B. 200 turns in the secondary coil and 200 turns in the primary coil.
  - C. a potential difference of 60V across the secondary coil and 12V across the primary.
  - D. a potential of 220V across the primary and 6V across the secondary.

Answer: .....

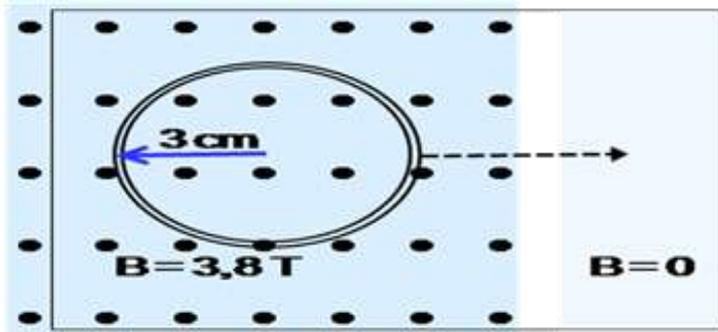
How sure are you of your answer?

Unsure

Sure

**Question 2**

- 2.1. A circular coil of radius 3cm contains 150 loops and is positioned perpendicular to a magnetic field of strength 3,8T. The coil is pulled from the field in 0,2s to a point where there is no magnetic field, as shown in the diagram below



Calculate

- 2.1.1. The change in magnetic flux in the coil.

.....  
 .....  
 .....

- 2.1.2. The induced emf in the coil.

.....  
 .....  
 .....

- 2.2. You are required to construct a step down transformer. It must step the voltage down from 240 V to 12 V. If there are 1000 turns on the primary coil, calculate how many turns there should be on the secondary coil.

.....  
 .....  
 .....

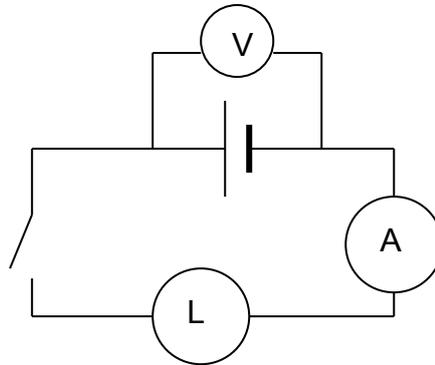
.....o0o.....

## APPENDIX N: ACTIVITY 1 - BASIC OF CURRENT ELECTRICITY

### Practical 1 : A simple circuit

1.1. You are supplied only with a torch cell, a bulb and a single piece of wire. Make the bulb shine. How many different times can you make this happen? Draw the arrangement in the space below.

1.2. Now use the circuit board supplied to build the simple circuit shown below.



1.3. Identify the different components (parts) of the circuit and the function of each component and record that information in the table below

Component	Function

1.4. Now disconnect any of the components of your circuit and record what happens.

.....

A **switch** is merely a thing that **opens** and **closes** a circuit. Electricity needs a complete pathway to flow. Substances that allow the current to flow through them are called **conductors**, while **insulators** are substances that do not allow electricity to flow through them.

### Voltmeters & Ammeters

A **VOLTMETER** is used to measure the amount of energy supplied by a cell or battery or the amount of energy received by the bulb or appliance. It is always connected in

**PARALLEL.**

An **AMMETER** is used to measure the amount of current that flows through a circuit and it is always connected in **SERIES**.

A voltmeter measures the energy difference per charge between two points in a circuit. If a charge gains energy as it passes through a cell or “loses” energy as it passes through an appliance then there will be a potential difference.

An ammeter measures how fast the charges move through the circuit. The rate of flow of charge past a point is called the current strength and is measured in amperes. The current flows from the positive terminal to the negative terminal.

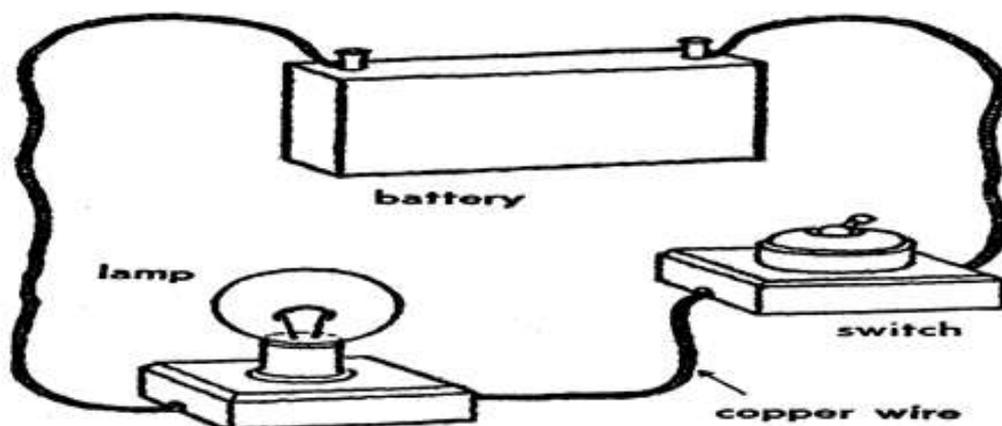
### Circuit diagrams

Scientists have developed a set of symbols for drawing circuit diagrams. These simplify the drawing and make it easier to interpret complicated circuits. Fill in the symbols in this table:

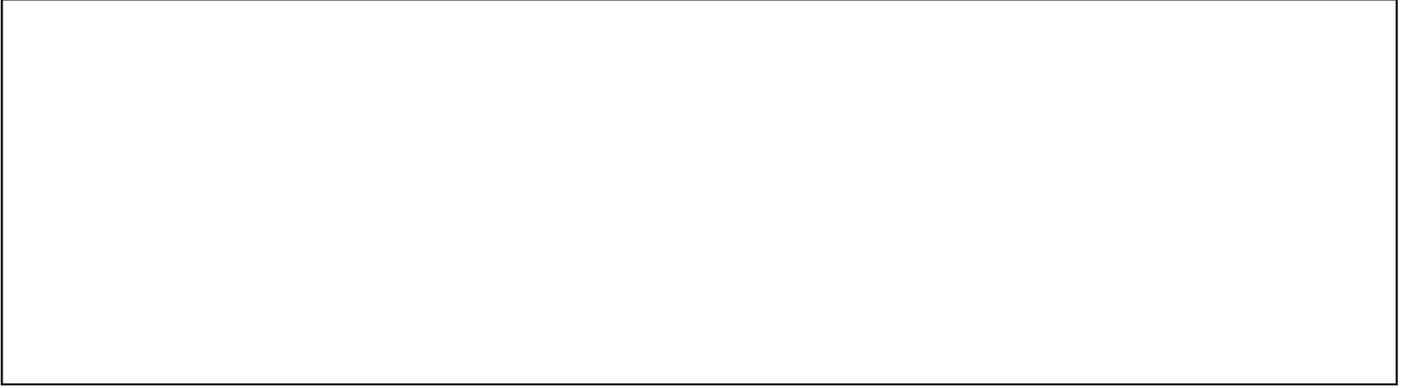
Component	Symbol
Cell	
Battery	
Open & closed switch	
Light bulb	
Resistor	
conductor	

### Activity 1

- Using the symbols in the table above, draw the circuit diagram for the circuit in the picture below. On the diagram indicate the direction of flow of conventional current.



## Circuit Diagram



### What is happening in a circuit?

Electric current is when **charges** move through a **wire**. They can only flow when the circuit is **closed**. The **cell / battery** gives the charges energy while the **light bulb** (or appliance) “uses” that energy. (The word “uses” is in inverted commas because energy is never used up but merely gets converted from one form to another). In the circuit you built in prac 1 : stored **chemical** potential energy (from the cell) is converted to **electrical** energy (in the wires) which is then converted to **light** and **heat** energy (in the light bulb).

## APPENDIX O: ACTIVITY 2: OHM'S LAW (EM1)

<p style="text-align: center;"><b>ACTIVITY EM.1</b> ELECTRICITY AND MAGNETISM</p>	<p style="text-align: center;"><b>AKTIWITEIT EM.1</b> ELEKTRISITEIT EN MAGNETISME</p>
<p style="text-align: center;"><b>Ohm's Law</b></p>	<p style="text-align: center;"><b>Ohm se Wet</b></p>
<p><i>Experiment file/ Eksperimentlêer</i> ACT EM.1</p>	
<p><b>Learning Outcome 1</b> Practical scientific inquiry and problem-solving skills</p> <p><b>Assessment Standard 1.1</b> Collect data regarding Ohm's law systematically with the emphasis on accuracy, reliability and the need to control one variable.</p> <p><b>Assessment Standard 1.2</b> Seek patterns and trends in the constructed potential difference versus current graphs in order to draw conclusions and formulate simple generalizations pertaining to Ohm's law.</p>	<p><b>Leeruitkoms 1</b> Praktiese wetenskaplike ondersoek- en probleem-oplossingsvaardighede.</p> <p><b>Asseseringstandaard 1.1</b> Versamel data met betrekking tot Ohm se wet met die klem op akkuraatheid, betroubaarheid en die noodsaak om een afhanklike te beheer.</p> <p><b>Asseseringstandaard 1.2</b> Identifiseer patrone en tendense in die getekende potensiaalverskil teen stroomsterkte grafieke ten einde gevolgtrekkings te maak en eenvoudige veralgemenings ten opsigte van Ohm se wet te formuleer.</p>
<p><b>Learning Outcome 2</b> Construct and apply scientific knowledge.</p> <p><b>Assessment Standard 2.2</b> Describe and explain prescribed knowledge of Ohm's law by accentuating the relationship between potential difference and current strength.</p> <p><b>Assessment Standard 2.3</b> Applying the knowledge of Ohm's law in familiar everyday contexts.</p>	<p><b>Leeruitkoms 2</b> Vertolking en toepassing van wetenskaplike kennis.</p> <p><b>Asseseringstandaard 2.2</b> Beskryf en verduidelik voorgeskrewe kennis van Ohm se wet deur die verwantskap tussen potensiaalverskil en stroomsterkte te beklemtoon.</p> <p><b>Asseseringstandaard 2.3</b> Pas die kennis ten opsigte van Ohm se wet in bekende alledaagse samehang toe.</p>
<p><b>Learning Outcome 3</b> The nature of science and its relationship to Technology, Society and the Environment.</p> <p><b>Assessment Standard 3.2</b> Discuss and describe the impact and inter-relationship of Ohm's law on socio-economic and human development.</p>	<p><b>Leeruitkoms 3</b> Die aard van wetenskap en die verband daarvan met Tegnologie, die Gemeenskap en Omgewing.</p> <p><b>Asseseringstandaard 3.2</b> Beskryf en verduidelik die invloed en onderlinge verwantskap van Ohm se wet op die sosio-ekonomiese en menslike ontwikkeling.</p>

**TOTAL MARK / TOTALE PUNT = 35 (+15 Science & Society) [50]**

## **SECTION A**

### **Electrical charge**

A positive charge means there are less electrons than protons present.

A negative charge means there are more electrons than protons present.

Symbol: Q

Unit : C

## **AFDELING A**

### **Elektriese lading**

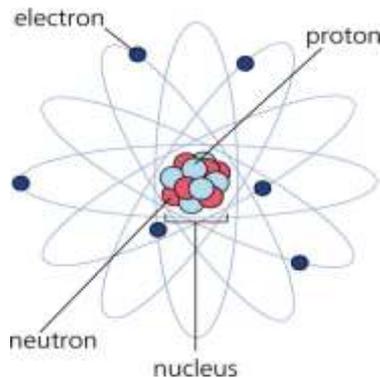
'n Positiewe lading beteken daar is minder elektrone as protone teenwoordig.

'n Negatiewe lading beteken daar is meer elektrone as protone teenwoordig.

Simbool: Q

Eenheid : C

### **Atom / Atoom**



### **Electric field**

The space around a charged object in which an electric charge would experience a force.

Symbol: E

Units: N.C<sup>-1</sup> or V.m<sup>-1</sup>

### **Elektriese veld**

Die ruimte rondom 'n gelaaiide voorwerp waarin 'n elektriese lading 'n krag sal ondervind.

Simbool: E

Eenhede: N.C<sup>-1</sup> of V.m<sup>-1</sup>

### **Mathematical formula/ Wiskundige formule**

$$E = \frac{F}{q} \quad \text{or/of} \quad E = \frac{V}{d}$$

### **Electric conductor**

A material that has free electrons that allows electrical current (charge) to flow relatively freely through it.

### **Insulators**

Materials that are not able to conduct an electric current (charge) due to a very high resistance.

### **Electrical current**

Electrical current is the flow of charge in a conductor when an electrical field is maintained within the conductor.

### **Current strength**

A measure of the rate at which charge passes a given point in a conductor. OR

A measure of the flow of charge past a point in an electric circuit in a given time.

Symbol: I

Unit : amperes (A)

### **Elektriese geleier**

'n Stof met vry elektrone wat elektriese stroom (lading) relatief vrylik toelaat om daardeur te vloei.

### **Isolators**

Materiaal wat nie in staat is om elektriese stroom (lading) te gelei nie as gevolg van 'n baie hoë weerstande.

### **Elektriese stroom**

Elektriese stroom is die vloei van lading deur 'n geleier wanneer 'n elektriese veld in die geleier gehandhaaf word.

### **Stroomsterkte**

Maatstaf van die tempo waarteen 'n lading verby 'n gegewe punt in 'n geleier vloei. OF

'n Maatstaf van die vloei van 'n lading verby 'n punt in 'n elektriese stroombaan binne 'n gegewe tydperk.

Simbool: I

Eenheid : A

$$Q = It \text{ or } I = \frac{Q}{t}$$

**Q** Charge in coulomb ( C )  
**I** Electrical current in ampere (A)  
**t** time in (s)

### Voltage or Potential Difference

The potential difference between any two points in a circuit is the amount of work done (or energy transferred) to move a charge from one point to another in a circuit.

Symbol: V

Unit : volts (V)

$$V = \frac{W}{Q}$$

**V** Potential difference in volts (V)  
**W** work or energy difference in joule (J)  
**Q** charge in coulomb ( C )

### Resistance

The electric property that impedes the flow of electric current in a conductor (circuit). OR

A measure of the ability of a material to oppose the flow of an electric current (charge) in a circuit.

The resistance is equal to the ratio of the potential difference (V) across the conductor, to the current strength (I) flowing through it.

Symbol: R

Unit : ohm ( $\Omega$ )

### Ohm's Law

The current strength between any two points in a conductor (resistor) is directly proportional to the potential difference between these points provided that the temperature of the conductor (resistor) remains constant.

### Mathematical relationship:

**$I \propto V$**  (if temperature of the resistor remains constant)

$$Q = It \text{ of } I = \frac{Q}{t}$$

**Q** *Lading* in coulomb ( C )  
**I** *Stroomsterkte* in ampere (A)  
**t** *tyd* in (s)

### Volt of potensiaalverskil

Die potensiaalverskil tussen enige twee punte in 'n stroombaan is die hoeveelheid werk verrig (of energie oorgedra) om 'n lading van een punt na 'n ander punt in 'n stroombaan te beweeg.

Simbool: V

Eenheid : V

$$V = \frac{W}{Q}$$

**V** *Potensiaalverskil* in volts (V)  
**W** *werk of verskil in energie* in joule (J)  
**Q** *lading* in coulomb ( C )

### Weerstand

Die elektriese eienskap wat die vloei van elektriese stroom in 'n geleier (stroombaan) vertraag. OF

'n Maatstaf van die vermoë van 'n stof om die vloei van 'n elektriese stroom (lading) in 'n stroombaan teen te werk.

Die weerstand is gelyk aan die verhouding van die potensiaalverskil (V) oor die geleier, tot die stroomsterkte (I) wat daarin vloei.

Simbool: R

Eenheid : ohm ( $\Omega$ )

### Ohm se wet

Die stroomsterkte tussen enige twee punte in 'n geleier (resistor) is direk eweredig aan die potensiaalverskil tussen die twee punte, mits die temperatuur van die geleier (resistor) konstant gehou word.

### Wiskundige verwantskap:

**$I \propto V$**  (indien die temperatuur van die resistor konstant bly)

### Mathematical equation/ Wiskundige vergelyking

$$V = IR \quad \text{or/of} \quad I = \frac{V}{R} \quad \text{or/of} \quad R = \frac{V}{I}$$

**R** Resistance in ohm ( $\Omega$ )  
**V** Potential difference in volts (V)  
**I** Current strength in ampere (A)

**R** *Weerstand* in ohm ( $\Omega$ )  
**V** *Potensiaalverskil* in volts (V)  
**I** *Stroomsterkte* in ampere (A)

## Ohm

The resistance of a conductor (resistor) is 1 ohm ( $\Omega$ ) when a potential difference of 1 volt causes a current of 1 ampere to flow in the conductor.

## Resistor

A component in an electric circuit used to provide resistance.

Electrical appliance in general refers to any resistor that can convert electrical energy into other forms of energy, e.g. an electric kettle converts electrical energy into heat energy.

## Ohmic and non-ohmic conductors

Ohmic conductors are materials for which Ohm's law holds true, e.g. silver, copper, aluminium, etc. Non-ohmic conductors do not obey Ohm's law, e.g. nichrome, tungsten, etc.

## Variables

A variable is physical amount that can be adjusted or changed quantitatively and/ or qualitatively in an experiment.

## Independent variables

The independent variable is the one you can change or manipulate in an experiment or investigation. The independent variable may be regarded as the cause/ source that produces/ induces an effect/ response.

It is usually indicated on the x-axis of a graph.

## Dependent variable

The dependant variable may be defined as the effect or result due to (in response to) the change (adjustment) in the independent variable.

The dependent variable changes as the independent variable is manipulated or changed.

This variable is indicated on the y-axis of a graph.

## Constant (controlled) variable

Only two variables viz. the independent variable and the dependent variable can be investigated at any one time in order to have a fair experiment or investigation.

The controlled or constant variables are all the other variables in an experiment that are kept constant in order not to influence the result of the investigation or experiment.

## Ohm

Die weerstand van 'n geleier (resistor) is 1 ohm ( $\Omega$ ) wanneer 'n potensiaalverskil van 1 volt veroorsaak dat 'n stroom van 1 ampère in die geleier vloei.

## Resistor

'n Komponent in 'n elektriese stroombaan wat gebruik word om 'n weerstand te voorsien.

Elektriese toestelle oor die algemeen verwys na enige resistor wat elektriese energie in ander vorms van energie kan omskep, bv. 'n elektriese ketel omskep elektriese energie in hitte energie.

## Ohmiese en nie-ohmiese geleiers

Ohmiese geleiers is materiaal wat Ohm se wet gehoorsaam, bv. silwer, koper, aluminium, ens. Nie-ohmiese geleiers gehoorsaam nie Ohm se wet nie, bv. nichroom, tungsten, ens.

## Veranderlikes

'n Veranderlike is 'n fisiese hoeveelheid wat kwantitatief en/ of kwalitatief in 'n eksperiment aangepas of verander kan word

## Onafhanklike veranderlike

Die onafhanklike veranderlike kan in 'n eksperiment of ondersoek verander of gemanipuleer word. Die onafhanklike veranderlike kan beskou word as die oorsaak/ bron wat 'n effek/ reaksie uitlok/ induseer.

Dit word gewoonlik op die x-as van 'n grafiek aangedui.

## Afhanklike veranderlike

Die afhanklike veranderlike kan as die effek of resultaat as gevolg van (in reaksie op) die verandering (aanpassing) in die onafhanklike veranderlike gedefinieer word. Die afhanklike veranderlike verander soos die onafhanklike veranderlike gemanipuleer of verander word.

Hierdie veranderlike word op die y-as van 'n grafiek aangedui.

## Gekontroleerde(konstante) veranderlike

Slegs twee veranderlikes nl. die onafhanklike en afhanklike veranderlike kan op een tyd ondersoek word om 'n betroubare eksperiment of ondersoek te kan hê.

Die gekontroleerde of konstante veranderlikes is al die ander veranderlikes in 'n eksperiment wat konstant gehou word ten einde nie die uitslag van die ondersoek of eksperiment te beïnvloed nie.

### Direct proportionality

Two variables are said to be directly proportional when a change brought about in the independent variable causes a **proportionally similar change in the same ratio** to occur in the dependent variable as long as all other variables remain constant. **OR**

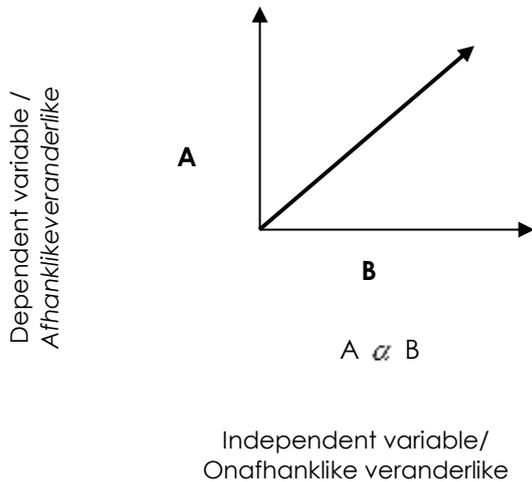
A relationship between an independent and a dependent variable of which the ratio is constant.

The shape of the graph is a straight line through the origin

### Inverse proportionality

Two variables are inversely proportional when a change brought about in the independent variable causes a **proportionally opposite change to occur in the same ratio** in the dependent variable while all other variables remain constant.

The shape of the graph is a hyperbola.



### Direkte eweredigheid

Twee veranderlikes is direk eweredig indien 'n verandering in die onafhanklike veranderlike 'n **soortgelyke eweredige verandering met dieselfde verhoudingsgetal** in die afhanklike veranderlike teweeg bring terwyl al die ander veranderlikes konstant bly. **OF**

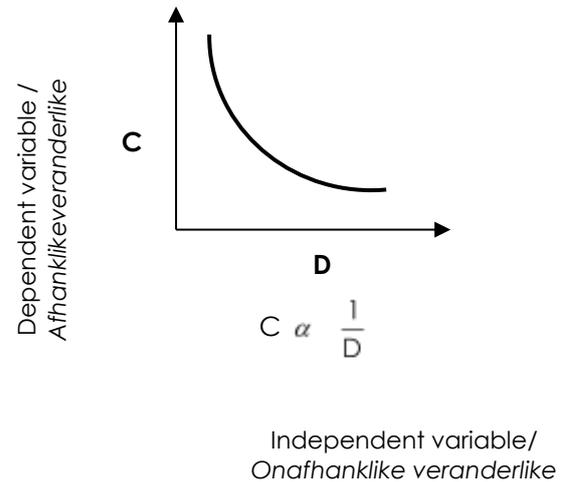
'n Verwantskap tussen 'n onafhanklike en 'n afhanklike veranderlike waarvan die verhouding konstant is.

Die vorm van die grafiek is 'n reguitlyn deur die oorsprong

### Omgekeerde eweredigheid

Twee veranderlikes is omgekeerd eweredig wanneer 'n verandering in die onafhanklike veranderlike 'n **eweredige teenoorgestelde verandering met dieselfde verhoudingsgetal** in die afhanklike veranderlike veroorsaak terwyl al die ander veranderlikes konstant bly.

Die vorm van die grafiek is 'n hiperbool.

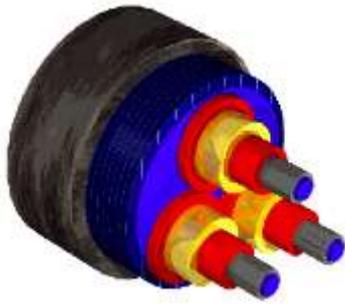


### PRACTICAL APPLICATIONS

- Pure metals are usually good conductors of electricity because of a low resistance (in the order of  $10^{-8}$  to  $10^{-6}$  ohm per meter) and are therefore, used as electric wiring in electric circuits to prevent energy being wasted as heat.
- Insulators such as porcelain and mica are mostly non-metals and have a very high resistance (in the order of  $10^8$  to  $10^{16}$  ohm per meter). They are used to insulate electrical conductors.
- Between the two extremes lie the very important group of materials called semiconductors like Germanium and Silicon, which is used extensively in the micro-electronic industry for the manufacturing of transistors, integrated circuits, etc.  
They have resistance of about 1 to 2000 ohm per meter.

### PRAKTIESE TOEPASSING

- Suiwer metale is gewoonlik baie goeie geleiers van elektrisiteit as gevolg van 'n lae weerstande (in die orde van  $10^{-8}$  tot  $10^{-6}$  ohm per meter) en word dus as elektriese bedrading in stroombane gebruik om energieverlies in die vorm van hitte te beperk.
- Isolator soos porselein en mika is meestal nie-metale en het 'n baie hoë weerstand (in die orde van  $10^8$  tot  $10^{16}$  ohm per meter). Hulle word gebruik om elektriese geleiers te isoleer.
- Tussen die twee uiterstes is daar 'n belangrike groep materiale, die halfgeleiers, bv. Germanium en Silikon, wat in die mikro-elektroniese nywerheid gebruik word vir die vervaardiging van transistors, geïntegreerde stroombane, ens. Dit het 'n weerstand van ongeveer 1 tot 2000 ohm per meter.



Insulated electrical cable  
Geïsoleerde elektriese kabel



Transistor

## ACTIVITY EM.1 ELECTRICITY AND MAGNETISM

### Ohm's Law

## AKTIWITEIT EM.1 ELEKTRISITEIT EN MAGNETISME

### Ohm se Wet

NAME  
NAAM

DATE  
DATUM

GRADE  
GRAAD

#### SECTION B

Preparation of the experiment

#### List of equipment

- Vernier Current & Voltage Probes
- Adjustable DC power supply or 4 size "D" torch cells and cell holder
- Electrical connecting wires
- Two suitable resistors (between  $12 \Omega$  and  $50 \Omega$ ) (10 W)
- Light bulb (6 V)

#### Precautions

- Take care that the positive lead from the power supply and the red terminal from the Current & Voltage Probe are correctly connected.
- The power capacity of the resistor should be high enough so that it does not overheat. A rating of 10 W is recommended.

**(Colour coded resistors work well)**

#### AFDELING B

Vorbereiding van die eksperiment

#### Lys van benodigdhede

- Vernier "Stroom –en Spanningsensors"
- Verstelbare gelykstrom kragbron of 4 "D" grootte flits-selle en selhouer.
- Elektriese geleidingsdrade
- Twee geskikte weerstande (tussen  $12 \Omega$  en  $50 \Omega$ ) 10W
- Gloeilampie (6 V)

#### Voorsorgmaatreëls

- Maak seker dat die positiewe draad van die kragbron en die rooi terminaal van die "Current & Voltage Probe" korrek gekoppel is.
- Die drywing van die weerstand moet hoog genoeg wees sodat dit nie oorverhit nie. 'n Waarde van 10 W word aanbeveel.

**(Kleurkode resistore werk goed)**

#### SECTION C

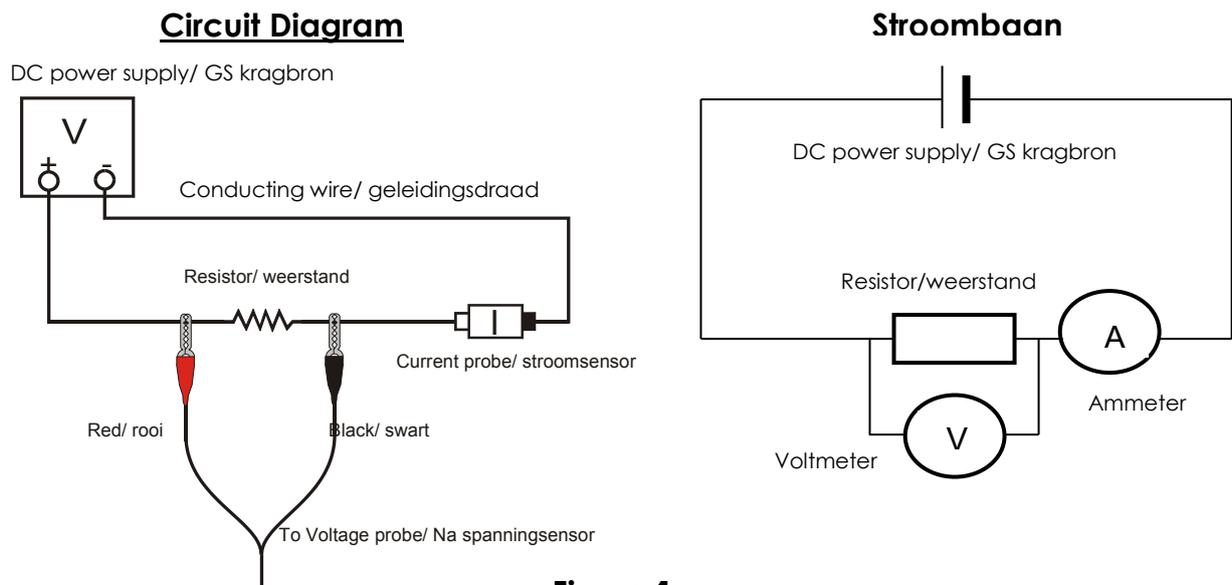
Executing the experiment

#### Experimental set up

#### AFDELING C

Uitvoer van die eksperiment

#### Eksperimentele opstelling



**Figure 1**

### Procedure

- Open the folder EM.1.
- A graph of potential difference vs. current will be displayed on the screen. The vertical axis is scaled from 0 to 0.4 A. The horizontal axis is scaled from 0 to 6 V. The meter window displays potential and current readings.
- Connect the Current and Voltage Probe to the LabPro interface.
- With the power supply turned off (or the circuit open), connect the power supply (or cells), to the first resistor, wires, current and voltage probes as shown in Figure 1. with the red connectors electrically linked to the positive side of the power supply.
- Have your teacher check the circuit before proceeding.

### Using the DC power supply unit

- On the "Experiment" menu, click "ZERO" or click **Zero** on the toolbar.
- A dialog box will appear. Tick both sensors and then click OK. This will set both probes on zero with no current flowing and with no voltage applied.
- Turn the control on the DC power supply to 0 V and then turn on the power supply.
- Make sure the power supply is set to 0 V. Click  to begin data collection. Click  to record the zero value.
- Increase the voltage on the power supply to the next increment reading. When the readings are stable click .
- Repeat this procedure three more times until you reach a voltage of 6.0 V.

### Prosedure

- Open die lêer EM.1
- 'n Grafiek van potensiaalverskil teenoor stroom sal op die skerm verskyn. Die vertikale as is vanaf 0 tot 0.4 A en die horisontale as vanaf 0 tot 6 V gekalibreer. Die metervenster sal beide potensiaalverskil- en stroomlesings aantoon.
- Verbind die "Current en Voltage Probe" aan die "LabPro-koppelvlak".
- Met die kragbron afgeskakel (of die stroombaam oop), verbind die kragbron (of selle), die resistor, geleidingsdrade, "Stroom -en Spanningsensors" soos in Figuur 1 met die rooi knypers elektries aan die positiewe kant van die kragbron gekoppel.
- Laat die onderwyser(es) die stroombaam nagaan voordat met die eksperiment voortgegaan word.

### Vir gebruik met die GS-kragbron

- Klik ZERO op die "Experiment menu" of klik **Zero** op die "toolbar".
- 'n Dialoogvenster sal verskyn. Merk beide sensors en klik dan OK. Dit sal beide die sensors op zero instel sonder stroom wat vloei en potensiaalverskil wat aangewend word.
- Verstel die GS-kragbron na 0 V en skakel die kragbron aan.
- Maak seker die kragbron is op 0 V gestel. Klik op  om data-insameling te begin. Klik op  om die zero-lesing te registreer.
- Verhoog die potensiaalverskil tot 'n volgende lesing. Klik op  sodra die lesings stabiliseer.
- Herhaal hierdie prosedure nog drie keer totdat die voltmeter-lesing 6.0 V bereik.

- Click  and set the power supply back to 0 V and switch it off. On the experiment menu, click "Store Latest Run".
- Repeat the same procedure using the second resistor and then the light bulb.

**Using torch cells**

- Place one cell in the cell holder but keep the circuit open.
- On the "Experiment" menu, click "ZERO" or click  on the toolbar.
- A dialog box will appear. Tick both sensors and then click OK. This will set both probes on zero with no current flowing and with no voltage applied.
- Click  to start data collection. Click  to record the zero value.
- Close the circuit containing only the one cell. Click  when the reading is stable.
- Increase the potential difference by adding a cell. Close the circuit and again click  when the reading stabilizes.
- Repeat the procedure two more times, each time adding a cell to the circuit.
- Click  and open the circuit.
- Click "Store latest run" on the "Experiment" menu.
- Repeat the same procedure using the second resistor and then the light bulb.

- Klik op  en stel die kragbron terug na 0 V en skakel dit dan af. Klik 'store latest run' op die 'experiment menu'.
- Herhaal die prosedure vir 'n tweede weerstand en die gloeilampie.

**Vir gebruik met flits-selle**

- Plaas 'n sel in die selhouer maar hou die stroombaan oop.
- Klik ZERO op die "Experiment menu" of klik  op die "toolbar".
- 'n Dialoogvenster sal verskyn. Merk beide sensors en klik dan OK. Dit sal beide die sensors op zero instel sonder stroom wat vloei en potensiaalverskil wat aangewend word .
- Klik op  om data-insameling te begin. Klik op  om die zero-lesing te registreer.
- Sluit die stroombaan wat slegs een sel bevat. Klik op  sodra die lesings stabiliseer.
- Voeg nog 'n sel in die stroombaan om die potensiaalverskil te verhoog. Sluit die stroombaan en klik op  sodra die lesings stabiliseer.
- Herhaal die prosedure nog twee keer en voeg elke keer nog 'n sel tot die stroombaan.
- Klik  en open die stroombaan.
- Klik "Store latest run" op die "Experiment menu".
- Herhaal dieselfde prosedure vir die tweede resistor en die gloeilampie.

**Question 1**

Record your results in the following table (see attached rubric).

**Table 1 / Tabel 1**

**Vraag 1**

1.1 Skryf jou resultate in die volgende tabel neer (sien aangehegte rubriek).

	Potential Difference Potensiaalverskil (V)	Current Stroom (I)	Constant Konstante ( $\frac{V}{I}$ )
<b>Resistor 1</b> ____ $\Omega$			
<b>Average value/ Gemiddelde waarde</b>			
<b>Resistor 2</b> ____ $\Omega$			
<b>Average value/ Gemiddelde waarde</b>			
<b>Light Bulb</b>			

Gloeilampie			

**Table Rubric**

	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>X</b>
Table Tabel	<ul style="list-style-type: none"> <li>All columns and rows completely filled in / Alle kolomme en rye volledig voltooi</li> <li>All resistor values indicated / Alle resistorwaardes aangedui</li> <li>V/I correctly calculated / Die berekening vir V/I is korrek</li> <li>Values accurate i.e. V/I constant. / Waardes is korrek maw. V/I is konstant</li> </ul>	3 of 4	2 of 4	1 of 4	Not attempted/ Geen poging aangewend

(4)

- 1.1. Name the:  
 1.1.1. dependant,  
 1.1.2. independent and  
 1.1.3. constant variables.

- 1.1. Gee die:  
 1.1.1. afhanklike veranderlike  
 1.1.2. onafhanklike veranderlike  
 1.1.3. konstante veranderlike.

(3)

- Study the graphs. Click the Linear Fit button,  to determine the mathematical relationship between the potential difference and the current strength. (See question 2.4).

- Bestudeer die grafieke. Klik op die liniêre regressieknoppie,  om die wiskundige verwantskap tussen potensiaalverskil en stroomsterkte te bepaal. (Sien vraag 2.4).

**Question 2**

- 2.1 Compare the slopes of the two straight line graphs to the real values of the resistors. Prove your answers with calculations.

**Vraag 2**

- 2.1 Vergelyk die hellings van die grafieke met die werklike waarde van die resistor. Staaf jou antwoord met berekeninge.

(5)

- 2.2. As the potential difference across the resistor is increased, what happens to the current flowing through the resistor?

- 2.2. Wat gebeur met die stroom wat deur die resistor vloei as die potensiaalverskil oor die resistor toeneem?

(2)

- 2.3. If the voltage is doubled, what would happen to the current strength?

- 2.3. Wat sal met die stroomsterkte gebeur as die potensiaalverskil verdubbel?

(2)

- |  |   |
|--|---|
| <p>2.4. Describe the relationship that exists between potential difference and current strength in words and then express it mathematically (i.e. in symbols).</p> | <p>2.4. Beskryf die verwantskap tussen potensiaalverskil en die stroomsterkte in woorde en druk dit dan wiskundig (in simbole) uit.</p> |
|--|---|

(2)

**Question 3**

- 3.1. State your observations regarding the light bulb with reference to:
- 3.1.1. the relationship between the potential difference and the brightness of the bulb;

**Vraag 3**

- 3.1. Stel jou waarneming aangaande die gloeilampie met betrekking tot:
- 3.1.1. die verband tussen potensiaalverskil en die helderheid van die lampie;

(2)

- |  |  |
|--|--|
| <p>3.1.2. the shape of the graph formed by the light bulb.</p> | <p>3.1.2. die vorm van die grafiek wat deur die gloeilampie gevorm is.</p> |
|--|--|

(2)

- |   |   |
|---|---|
| <p>3.2. Explain the behavior of the light bulb in terms of Ohm's Law.</p> | <p>3.2. Verduidelik die gedrag van die gloeilampie in terme van Ohm se Wet.</p> |
|---|---|

(3)

**Question 4**

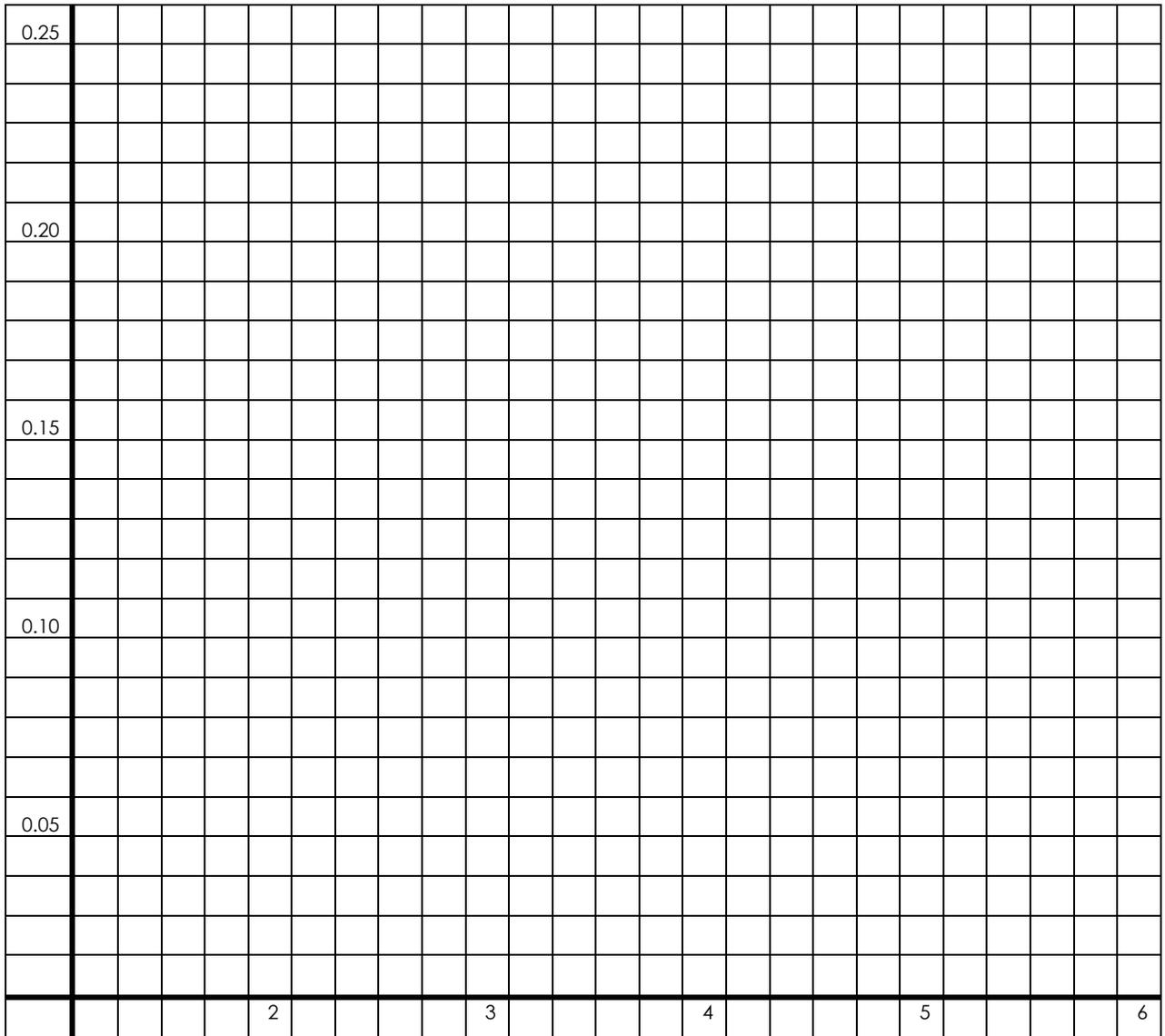
- 4.1 Use the following data and draw a potential difference vs. current strength graph. (See attached Rubric)

**Vraag 4**

- 4.1 Gebruik die volgende data en trek 'n grafiek van potensiaalverskil teenoor stroomsterkte. (Sien aangehegte rubriek)

Potential difference / Potensiaalverskil (V)	Current strength / Stroomsterkte (I)
0	0
0,4	0,02
0,6	0,03
1	0,05
2	0,1
3,5	0,175
5	0,25

Title / Titel \_\_\_\_\_



**Graph Rubric**

	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>X</b>
Graph Plotting Teken van Grafiek	<ul style="list-style-type: none"> <li>• Correct title / Korrekte titel</li> <li>• Both axes labeled correctly / Korrekte byskrifte vir beide asse</li> <li>• Coordinates correctly plotted / koördinate korrek aangedui</li> <li>• Coordinates joined correctly / koördinate korrek verbind</li> <li>• Variables plotted on the appropriate axes/ Veranderlikes met die korrekte asse geassosieer</li> <li>• All units included / alle eenhede ingesluit</li> </ul>	4 – 5 of 6	2 – 3 of 6	1 of 6	No attempt Geen poging aangewend

(4)

4.2 Use your graph and calculate the resistance of the resistor.

4.2 Gebruik jou grafiek en bepaal die weerstand van die resistor.

(3)

4.3. Determine the current strength if the potential difference is 1.5V. Show on the graph how you determined the value.

4.3 Bepaal die stroomsterkte as die potensiaalverskil 1.5.V is. Dui op die grafiek aan hoe jy die waarde bepaal het.

(3)

4.4. What would the potential difference be if the current strength is 0.14A? Show on the graph how you determined the value.

4.4. Wat sal die potensiaalverskil wees as die stroomsterkte 0.14 A is? Dui op die grafiek aan hoe jy die waarde bepaal het.

(3)

## SCIENCE AND SOCIETY

### Question 5

Discuss the following questions in your groups

5.1 Which resource is used as the main source of electricity in SA?

## WETENSKAP EN DIE SAMELEWING

### Vraag 5

Besprek die volgende vrae in julle groepe

5.1 Watter hulpbron word as hoofbron van elektrisiteit in SA gebruik?

(1)

5.2 Is it a renewable or a non-renewable resource? Explain the difference.

5.2 Is dit 'n hernubare of nie-hernubare bron. Verduidelik die verskil tussen die begrippe.

(4)

5.3 Discuss at least two advantages and two disadvantages of using this resource.

5.3 Besprek ten minste twee voordele en twee nadele van die gebruik van die hulpbron.

(4)

5.4 Suggest at least one alternative to the source mentioned in 5.1. and give at least two reasons to motivate your suggestion.

5.4 Stel ten minste een alternatiewe bron vir die bron in 5.1 genoem voor en gee twee redes vir jou voorstel.

(3)

## **APPENDIX P: ACTIVITY 3 - SERIES AND PARALLEL CONNECTIONS PRACTICAL**

Construct, using the circuit board given and then draw the following circuits:

1. Two cells in series:
2. Two cells in parallel:
3. Two bulbs in series:
4. Two bulbs in parallel:
5. Two cells in series, connected to two bulbs in series and a switch (open), an ammeter in series and a voltmeter across one bulb.
6. Two cells in parallel, connected to two bulbs in parallel and a switch (open), an ammeter in series and a voltmeter across the cells.
7. Two cells in series connected to two bulbs in parallel, a switch, an ammeter in series and a voltmeter across the one bulb.

### **SERIES AND PARALLEL CONNECTIONS PRACTICAL**

Construct, using the circuit board given and then draw the following circuits:

1. Two cells in series:

2. Two cells in parallel:
  
3. Two bulbs in series:
  
4. Two bulbs in parallel:
  
5. Two cells in series, connected to two bulbs in series and a switch (open), an ammeter in series and a voltmeter across one bulb.
  
6. Two cells in parallel, connected to two bulbs in parallel and a switch (open), an ammeter in series and a voltmeter across the cells.
  
7. Two cells in series connected to two bulbs in parallel, a switch, an ammeter in series and a voltmeter across the one bulb.

## APPENDIX P: ACTIVITY 4 – SERIES AND PARALLEL CIRCUITS (EM2)

<p style="text-align: center;"><b>ACTIVITY EM.2</b> ELECTRICITY AND MAGNETISM</p>	<p style="text-align: center;"><b>AKTIWITEIT EM.2</b> ELEKTRISITEIT EN MAGNETISME</p>
<p style="text-align: center;"><b>Series and Parallel connections</b></p>	<p style="text-align: center;"><b>Serie en Parallele skakelings</b></p>
<p>Experiment file/ Eksperimentleërs ACT EM.2</p>	
<p><b>Learning Outcome 1</b> Practical scientific inquiry and problem-solving skills</p> <p><b>Assessment Standard 1.1</b> Collect data systematically with regard to accuracy, reliability and the need to control one variable using circuits with resistors connected in series and in parallel.</p> <p><b>Assessment Standard 1.3</b> Interpret patterns and trends in collected data in order to analyze and represent them in different ways to draw conclusions, formulate simple generalizations with regard to the relationship between potential difference and current strength when resistors are connected in series and in parallel.</p>	<p><b>Leeruitkoms 1</b> Praktiese wetenskaplike ondersoek- en probleem-oplossingsvaardighede.</p> <p><b>Asseseringstandaard 1.1</b> Kollekteer data m.b.t. akkuraatheid, betroubaarheid en die noodsaak om een afhanklike te beheer deur van stroombane, waarin resistors in serie en parallel geskakel is, gebruik te maak.</p> <p><b>Asseseringstandaard 1.3</b> Vertolk patrone en tendense in gekollekteerde inligting om die data te analiseer en op verskillende wyse voor te stel om gevolgtrekkings te kan maak en eenvoudige veralgemenings te kan formuleer t.a.v. die verhouding tussen potensiaalverskil en stroomsterkte wanneer resistors in serie en parallel geskakel is.</p>
<p><b>Learning Outcome 2</b> Construct and apply scientific knowledge.</p> <p><b>Assessment Standard 2.1</b> Record and discuss basic prescribed scientific knowledge regarding resistors connected in series and in parallel.</p> <p><b>Assessment Standard 2.3</b> Apply the knowledge of resistors connected in series and in parallel in ordinary everyday contexts.</p>	<p><b>Leeruitkoms 2</b> Vertolking en toepassing van wetenskaplike kennis.</p> <p><b>Asseseringstandaard 2.1</b> Omskryf en bespreek basiese voorgeskrewe wetenskaplike kennis rakende resistors wat in serie en parallel geskakel is.</p> <p><b>Asseseringstandaard 2.3</b> Pas die kennis van resistors in serie en in parallel geskakel in bekende alledaagse konteks toe.</p>
<p><b>Learning Outcome 3</b> The nature of science and its relationship to Technology, Society and the Environment.</p> <p><b>Assessment Standard 3.2</b> Discuss and describe the interrelationship and impact of resistors in series and in parallel on socio-economic and human development.</p>	<p><b>Leeruitkoms 3</b> Die aard van wetenskap en die verband daarvan met Tegnologie, die Gemeenskap en Omgewing.</p> <p><b>Asseseringstandaard 3.2</b> Beskryf en verduidelik die onderlinge verwantskap en impak van resistors in serie en parallel op die sosio-ekonomiese en menslike ontwikkeling.</p>

**TOTAL MARK / TOTALE PUNT = 50**

## SECTION A

### **Electrical current**

Electrical current is the flow of charge in a conductor when an electrical field is maintained within the conductor.

### **Current strength**

A measure of the rate at which charge passes a given point in a conductor. OR

A measure of the flow of charge past a point in an electric circuit in a given time.

Symbol: I

Unit : amperes (A)

$$Q = It \text{ or } I = \frac{Q}{t}$$

Q Charge in coulomb ( C )

I Electrical current in ampere (A)

t time in (s)

### **Ammeter**

An instrument with a very low internal resistance that measures current strength and is always connected in series.



### **Voltage or Potential Difference**

The potential difference between any two points in a circuit is the amount of work done (or energy transferred) to move a charge from one point in a circuit to another.

Symbol: V

Unit : volts (V)

$$V = \frac{W}{Q}$$

V Potential difference in volts (V)

W work or energy difference in joule (J)

Q charge in coulomb ( C )

## AFDELING A

### **Elektriese stroom**

Elektriese stroom is die vloeï van lading deur 'n geleier wanneer 'n elektriese veld in die geleier gehandhaaf word.

### **Stroomsterkte**

Maatstaf van die tempo waarteen 'n lading verby 'n gegewe punt in 'n geleier vloei. OF

'n Maatstaf van die vloeï van 'n lading verby 'n punt in 'n elektriese stroombaan binne 'n gegewe tydperk.

Simbool: I

Eenheid : A

$$Q = It \text{ of } I = \frac{Q}{t}$$

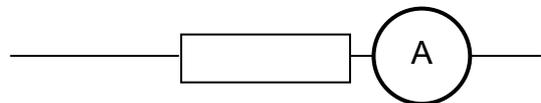
Q Lading in coulomb ( C )

I Stroomsterkte in ampere (A)

t tyd in (s)

### **Ammeter**

'n Instrument met 'n baie lae interne weerstand wat gebruik word om stroomsterkte te meet en wat altyd in serie geskakel word.



### **Volt of potensiaalverskil**

Die potensiaalverskil tussen enige twee punte in 'n stroombaan is die hoeveelheid werk verrig (of energie oorgedra) om 'n lading van een punt na 'n ander punt in 'n stroombaan te beweeg.

Simbool: V

Eenheid : V

$$V = \frac{W}{Q}$$

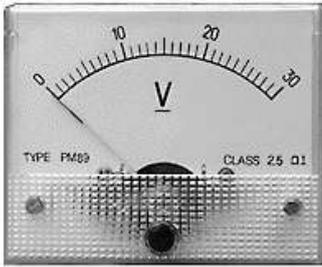
V Potensiaalverskil in volts (V)

W werk of verskil in energie in joule (J)

Q lading in coulomb ( C )

### Voltmeter

An instrument with a high resistance that measures potential difference and is always connected in parallel in a circuit.



### Resistance

The electric property that impedes the flow of electric current in a conductor (circuit). OR A measure of the ability of a material to oppose the flow of an electric current (charge) in a circuit.

The resistance is equal to the ratio of the potential difference (V) across the conductor, to the current strength (I) flowing through it.

Symbol: R

Unit : ohm (Ω)

### Ohm's Law

The current strength between any two points in a conductor (resistor) is directly proportional to the potential difference between these points provided that the temperature of the conductor (resistor) remains constant.

### Mathematical relationship:

$I \propto V$  (if temperature of the resistor remains constant)

### Mathematical equation/ Wiskundige vergelyking

$$V = IR \quad \text{or/of} \quad I = \frac{V}{R} \quad \text{or/of} \quad R = \frac{V}{I}$$

**R** Resistance in ohm (Ω)

**V** Potential difference in volts (V)

**I** Current strength in ampere (A)

### Ohm

The resistance of a conductor (resistor) is 1 ohm (Ω) when a potential difference of 1 volt causes a current of 1 ampere to flow in the conductor.

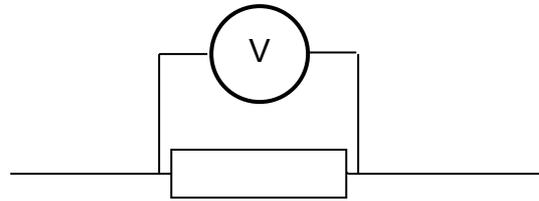
### Resistor

A component in an electric circuit used to provide resistance against the flow of electric current.

Resistors are manufactured such that their resistance value lies within a tolerance. Tolerance

### Voltmeter

'n Instrument met 'n hoë weerstand wat gebruik word om potensiaalverskil te meet en wat altyd in parallel geskakel word.



### Weerstand

Die elektriese eienskap wat die vloei van elektriese stroom in 'n geleier (stroombaan) vertraag. OF

'n Maatstaf van die vermoë van 'n stof om die vloei van 'n elektriese stroom (lading) in 'n stroombaan teen te werk.

Die weerstand is gelyk aan die verhouding van die potensiaalverskil (V) oor die geleier, tot die stroomsterkte (I) wat daarin vloei.

Simbool: R

Eenheid : ohm (Ω)

### Ohm se wet

Die stroomsterkte tussen enige twee punte in 'n geleier (resistor) is direk eweredig aan die potensiaalverskil tussen die twee punte, mits die temperatuur van die geleier (resistor) konstant gehou word.

### Wiskundige verwantskap:

$I \propto V$  (indien die temperatuur van die resistor konstant bly)

**R** Weerstand in ohm (Ω)

**V** Potensiaalverskil in volts (V)

**I** Stroomsterkte in ampere (A)

### Ohm

Die weerstand van 'n geleier (resistor) is 1 ohm (Ω) wanneer 'n potensiaalverskil van 1 volt veroorsaak dat 'n stroom van 1 ampère in die geleier vloei.

### Resistor

'n Komponent in 'n elektriese stroombaan wat gebruik word om 'n weerstand teen elektriese stroom te bied.

Resistors word vervaardig sodat hulle weerstandswaarde binne 'n toleransie val. Toleransie is 'n

is a percentage rating, showing how much the resistance is allowed to vary from the actual value. This percentage rating is either labeled as a number or indicated with a colour code on the resistor.

E.g. A 5% tolerance means that the resistor could have a value with a  $\pm 5\%$  play of the actual value. A  $20\Omega$  resistor could therefore, have a value between  $19\Omega$  and  $21\Omega$ .

### Series circuit

Resistors are in series when they are connected in a chain end to end so that there is only one pathway for the current to follow. The total current flows through each resistor in turn.

The current strength is the same at every point in the circuit.

Resistors in series are potential dividers as each resistor gets a proportional share of the potential.

persentasieskatting wat aandui hoeveel die weerstand toegelaat is om van sy werklike waarde af te wyk. Hierdie persentasieskatting word op die resistor of as 'n getal of deur middel van 'n kleurkode aangedui.

Bv. 'n 5% toleransie beteken dat die resistor 'n waarde met 'n speling van  $\pm 5\%$  van die werklike waarde kan hê. 'n  $20\Omega$  resistor kan dus 'n waarde tussen  $19\Omega$  en  $21\Omega$  hê.

### Seriestroombaan

Resistors is in serie as hulle in 'n ketting punt aan punt gekoppel is sodat daar slegs een roete vir die stroom is om deur te vloei. Die totale stroom vloei om die beurt deur elke resistor.

Die stroomsterkte in die stroombaan is oral dieselfde.

Resistors in serie is potensiaalverdelers aangesien elke resistor 'n eweredige deel van die potensiaal ontvang.

### Resistors connected in series / Resistors in serie geskakel

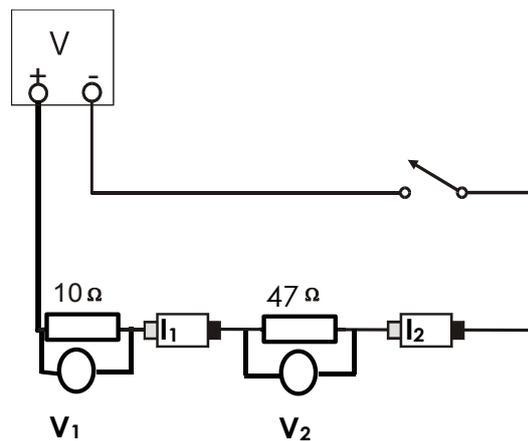
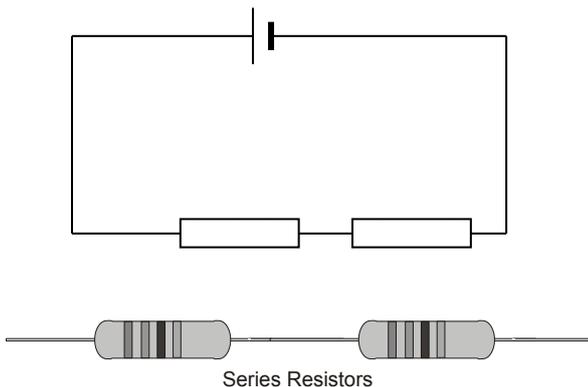


Fig 1

$$R_{eff} = R_1 + R_2$$

$$V_T = V_1 + V_2$$

$$I_T = I_1 = I_2$$

$$V_T = IR_{eff}$$

$$V_1 = IR_1$$

$$V_2 = IR_2$$

### Parallel circuit

Resistors are in parallel when each are connected side-by-side between the same two points in a circuit so that there is more than one pathway for the current to flow through.

Each resistor carries its own current strength which differs if the resistors are not the same.

The total current strength entering or leaving a parallel resistor combination is equal to the sum of the individual current strengths in each parallel resistors.

Resistors in parallel are current dividers as each resistor receives a proportional share of the total

### Parallele stroombaan

Resistors is parallel indien elkeen sy-aan-sy tussen dieselfde twee punte in 'n stroombaan geskakel is sodat daar meer as een roete vir die stroom is om in te vloei.

Elke resistor dra sy eie stroomsterkte wat verskil indien die resistors verskil.

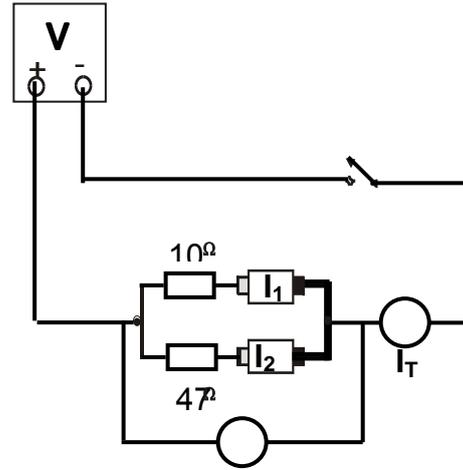
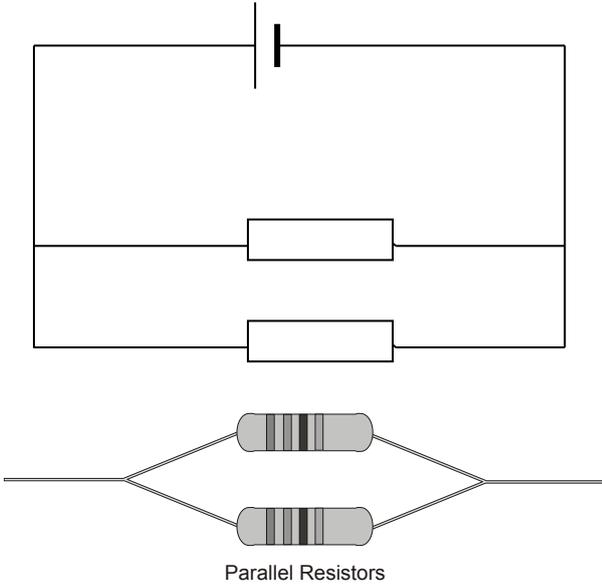
Die totale stroomsterkte wat die resistors in 'n parallele kombinasie binnevloei of verlaat is gelyk aan die som van die individuele stroomsterktes in elke parallele resistor.

Resistors in parallel is stroomverdelers aangesien elke resistor 'n eweredige deel van die totale

current.

stroomsterkte ontvang.

**Resistors connected in parallel/ Resistors in parallel geskakel**



**Fig 2**

$$1/R_{\text{eff}} = 1/R_1 + 1/R_2$$

$$V_T = V_1 = V_2$$

$$I_T = I_1 + I_2$$

$$V_T = I_T R_{\text{eff}}$$

$$V_1 = I_1 R_1$$

$$V_2 = I_2 R_2$$

**PRACTICAL APPLICATIONS**

1. The small decorative lights on a Christmas tree often consist of small bulbs which are connected in series so that they can be switched on and off by one special bulb in the circuit. If one of the bulbs fuses none of the others will burn because the circuit will be broken.
2. The electrical appliances in a house are connected in parallel and each one operates independently from the others. If one of the appliances does not function it will not influence the performance of the others.

**PRAKTIESE TOEPASSINGS**

1. Die klein sierliggies op 'n kersboom bestaan gewoonlik uit klein gloeilampies wat in serie geskakel is sodat hulle aan- en afgeskakel kan word met behulp van 'n spesiale lampie in die stroombaan. Indien enige een van die lampies uitbrand, sal nie een van die ander brand nie aangesien die stroombaan gebreek is.
2. Die elektriese toebehore in 'n huis word parallel gekoppel en elkeen werk onafhanklik van die ander. Indien een van die toestelle nie funksioneer nie sal dit nie die ander se werkverrigting beïnvloed nie.

## ACTIVITY EM.2

### ELECTRICITY AND MAGNETISM

#### Series and Parallel connections

## AKTIWITEIT EM.2

### ELEKTRISITEIT EN MAGNETISME

#### Serie en Parallele skakeling

NAME  
NAAM

DATE  
DATUM

GRADE  
GRAAD

#### SECTION B

##### Introductory activities:

###### Colour coded resistor

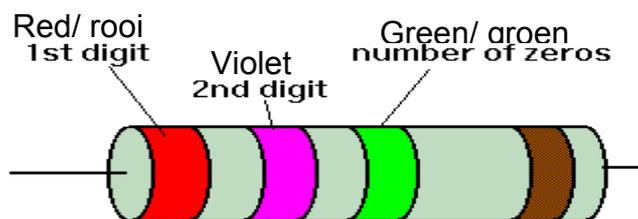
- Ignore the colour of the resistor body and concentrate on the colour bands.
- Most resistors have three colour bands close together at one end and one single band at the other.
- The three adjacent bands give the resistor value.
- The colour band nearest the wire lead gives the value of the first digit. e.g. Brown = 1.
- The next band gives the value of the next digit e.g. red = 2
- The third band gives the number of zeros which follow the two digits. e.g. orange = 3 zeros = 000.
- Therefore a resistor with brown, red, orange bands would have a value of 12000 ohms.

#### AFDELING B

##### Inleidende aktiwiteite:

###### Resistor met kleurkodes

- Ignoreer die kleur van die resistor en konsentreer op die kleurbande.
- Meeste resistors het drie kleurbande naby mekaar aan een kant en 'n enkele band aan die teenoorgestelde kant.
- Die drie naasliggende bande gee die waarde van die resistor.
- Die eerste kleurband naaste aan die geleidingsdraad gee die eerste syfer bv bruin = 1.
- Die tweede kleurband gee die tweede syfer aan bv. Rooi = 2.
- Die derde kleurband gee die aantal nulle wat op die twee syfers volg bv. oranje = 3 nulle = 000.
- Die waarde van 'n resistor met bruin, rooi, oranje bande het dan 'n waarde van 12 000 ohms.



This resistor has a value of 2,700,000 ohms.

Die resistor het 'n waarde van 2 700 000 ohms

- A green-blue-black resistor would be 56 ohms (black indicates that there are no zeros).

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

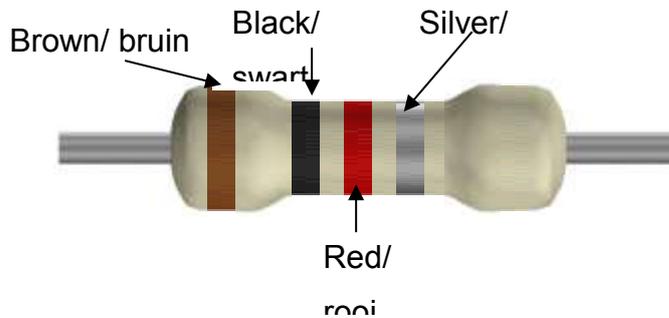
- If the third band is silver then divide the value of the first two digits by 100, if gold divide by 10. e.g. red-violet-gold is 2.7 ohms.
- The fourth band indicates the tolerance. E.g. brown indicates plus or minus 1%. A 100 ohm 1% resistor can have a value between 99 ohms and 101 ohms.

**brown 1% ; red 2% ; gold 5% ; silver 10%  
none 20%**

If there is a fifth pink band this indicates a high stability resistor.

**Question 1**

Determine the resistance of the following resistors (show your calculations).



1.1.

---



---



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- 'n Groen-blou-swart resistor sal 56 ohms wees (swart dui daarop dat geen nulle volg nie).

Swart	0
Bruin	1
Rooi	2
Oranje	3
Geel	4
Groen	5
Blou	6
Pers	7
Grys	8
Wit	9

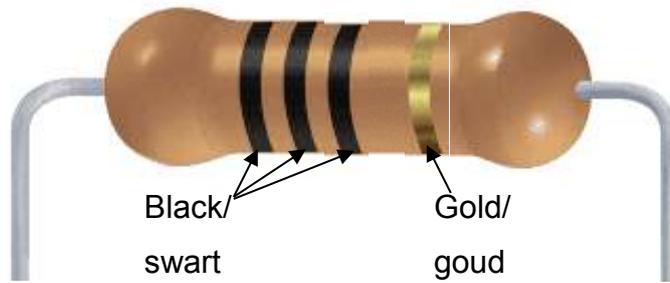
- Indien die derde band silwer is, word die waarde van die eerste twee syfers deur 100 gedeel; indien goud, deur 10 gedeel bv. Rooi-violet-goud dui op 2.7 ohms.
- Die vierde band dui die toleransie (weerstandskapasiteit) aan. Bv. bruin beteken plus of minus 1%. 'n 100 ohm resistor met 'n toleransie van 1 % kan 'n waarde tussen 99 ohms en 101 ohms hê.

**bruin 1% ; rooi 2% ; goud 5% ; silwer 10%  
geen 20%**

Indien daar 'n vyfde pienk band is, dui dit op 'n resistor met 'n hoë stabiliteit.

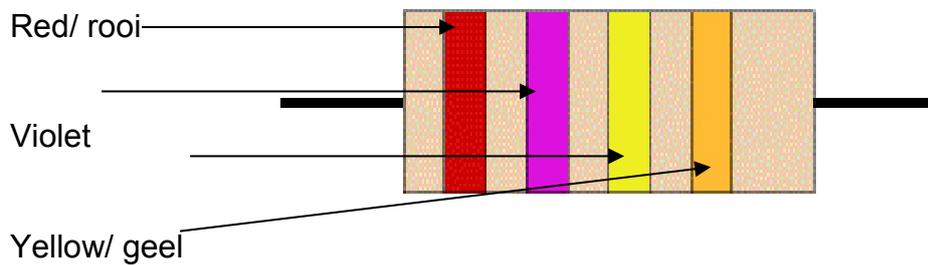
**Vraag 1**

Bepaal die weerstand van die volgende resistor. ( Toon jou berekening).



1.2.

(3)



1.3.

(3)

### List of equipment

- Vernier Current & Voltage Probes
- Low-voltage DC power supply or 2 size "D" torch cells and cell holders
- Two 10-Ω resistors
- Two 47-Ω resistors
- Connecting wire

ANY SUITABLE COMBINATION OF RESISTORS BETWEEN 10Ω AND 70Ω MAY BE USED.

### Precautions

- The output voltage of the power supply must remain constant as readings of different runs will be compared.
- Use resistors with suitable power ratings. If the power rating is too low the resistor will burn. Power ratings of 5W - 10W is recommended.

### Lys van toerusting

- Vernier Stroom- en Voltensors (Spanningsensors)
- Lae spanning GS kragbron or 2 "D"-grootte flitselle en selhouer
- Twee 10-Ω resistors
- Twee 47-Ω resistors
- Geleidingsdrade

ENIGE GESKIKTE RESISTORKOMBINASIES TUSSEN 10Ω EN 70Ω MAG GEBRUIK WORD.

### Voorsorgmaatreëls

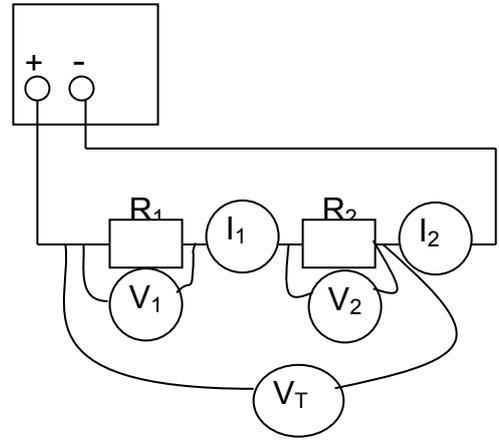
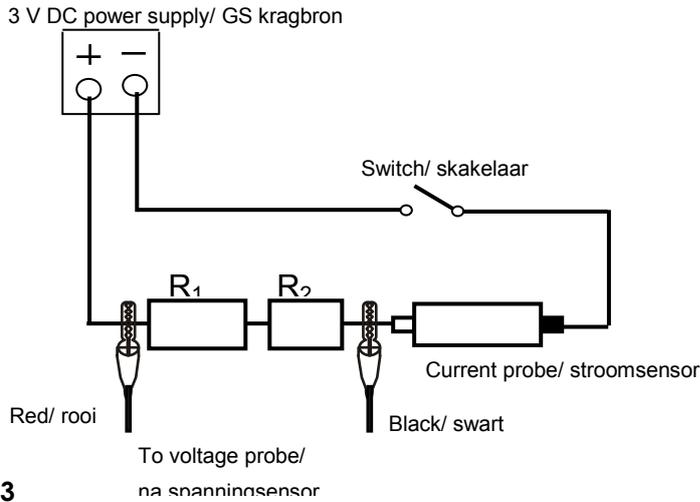
- Die leweringspotensiaal van die kragbron moet konstant bly, omdat lesings van verskillende lopies vergelyk sal word.
- Gebruik resistors met geskikte drywingswaardes. Indien die drywingswaardes te laag is, sal die resistor uitbrand. Drywingwaardes van 5W – 10W word aanbeveel.

**Experimental set-up of equipment**

**Opstelling van die eksperimentele apparaat**

**Part I: Circuit in series**

**Deel I: Stroombaan in serie**



**Fig 3**

**SECTION C  
Procedure**

**Main activities**

- For each of the two resistor values you are using, note the tolerance rating (if applicable). This value is indicated on the resistor either as a number or a colour code.
- Record these values in Table 1.
- Calculate the range of resistance values that fall in this tolerance range. Enter your answers in Table 1.

**AFDELING C  
Prosedure**

**Hoof aktiwiteite**

- Let op die toleransiewaardes (waar van toepassing) vir elk van die twee resistors wat jy gebruik. Hierdie waarde word op die resistor as 'n getal of deur 'n kleurkode aangedui.
- Vul hierdie waardes op Tabel 1 in.
- Bereken die reikwydte van die weerstands=waardes wat binne die toleransieband val. Vul jou antwoorde op Tabel 1 in.

**Table 1 / Tabel 1**

Resistor	Value of resistor/ Waarde van resistor ( $\Omega$ )	Tolerance of resistor Toleransie van die resistor (%)	Range of the resistance Reikwydte van die weerstand ( $\Omega$ )
1			
2			

(2)

**Question 2**

2.1 Use your prior knowledge of electricity to predict how resistors in series would affect current strength. What would you expect the effective resistance of two equal resistors in series to be, compared to the resistance of one of the resistor?

**Vraag 2**

2.1 Gebruik jou voorkennis van elektrisiteit en voorspel hoe resistors in serie geskakel stroomsterkte sal affekteer. Wat verwag jy sal die effektiewe weerstand van twee gelyke resistors in serie wees in vergelyking met die weerstand van een van die resistors?

(2)

2.2 Use your prior knowledge of electricity to predict how parallel resistors would affect current strength. What would you expect the effective resistance of two equal resistors in parallel to be, compared to the resistance of one of the

2.2. Gebruik jou voorkennis van elektrisiteit en voorspel hoe resistors in parallel stroomsterkte sal beïnvloed. Wat verwag jy sal die effektiewe weerstand van twee gelyke resistors in parallel wees in vergelyking met die weerstand van een

resistors?

van die resistors?

(2)

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>• Open the file ACT EM.2 Part 1</li> <li>• Connect the Voltage and Current Probe to the LabPro interface.</li> <li>• Set the circuit up with the resistors in series as in Figure 3 using <math>10\Omega</math> resistors for both resistors <math>R_1</math> and <math>R_2</math>. The red clamps (+) of the Voltage and Current Probes must be linked to the positive pole of the DC power supply.</li> <li>• Readings can be taken from the meter window at any time.</li> <li>• To test the circuit close the switch for 1 second.</li> <li>• With the switch open click on  and then click on OK.</li> <li>• Close the switch and click on the  button to obtain the current (<math>I</math>) and total voltage (<math>V_T</math>).</li> <li>• Record the values, in Table 2.</li> <li>• Connect the leads of the Voltage Probe across resistor, <math>R_1</math>.</li> <li>• Close the switch to complete the circuit and read this voltage (<math>V_1</math>) and compare the current (<math>I</math>) with the previous reading.</li> <li>• Record this value in Table 2.</li> <li>• Connect the leads of the Voltage Probe across resistor, <math>R_2</math>.</li> <li>• Close the switch to complete the circuit and read this voltage (<math>V_2</math>) and compare the current (<math>I</math>) with the previous reading.</li> <li>• Record this value in Table 2.</li> <li>• Open the switch and click the  button.</li> <li>• Repeat the experiment with a <math>47\Omega</math> resistor substituted for resistor, <math>R_2</math>.</li> <li>• Record your data in Table 2.</li> <li>• Repeat the experiment with a <math>47\Omega</math> resistor for both resistors, <math>R_1</math> and <math>R_2</math>.</li> <li>• Record the data in Table 2.</li> </ul> | <ul style="list-style-type: none"> <li>• Open die lêer, ACT EM.2 Part 1</li> <li>• Koppel die Spanning- en Stroomsensor aan die "LabPro"-koppelvlak.</li> <li>• Stel die stroombaan in serie op soos in Figuur 3 met <math>10\Omega</math> resistors elk in die plek van <math>R_1</math> and <math>R_2</math>. Die rooi knypers (+) van die Spanning- en Stroomsensors moet aan die positiewe pool van die GS-kragbron gekoppel word.</li> <li>• Lesings kan enige tyd vanaf die metervensters geneem word.</li> <li>• Sluit die skakelaar vir een sekonde om die stroombaan te toets.</li> <li>• Klik op  terwyl die skakelaar oop is en klik dan OK.</li> <li>• Sluit weer die skakelaar en klik op  knoppie om die lesings vir die stroom (<math>I</math>) en totale potensiaalverskil (<math>V_T</math>) te neem.</li> <li>• Vul die waardes op Tabel 2 in.</li> <li>• Koppel die geleidingsdrade van die Spanningsensor oor resistor, <math>R_1</math>.</li> <li>• Sluit die skakelaar en neem die volt-lesing (<math>V_1</math>) en vergelyk die stroom (<math>I</math>) met die vorige lesing.</li> <li>• Vul die waarde op Tabel 2 in.</li> <li>• Koppel die geleidingsdrade van die Spanningsensor oor resistor, <math>R_2</math>.</li> <li>• Sluit die skakelaar en neem die volt-lesing (<math>V_2</math>) en vergelyk die stroom (<math>I</math>) met die vorige lesing.</li> <li>• Vul die waarde op Tabel 2 in.</li> <li>• Maak die skakelaar oop en klik op  knoppie.</li> <li>• Herhaal die eksperiment met 'n <math>47\Omega</math>-resistor in die plek van resistor, <math>R_2</math>.</li> <li>• Vul die waardes op Tabel 2 in.</li> <li>• Herhaal die eksperiment met 'n <math>47\Omega</math>-resistor vir beide resistors, <math>R_1</math> en <math>R_2</math>.</li> <li>• Vul die waardes op Tabel 2 in.</li> </ul> |
|---|---|

**Table 2 / Tabel 2**

Part I: Circuits in series / Deel I: Stroombane in serie							
	$R_1$ ( $\Omega$ )	$R_2$ ( $\Omega$ )	$I$ (A)	$V_T$ (V)	$V_1$ (V)	$V_2$ (V)	$R_{eff}$ ( $\Omega$ )
1	10	10					
2	10	47					
3	47	47					

(4)

**Question 3**

Examine the results in Table 2.

3.1. Examine and analyse the relationship between the three voltage readings:  $V_1$ ,  $V_2$ , and  $V_T$ ?

**Vraag 3**

Bestudeer die resultate in Tabel 2.

3.1. Ondersoek en ontleed die verwantskap tussen die drie voltlesings:  $V_1$ ,  $V_2$  and  $V_T$ ?

(2)

3.2. What do you notice about the current strength in a circuit which is connected in series?

3.2. Wat let jy op omtrent die stroomsterkte in 'n stroombaan wat in serie geskakel is?

(1)

3.3 Use the results in Table 2 and your knowledge of Ohm's law to show that the equivalent resistance of two resistors  $R_1$  and  $R_2$  in series is  $R$ , where  $R = R_1 + R_2$ .

3.3. Gebruik die resultate in Tabel 2 en jou kennis van Ohm se wet om aan te toon dat die ekwivalente weerstand van resistor  $R_1$  en  $R_2$  in serie  $R$  is, waar  $R = R_1 + R_2$ .

(3)

3.4. Use Ohm's law and the experimental results to calculate the resistance of each set of resistor.

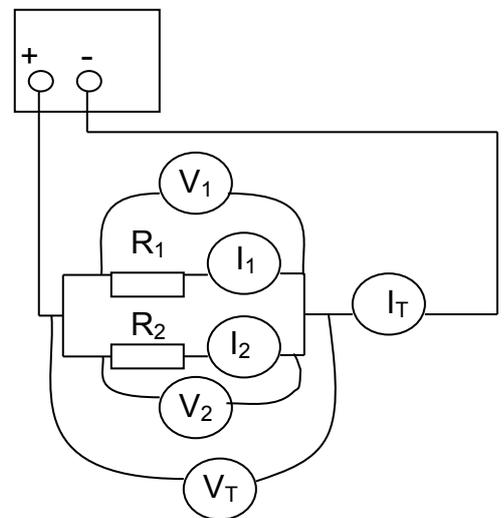
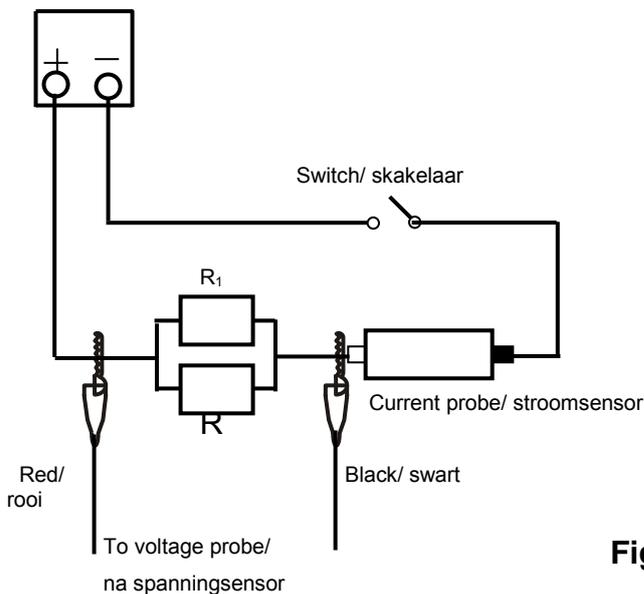
3.4. Gebruik Ohm se wet en die eksperimentele resultate om die weerstand van elke stel resistors te bereken.

(4)

**Part II: Circuit in parallel**

**Deel II: Stroombaan in parallel**

3 V DC power supply/ GS kragbron



**Fig. 4**

**Procedure**

- Open file, ACT EM.2 Part 2.
- Connect the parallel circuit shown in Figure 4 using 10-Ω resistors for both resistors 1 and 2. The red clamps (+) of the Voltage and Current Probes must be linked to the positive pole of the DC power supply.
- As in Part I, readings can be taken at any time from the meter window.
- To test your circuit, close the switch for 1 second.
- With the switch open click on  and then click on OK.
- Close the switch to complete the circuit again and click on the  button to obtain the current ( $I_T$ ) and total voltage ( $V_T$ ).
- Record the values in Table 3.
- Connect the resistor,  $R_1$  and ammeter,  $I_1$  in series, with the Voltage Probe,  $V_1$  parallel across the resistor  $R_1$  and the ammeter,  $I_1$ .
- Close the switch and read the voltage ( $V_1$ ) across resistor,  $R_1$  and the current,  $I_1$  flowing through resistor  $R_1$ .
- Record this value in Table 3 below.
- Connect the resistor,  $R_2$  and ammeter,  $I_2$  in series, with the Voltage Probe,  $V_2$  parallel across the resistor  $R_2$  and the ammeter,  $I_2$ .
- Close the switch and read the voltage ( $V_2$ ) across resistor,  $R_2$  and the current,  $I_2$  flowing through resistor,  $R_2$ .
- Record this value in Table 3.
- Open the switch and click on .
- Repeat the experiment with a 47Ω resistor substituted for resistor,  $R_2$ .
- Record this value in Table 3.
- Repeat experiment with a 47Ω resistor for both resistors,  $R_1$  and  $R_2$ .
- Record these values in table 3.

**Prosedure**

- Open die lêer ACT EM.2 Part 2.
- Stel die parallelle stroombaan op soos in Figuur 4 met 10 Ω-resistors vir beide resistors 1 en 2. Die rooi knypers (+) van die Spanning- en Stroomsensors moet aan die positiewe pool van die GS-kragbron gekoppel word.
- Soos in Deel I, kan lesings enige tyd vanaf die metervenster geneem word.
- Toets die stroombaan deur die skakelaar vir 1 sekonde te sluit.
- Met die skakelaar oop klik op  en klik dan OK.
- Sluit die skakelaar en klik op  om die lesings vir die stroom ( $I_T$ ) en totale potensiaalverskil ( $V_T$ ) te neem.
- Vul die lesings op Tabel 3 in.
- Koppel resistor,  $R_1$  en ammeter,  $I_1$  in serie en die Spanningsensor,  $V_1$  parallel oor die resistor,  $R_1$  en die ammeter,  $I_1$ .
- Sluit die skakelaar en neem die volt-lesing ( $V_1$ ) oor resistor,  $R_1$  en die stroomlesing,  $I_1$  wat deur die resistor  $R_1$  vloei.
- Vul die waarde op Tabel 3 in.
- Koppel resistor,  $R_2$  en ammeter,  $I_2$  in serie en die Spanningsensor,  $V_2$  parallel oor die resistor,  $R_2$  en die ammeter,  $I_2$ .
- Sluit die skakelaar en neem die volt-lesing ( $V_2$ ) oor resistor,  $R_2$  en die stroomlesing,  $I_2$  wat deur die resistor,  $R_2$  vloei.
- Vul die waarde op tabel 3 in.
- Open die skakelaar en klik .
- Herhaal die eksperiment met 'n 47Ω resistor in die plek van resistor,  $R_2$ .
- Vul die waarde op Tabel 3 in.
- Herhaal experiment met 'n 47Ω resistor vir beide resistors,  $R_1$  en  $R_2$ .
- Vul die waardes op Tabel 3 in.

**Table 3 / Tabel 3**

Part II: Circuits in parallel									
Deel II: Stroombane in parallel									
	$R_1$ (Ω)	$R_2$ (Ω)	$I_1$ (A)	$I_2$ (A)	$I_T$ (A)	$V_T$ (V)	$V_1$ (V)	$V_2$ (V)	$R_{eq}$ (Ω)
1	10	10							
2	10	47							
3	47	47							

(4)

**Question 4**

Examine the results in Table 3.

- 4.1. Use your results in Table 3 and your knowledge of Ohm's law to show that the equivalent resistance of two resistors  $R_1$  and  $R_2$  in parallel

**Vraag 4**

Bestudeer die resultate in Tabel 3.

- 4.1. Gebruik jou lesings in Tabel 3 en jou kennis van Ohm se wet om aan te toon dat die ekwivalente weerstand van parallelle resistor

is R, where  $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ .

R<sub>1</sub> en R<sub>2</sub>, R is waar  $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

(3)

4.2. Examine and analyse the relationship between the three voltage readings V<sub>1</sub>, V<sub>2</sub>, and V<sub>T</sub> in a parallel circuit.

4.2. Onderzoek en ontleed die verwantskap tussen die drie voltlesings V<sub>1</sub>, V<sub>2</sub> and V<sub>T</sub> in 'n parallele stroombaan.

(2)

4.3. Examine and analyse the relationship between I<sub>1</sub>, I<sub>2</sub> and I<sub>T</sub>.

4.3. Onderzoek en analiseer die verwantskap tussen I<sub>1</sub>, I<sub>2</sub> and I<sub>T</sub>.

(2)

4.4. Draw general conclusions about current strength and potential difference with regards to:  
4.4.1. resistors in series;

4.4. Maak algemene gevolgtrekkings aangaande die stroomsterkte en potensiaalverskil ten opsigte van:  
4.4.1. resistors in serie;

(2)

4.4.2. resistors in parallel.

4.4.2. resistors in parallel

(2)

## SCIENCE AND SOCIETY

### Question 5

5.1 Name one advantage and one disadvantage of connecting light bulbs in parallel and how this is utilized by electricians to set up the electrical wiring in homes.

## WETENSKAP EN DIE SAMELEWING

### Vraag 5

5.1 Noem een voordeel en een nadeel verbonde aan die skakeling van gloeilampe in parallel en hoe dit deur elektrisiëns aangewend word om die elektriese bedrading in huise te doen.

(3)

5.2. Are street lights connected in series or in parallel? Explain your answer.

5.2. Is straatligte in serie of in parallel geskakel? Verduidelik jou antwoord.

(3)

## APPENDIX Q: ACTIVITY 5: RESISTANCE

### Factors Affecting the Resistance of a Conductor

Investigative question:

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Hypothesis:

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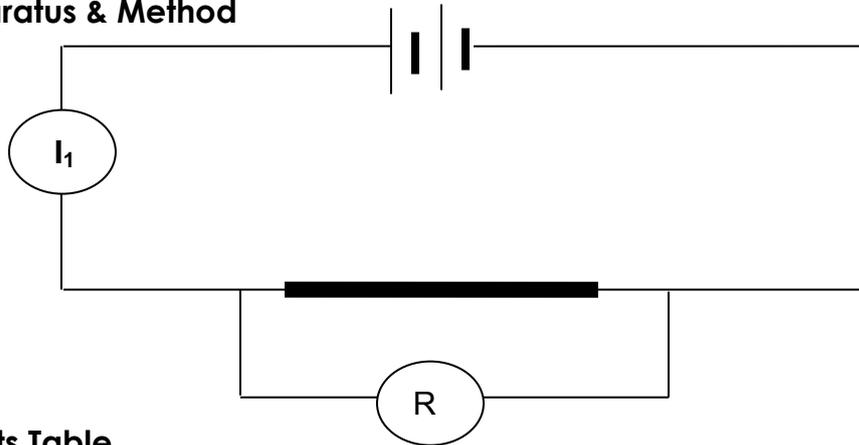


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Variables

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

Apparatus & Method



Results Table

Length				Thickness			
Length	Potential Difference (V)	Current (A)	Resistance ( $\Omega$ )	Diameter	V (V)	I (A)	R ( $\Omega$ )
L				0.2mm			
2L				0.4mm			
3L							
Type of Material				Temperature			
Substance	V (V)	I (A)	R ( $\Omega$ )	Temperature	V (V)	I (A)	R ( $\Omega$ )
Nichrome				Cold Resistor			
Copper				Hot Resistor			
Eureka							

Conclusion and Discussion:

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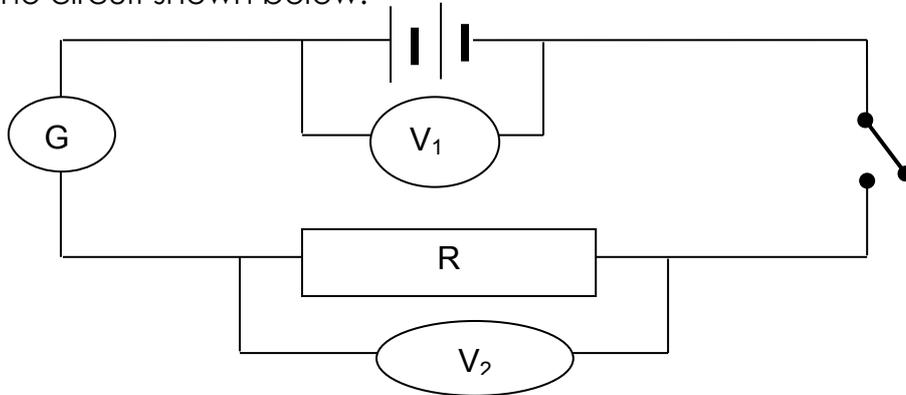
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**EMF and Internal Resistance**

**Aim:** To investigate the relationship between potential difference ( $V$ ), Emf ( $\epsilon$ ) and internal resistance ( $r$ ).

**Method and Apparatus**

Construct the circuit shown below:



1. With the **switch open**, connect the voltmeter across the battery ( $V_1$ ). Record your result in the table below.
2. With the **switch still open**, connect the voltmeter across the resistor ( $V_2$ ). Record your result in the table below.
3. What is the reading on the ammeter?  
.....
4. Now **close the switch**, record the reading on  $V_1$  and  $V_2$  respectively.

**Results**

SWITCH OPEN				
$V_1$		$V_2$		A
SWITCH CLOSED				
$V_1$		$V_2$		A

What do you notice about  $V_1$  when the switch is open and when it is closed?

.....

Explain the ammeter readings in both cases.

.....

What do you notice about  $V_2$  when the switch is open and when it is closed?

.....

Use the above table to calculate:

“lost” volts ( $v$ ): .....

Internal resistance ( $r$ ): .....

**Conclusion**

.....

.....

<p style="text-align: center;"><b>ACTIVITY EM.3</b> ELECTRICITY AND MAGNETISM</p>	<p style="text-align: center;"><b>AKTIWITEIT EM.3</b> ELEKTRISITEIT EN MAGNETISME</p>
<p style="text-align: center;"><b>Electromagnets</b></p>	<p style="text-align: center;"><b>Elektromagnete</b></p>
<p><i>Experiment file/ Eksperimentlêer</i> ACT EM.3</p>	
<p><b>Learning Outcome 1</b> Practical scientific inquiry and problem-solving skills</p> <p><b>Assessment Standard 1.1</b> Plan and conduct a scientific investigation on electromagnetism with regard to accuracy, reliability and the need to control one variable.</p> <p><b>Assessment Standard 1.2</b> Seek patterns and trends in the collected data to draw conclusions and to formulate simple generalizations with regard to the relationship between the number of wire windings and magnetic field strength; the current strength and magnetic field strength; the iron core and magnetic field strength.</p>	<p><b>Leeruitkoms 1</b> Praktiese wetenskaplike ondersoek- en probleem-oplossingsvaardighede.</p> <p><b>Asseseringstandaard 1.1</b> Beplan en voer 'n wetenskaplike ondersoek ten opsigte van elektromagnetisme uit met die oog op akkuraatheid, betroubaarheid en die noodsaak om een veranderlike te kontroleer.</p> <p><b>Asseseringstandaard 1.2</b> Soek patrone en tendense in die versamelde data om gevolgtrekkings te maak en eenvoudige veralgemenings ten opsigte van die verband tussen die aantal windings en die sterkte van die magneetveld; stroomsterkte en die sterkte van die magneetveld; die ysterkern en die sterkte van die magneetveld te formuleer.</p>
<p><b>Learning Outcome 2</b> Construct and apply scientific knowledge.</p> <p><b>Assessment Standard 2.2</b> Express and explain electromagnets indicating the relationship between the number of wire windings and magnetic field strength; the current strength and magnetic field strength; the iron core and magnetic field strength.</p> <p><b>Assessment Standard 2.3</b> Apply the information about electromagnets in everyday life contexts.</p>	<p><b>Leeruitkoms 2</b> Vertolking en toepassing van wetenskaplike kennis.</p> <p><b>Asseseringstandaard 2.2</b> Beskryf en verduidelik elektromagnetisme deur die verband tussen die aantal draadwindings en die sterkte van die magneetveld; stroomsterkte en die sterkte van die magneetveld; die ysterkern en die sterkte van die magneetveld uit te lig.</p> <p><b>Asseseringstandaard 2.3</b> Pas die inligting ten aansien van elektromagnetisme in alledaagse kontekste toe.</p>
<p><b>Learning Outcome 3</b> The nature of science and its relationship to Technology, Society and the Environment.</p> <p><b>Assessment Standard 3.2</b> Discuss and describe the impact of electromagnets on socio-economic and human development.</p>	<p><b>Leeruitkoms 3</b> Die aard van wetenskap en die verband daarvan met Tegnologie, die Gemeenskap en Omgewing.</p> <p><b>Asseseringstandaard 3.2</b> Bespreek en verduidelik hoe elektromagnete die sosio-ekonomiese en menslike ontwikkeling beïnvloed</p>

**TOTAL MARK / TOTALE PUNT = 50**

## SECTION A

### **Solenoid**

A coil of insulated electrical wire, usually cylindrical in shape, which produces a magnetic field similar to a bar magnet if an electric current passes through it.

Units of magnetic field: **Tesla**

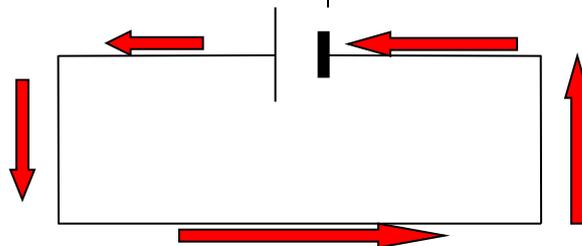
Symbol: T

### **Electromagnet**

A temporary magnet consisting of a solenoid coil wound around a soft iron core. The iron core becomes magnetized when an electric current flows through the coil thus inducing a magnetic field.

### **Conventional current**

An electric current considered to flow from positive to negative in the external circuit i.e. in the opposite direction to electron flow.



### **Factors that influence the strength of magnetic fields**

- Type of core material used inside coil
- The number of wire windings
- The magnitude of the electrical current

### **Hard magnetic materials**

- cannot easily be magnetised (i.e. have a low susceptibility for magnetism)
- keep their magnetism very long (i.e. have a high retentivity)
- used to make permanent magnets,
- e.g. cobalt alloys; certain steel

### **Soft magnetic materials**

- can easily be magnetised (i.e. have a high susceptibility for magnetism)
- loses its magnetism easily (i.e. have a low retentivity)
- used in electromagnets
- e.g. iron

## AFDELING A

### **Solenoid**

'n Spoel van geïsoleerde elektriese geleidingsdraad, gewoonlik silindries in vorm, wat 'n magneetveld, soortgelyk aan die van 'n staafmagneet, veroorsaak.

Eenheid van magneetveld: **Tesla**

Simbool: T

### **Elektromagneet**

'n Tydelike magneet wat bestaan uit 'n solenoidspoel wat rondom 'n sagte ysterkern gedraai is. Die ysterkern word gemagnetiseer as 'n elektriese stroom deur die windings vloei en sodoende 'n magneetveld induseer.

### **Konvensionele stroom**

'n Elektriese stroom wat beskou word om vanaf positief na negatief in die uitwendige stroombaan te vloei dws. die teenoorgestelde rigting van elektronvloei.

### **Faktore wat die sterkte van magneetvelde beïnvloed**

- Tipe kernmateriaal binne-in die spoel
- Die aantal windings
- Die grootte van die elektriese stroom

### **Harde magnetiese stowwe**

- word nie maklik gemagnetiseer nie (het 'n lae vatbaarheid vir magnetisme)
- behou magnetisme baie lank (het 'n hoë retentiwiteit of behoudsvermoë)
- word gebruik as permanente magnete
- bv. kobalt allooie en sekere staal

### **Sagte magnetiese stowwe**

- word maklik gemagnetiseer (het 'n hoë vatbaarheid vir magnetisme)
- verloor magnetisme maklik (het 'n lae retentiwiteit)
- gebruik in elektromagnete
- bv yster

**The Right Hand Solenoid Rule** is used to determine the polarity of the electromagnet (solenoid).

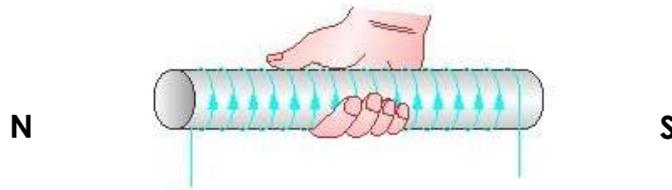
*If you place your right hand around the solenoid with your thumb outstretched, and your curled fingers pointing in the direction of the conventional current, then your thumb points in the direction of the magnetic field inside the solenoid i.e. in the direction of the north pole of the solenoid.*

**Die Regterhand Solenoïdreël** word gebruik om die polariteit van 'n elektromagneet (solenoid) te bepaal.

*Indien jou regterhand, met jou duim uitgestrek, om die solenoïd geplaas word, met die vingers in die rigting van die konvensionele stroom gekrul, dan wys die duim in die rigting van die magneetveld binne die solenoid dws. in die rigting van die noordpool van die solenoid. .*

The fingers indicate the direction of the conventional current.

*Die vingers dui die rigting van die konvensionele stroom aan*



The thumb points to the N-pole / *Die duim wys in die rigting van die N-pool*

### Preliminary Activity

#### Question 1

Consider the following diagram

### Inleidende Aktiwiteit

#### Vraag 1

Bestudeer die volgende foto.



1.1. Provide a name for this device.

1.1. Verskaf 'n naam vir hierdie toestel.

1.2. Explain in detail how the device works and where in the industry it is commonly used.

1.2. Verduidelik hoe die toestel werk en waar dit gewoonlik in die industrie gebruik word.

(4)

1.3. Is soft or a hard iron used to build this device? Explain your answer.

1.3. Word sagte of harde yster gebruik om die toestel te vervaardig? Verduidelik jou antwoord.

(2)

## PRACTICAL APPLICATIONS

Electromagnets are used in applications where magnetism has to be switched on and off.

### Relays

Relays are used as secondary switches. It is sometimes impossible to switch electricity directly on or off, either because of the inaccessibility of the switch or the magnitude of the current strength. In such cases relays are used. The relay is a switch that is activated by an electromagnet. The electromagnet is switched on or off by means of an ordinary switch. Relays are used in cars, remote control switches & in electronics.

### TV tubes

In TV or other cathode ray tubes the electron beams are diverted by electromagnets. The diverted beams fall on a fluorescent screen which glows to produce the desired images

### Other

Other uses of electromagnets include devices such as electric motors and electric doorbells.

## PRAKTIESE TOEPASSING

Elektromagnete word aangewend waar magnetisme aan- en afgeskakel word.

### Oorskakelaars (relais)

Oorskakelaars word as sekondêre skakelaars gebruik. Dit is soms onmoontlik om elektrisiteit direk aan of af te skakel a.g.v. die ontoeganklikheid van die skakelaar of die grootte van die stroomsterkte. In sulke gevalle word relais gebruik. Die oorskakelaar word deur 'n elektromagneet geaktiveer. Die elektromagneet word deur 'n gewone skakelaar aan of af geskakel. Relais word in motors, afstandbeheerskakelaars en ander elektroniese apparaat gebruik.

### TV buise

In 'n TV en ander katodestraal buise word die elektron bundels deur elektromagnete beheer. Die bundels word op 'n fluoressensieskerm gewerp om die verlangde beeld te vorm.

### Ander

Ander gebruike van elektromagnete sluit elektriese motors en deurklokkies in.

## ACTIVITY EM.3

### ELECTRICITY AND MAGNETISM

#### Electromagnets

NAME  
NAAM

DATE  
DATUM

## AKTIWITEIT EM.3

### ELEKTRISITEIT EN MAGNETISME

#### Elektromagnete

GRADE  
GRAAD

#### SECTION B

##### List of equipment

- Vernier Magnetic Field Sensor
- Vernier Electric current probe
- 15 mm iron nail
- 80 cm piece of insulated wire
- Two torch batteries (size D) or DC-power source (3 V)
- Cell holder
- Masking tape
- Connecting wires
- Iron, copper and aluminium filings
- Retort stand and clamp

##### Precaution

- The magnetic field sensor should be set to its lowest setting.
- Wrap all windings so that they are equidistant from the nail ends.

##### Experimental set-up

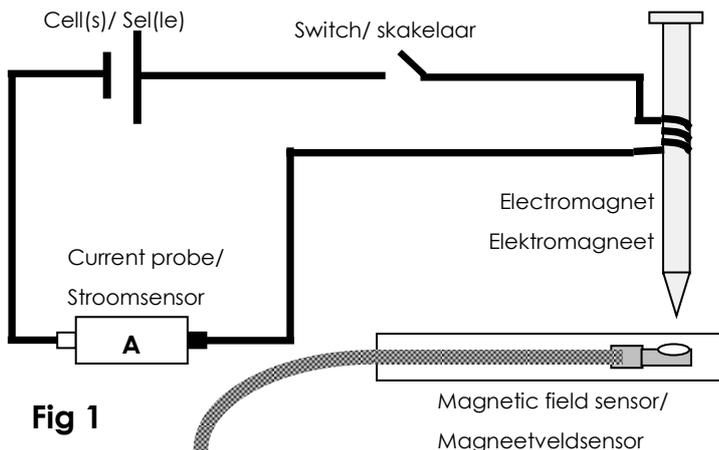


Fig 1

#### AFDELING B

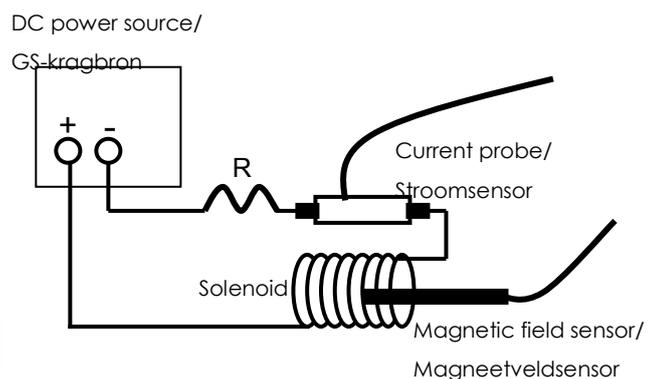
##### Lys van toerusting

- Vernier Magneetveld Sensor
- Vernier Elektriese stroomsensor
- 15 ml yster spyker
- 80 cm geïsoleerde draad
- Twee flitselle (grootte D) of GS-kragbron (3V)
- Selhouer
- Maskeerband
- Geleidingsdrade
- Yster-, koper- en aluminiumvylsels
- Retortstaander en klem

##### Voorsorgmaatreëls

- Die magneetveldsensor moet op sy laagste verstelling gebruik word
- Draai alle windings sodat dit naastenby ewever vanaf die ente van die spyker is.

##### Opstelling van die apparaat



#### SECTION C

##### Procedure

##### Introductory activities

- Wind a length of insulated wire around an iron nail.
- Connect the ends of the wire to a torch cell.

#### AFDELING C

##### Prosedure

##### Inleidende aktiwiteite

- Draai 'n lengte geïsoleerde draad om 'n yster spyker.
- Verbind die draad ente aan 'n flitsel

- Hold the nail next to:
  - Iron filings
  - Copper or brass filings
  - Aluminum filings
- Observe the behaviour of the metals.
- Record your observations.

### Question 2

2.1 What is observed when the current-carrying iron nail is brought near the different metals? Give a reason for your answers.

2.1.1. iron filings

- Hou die spyker naby:
  - Ystervylsels
  - Koper- of geelkopervylsels
  - Aluminiumvylsels
- Let op die gedrag van die metale.
- Notuleer jou waarnemings.

### Vraag 2

2.1 Wat neem jy waar as die stroomdraende yster spyker naby die verskillende metale gebring word? Verskaf 'n rede vir jou antwoord.

2.1.1. Ystervylsels

(2)

2.1.2 copper or brass filings

2.1.2 Koper- of geelkopervylsels

(2)

2.1.3 Aluminum filings

2.1.3 Aluminiumvylsels

(2)

2.2.1. What do you observe when the electricity is switched off and the nail brought near the iron filings?

2.2.1. Wat neem jy waar as die elektrisiteit afgeskakel word en die spyker naby die vylsels gehou word?

(1)

2.2.2. What is such an appliance called that behaves like the nail?

2.2.2. Wat noem ons 'n toestel wat hom soos die ysterspyker gedra?

(1)

### Main activities

- Tape the magnetic sensor to the table as in Figure 1.
- Open file, ACT EM.3 LEARNER - MF vs TURNS.
- Clamp the iron nail in a retort stand and place its sharp end perpendicular to the sensitive spot of the Magnetic Field Sensor, as shown in Figure 1.
- Connect the circuit as in Figure 1 but do not yet wind the wire around the nail.
- Zero the sensors with the circuit open.
- Close the circuit and click .
- When the reading has stabilized, click .
- Type "0" in the Edit box (for 0 windings).
- Click OK. The magnetic field strength value for zero windings is now saved.
- **Caution: The battery will become warm as it is used. To keep it from getting hot, and to save energy, open the switch immediately after  has been clicked.**

### Hoofaktiwiteite

- Plak die magnetiese sensor op die tafel soos in Figuur 1.
- Open lêer, ACT EM.3 LEARNER - MF vs TURNS.
- Klem die ysterspyker in 'n retortstaander sodat die skerp punt loodreg teenoor die sensitiewe gedeelte van die Magneetveldsensor staan, soos in Figuur 1 aangedui.
- Stel die stroombaan soos in Figuur 1 op maar sonder die windings om die spyker.
- Zero die sensors met die stroombaan oop.
- Sluit die stroombaan en klik .
- Klik  sodra die lesings stabiliseer.
- Tik "0" in die "Edit"-venster (vir geen windings).
- Klik OK. Die waarde van die magneetveldsterkte vir nul windings is nou gestoor.
- **Versigtig: Die battery word warm soos wat dit gebruik word. Om te verhoed dat dit oorverhit en om energie te bespaar, maak die skakelaar onmiddellik oop nadat  geklik is.**

- Tightly wind the wire 3 times around the nail as shown in Fig 1. Press the windings tightly to the bottom of the nail and hold it there.
- **Important:** If the reading decreases, reverse the connections.
- Close the circuit and when the reading has stabilized, click .
- Type "3" in the Edit box (for 3 windings). Click OK. The magnetic field strength value for 3 windings is now saved.
- Also record the electric current strength.
- Repeat the procedure for 6, 9, 12, 15, 18, and 21 windings.
- Click  to end data collection.
- Click "Store latest run" on the "Experiment" menu.
- Record the magnetic field strength values displayed in the Table window in Table 1.
- Remove the nail carefully and collect data for another run with 21 windings without the nail.
- Zero the sensors with the circuit open.
- Close the circuit and click .
- When the reading has stabilized, click .
- Type "0" in the Edit box (for 0 windings). Click OK. The magnetic field strength value for zero windings is now saved. Open the circuit.
- Place the coil with 21 windings (without the nail) in position over the Magnetic Field Sensor and close the circuit.
- When the reading has stabilized, click .
- Type "21" in the Edit box (for 21 windings). Click OK. The magnetic field strength value for 21 windings is now saved.
- Click  to end data collection.
- "Store latest run" on the "Experiment" menu.
- Record your data in Table 2.
- Open file, ACT EM.3 LEARNER-MF vs CURRENT.
- Insert the nail in the coil with 21 turns.
- Zero the sensors with the circuit open.
- Close the circuit and click . When the reading has stabilized, click .
- Type "0" in the Edit box (for 0 windings). Click OK. The magnetic field strength value for zero windings is now saved. Open the circuit.
- Place the nail with 21 windings in position over the Magnetic Field Sensor and close the circuit.
- When the reading has stabilized, click . Type "21" in the Edit box (for 21 windings). Click OK. The magnetic field strength value for 21 windings is now saved. Click  to end data collection. "Store latest run" on the "Experiment" menu.
- Add another cell to the battery (or double the voltage) and record another run.
- Record your data in Table 2.
- Answer the questions that follows.
- Draai 3 windings baie stewig om die spyker, soos in Fig 1 aangedui. Druk die windings styf teen die onderkant van die spyker en hou dit daar.
- **Belangrik:** Indien die lesing afneem, draai die geleidingsdrade om.
- Sluit die stroombaan en klik  sodra die lesing stabiliseer.
- Tik "3" in die "Edit"-venster (vir 3 windings). Klik OK. Die magneetveldsterkte vir 3 windings is nou gestoor.
- Notuleer ook die elektriese stroomsterkte.
- Herhaal die prosedure vir 6, 9, 12, 15, 18 en 21 windings.
- Klik  om data-insameling te stop.
- Klik "Store latest run" op die "Experiment menu".
- Notuleer die waardes van die magneetveldsterkte wat in die Tabelvenster voorkom in Tabel 1.
- Verwyder die spyker versigtig en versamel data vir nog 'n lopies vir 21 windings sonder die spyker.
- Zero die sensors met die stroombaan oop.
- Sluit die stroombaan en klik .
- Klik  sodra die lesings stabiliseer.
- Tik "0" in die "Edit"-venster (vir 0 windings). Klik OK. Die waarde van die magneetveldsterkte vir nul windings is nou gestoor. Maak die stroombaan oop.
- Plaas die spoel met 21 windings (sonder die spyker) in posisie oor die Magneetveldsensor en sluit die stroombaan.
- Klik  sodra die lesing stabiliseer.
- Tik "21" in die "Edit"-venster (vir 21 windings). Klik OK. Die magneetveldsterkte vir 21 windings is nou gestoor.
- Klik  om data-insameling te stop.
- Klik "Store latest run" op die "Experiment menu".
- Notuleer die data in Tabel 2.
- Open lêer, ACT EM.3 LEARNER-MF vs CURRENT.
- Plaas die spyker in die spoel met 21 windings.
- Zero die sensors met die stroombaan oop.
- Sluit die stroombaan en klik . Klik  sodra die lesings stabiliseer.
- Tik "0" in die "Edit"-venster (vir 0 windings). Klik OK. Die waarde van die magneetveldsterkte vir nul windings is nou gestoor. Maak die stroombaan oop.
- Plaas die spoel met 21 windings in posisie oor die Magneetveldsensor en sluit die stroombaan.
- Klik  sodra die lesing stabiliseer.
- Tik "21" in die "Edit"-venster (vir 21 windings). Klik OK. Die magneetveldsterkte vir 21 windings is nou gestoor. Klik  om data-insameling te stop. "Store latest run" op die "Experiment menu".
- Voeg nog 'n sel by die battery (of verdubbel die potensiaal verskil) en kollekteer nog 'n lesing.
- Teken die data aan in Tabel 2.
- Voltooi die volgende vrae.

**Table 1 / Tabel 1**

Influence of the number of windings <i>Invloed van die aantal windings</i>			
Windings / Windings (#)	Magnetic Field Magneetveld (mT)	Windings Windings (#)	Magnetic Field Magneetveld (mT)
0		12	
3		15	
6		18	
9		21	
Average electric current strength <i>Gemiddelde elektriese stroomsterkte</i>			_____ A

(4)

**Table 2 / Tabel 2**

Influence of iron core <i>Invloed van ysterkern</i>	
Windings/ Windings # 21	Magnetic field Magneetveld
1 cell/ sel: Current = ____ A	
With nail Met spyker	
Without nail sonder spyker	

Influence of current strength <i>Invloed van stroomsterkte</i>		
Windings/ Windings # 21	Magnetic field Magneetveld	
without nail / sonder spyker		
1 cell 1 sel	I= ____ A	
2 cells 2 selle	I= ____ A	

(4)

**Table: Assessment Rubric**  
**Tabel: Asseseringsubriek**

	4	3	2	1	X
Table	<ul style="list-style-type: none"> <li>All columns and rows completed correctly/ <i>Alle kolomme en rye korrek gevulfooi</i></li> <li>Current strength values included/ <i>Stroomsterktewaardes ingesluit</i></li> <li>Values correctly calculated/ <i>Waardes korrek bereken</i></li> <li>Values accurate/ <i>Waardes akkuraat</i></li> </ul>	3 of/ uit 4	2 of/ uit 4	1 of/ uit 4	Not attempted/ Geen poging aangewend nie

**QUESTION 3**

3.1 What is the relationship between the number of windings and magnetic field strength?

**VRAAG 3**

3.1 Wat is die verwantskap tussen die aantal windings en die magneetveldsterkte?

(1)

3.2. How does the iron core (nail) influence the magnetic field strength?

3.2. Hoe beïnvloed die ysterkern (spyker) die grootte van die magneetveldsterkte?

(1)

3.3. How does the electric current strength influence the magnetic field strength?

3.3. Hoe beïnvloed die elektriese stroomsterkte die die magneetveldsterkte?

(1)

**QUESTION 4**

4.1 Use the following table and draw a graph of magnetic field vs number of windings. (See Rubric)

**VRAAG 4**

4.1 Gebruik die volgende tabel en trek 'n grafiek van magneetveld teenoor die aantal windings. (See Rubriek)

Current strenght / <i>Stroomsterkte</i>	
Magnetic field / <i>Magneetveld</i> (mT)	Number of windings / <i>Aantal windings</i>
0,02	2
0,04	4
0,06	6
0,08	8

0.10									
0.08									
0.06									
0.04									
0.02									
0	2	4	6	8	10				

**Graph: Assessment Rubric**  
**Grafiek: Asseseringsrubriek**

	4	3	2	1	X
<i>Graph Plotting/</i> <i>Trek van grafiek</i>	<ul style="list-style-type: none"> <li>• Correct title/ <i>Korrekte naam</i></li> <li>• Both axes labeled/ <i>Beide asse van byskrifte voorsien</i></li> <li>• Coordinates correctly plotted/ <i>Koördinate korrek aangebring</i></li> <li>• Coordinates joined correctly/ <i>Koördinate korrek verbind</i></li> <li>• Variables placed on the appropriate axes/ <i>Veranderlikes op die gepaste asse geplaas</i></li> <li>• All units indicated/ <i>Alle eenhede aangedui</i></li> </ul>	4 – 5 of/ uit 6	2 – 3 of/uit 6	1 of/uit 6	Not attempted Geen poging aangewend

(4)

4.2. What would the magnetic field strength on your graph be for 5 windings? Show on graph how you determined your answer.

4.2. Wat sal die lesing vir die magneetveldsterkte vir 5 windings op jou grafiek wees? Dui op die grafiek aan hoe jy die antwoord bepaal het.

(2)

4.3 Which physical entity is the dependant variable in this case?

4.3 Watter fisiese grootheid is in die geval die afhanklike veranderlike?

(2)

4.4 Motivate your answer in 4.3.

4.4 Motiveer jou antwoord in 4.3.

(2)

4.5 What do you predict will the magnetic field for 30 windings be?

4.5 Wat voorspel jy sal die lesing vir die magneetveld vir 30 windings wees?

(1)

4.6 Explain your prediction in 4.5.

4.6 Verduidelik jou voorspelling in 4.5.

(2)

4.7. The same experiment is repeated, but the electric current strength through the windings is increased. Use a dotted line to show on your graph what the new graph will look like.

4.7 Dieselfde eksperiment word uitgevoer, maar die stroomsterkte deur die windings word verhoog. Gebruik 'n stippellyn op jou grafiek om aan te toon hoe die nuwe grafiek sal lyk.

(2)

## SCIENCE AND SOCIETY

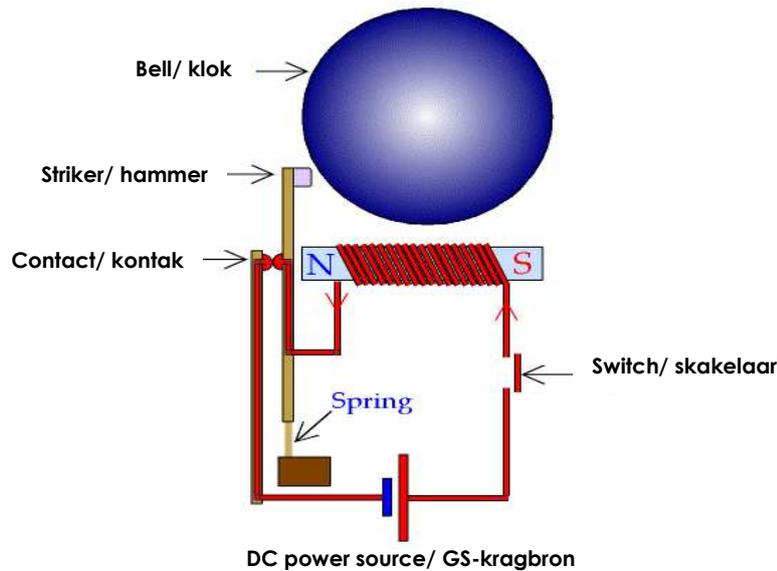
### Question 5

5.1 Consider the following diagram of an electric bell. An Electric bell makes use of electromagnetism. Explain, in detail, making reference to the diagram how a doorbell works.

## WETenskap EN DIE SAMELEWING

### Vraag 5

5.1 Bestudeer die volgende diagram van 'n elektriese klokkie. 'n Elektriese klokkie maak van elektromagnetisme gebruik. Verduidelik breedvoerig, deur na die diagram te verwys, hoe 'n elektriese klokkie werk.



(6)

5.2 Name two other appliances where electromagnetism is applied.

5.2 Noem twee ander toestelle waar elektromagnetisme toegepas word.

(2)

## APPENDIX S: ACTIVITY 7 – EM5

<p style="text-align: center;"><b>ACTIVITY EM.5</b> ELECTRICITY AND MAGNETISM</p>	<p style="text-align: center;"><b>AKTIWITEIT EM.5</b> ELEKTRISITEIT EN MAGNETISME</p>
<p style="text-align: center;"><b>Electromagnetic induction</b></p>	<p style="text-align: center;"><b>Elektromagnetiese induksie</b></p>
<p style="text-align: center;"><i>Experiment file/ Eksperimentlêer</i> ACT EM.5</p>	
<p><b>Learning Outcome 1</b> Practical scientific inquiry and problem-solving skills</p> <p><b>Assessment Standard 1.1</b> Collect data regarding electromagnetic induction systematically with the emphasis on accuracy, reliability and the need to control one variable.</p> <p><b>Assessment Standard 1.2</b> Seek patterns and trends in data collected from graphs in order to analyze and explain the relationship between induced emf and the strength of the magnet, number of turns and the relative speed between coil and the magnet.</p>	<p><b>Leeruitkoms 1</b> Praktiese wetenskaplike ondersoek- en probleem-oplossingsvaardighede.</p> <p><b>Asseseringstandaard 1.1</b> Versamel data in verband met elektromagnetiese induksie sistematies met die klem op akkuraatheid, betroubaarheid en die noodsaak om een veranderlike te kontroleer.</p> <p><b>Asseseringstandaard 1.2</b> Soek patrone en tendense in inligting wat van grafieke versamel is om die verband tussen geïnduseerde emk en magneetsterkte, aantal windings en relatiewe spoed tussen spoel en magneet te analiseer en te verduidelik.</p>
<p><b>Learning Outcome 2</b> Construct and apply scientific knowledge.</p> <p><b>Assessment Standard 2.2</b> Interpret and explain the principle of electromagnetic induction and apply the solenoid rule to determine the direction of the induced current.</p> <p><b>Assessment Standard 2.3.</b> Apply the acquired knowledge pertaining to electromagnetic induction in everyday life contexts.</p>	<p><b>Leeruitkoms 2</b> Vertolk en pas wetenskaplike kennis toe.</p> <p><b>Asseseringstandaard 2.2</b> Interpreteer en verduidelik die beginsel van elektromagnetiese induksie en pas die solenoidreël toe om die rigting van die geïnduseerde stroom te bepaal.</p> <p><b>Asseseringstandaard 2.3</b> Pas die verworwe kennis rakende elektromagnetiese induksie toe op situasies in die alledaagse lewe.</p>
<p><b>Learning Outcome 3</b> The nature of science and its relationship to Technology, Society and the Environment.</p> <p><b>Assessment Standard 3.2</b> Discuss the impact of electromagnetic induction on sustainable local development of resources and the environment.</p>	<p><b>Leeruitkoms 3</b> Die aard van wetenskap en die verband daarvan met Tegnologie, die Samelewing en Omgewing.</p> <p><b>Asseseringstandaard 3.2</b> Bespreek die impak van elektromagnetiese induksie op volhoubare plaaslike ontwikkeling van hulpbronne en die omgewing.</p>

**TOTAL MARK / TOTALE PUNT = 45**

**SECTION A**

**Magnetic field**

The region around a bar magnet or a current carrying solenoid in which magnetic material will experience a magnetic force

**Magnetic field density**

Magnetic field density refers to the strength of a magnetic field i.e. the number of field lines passing through a unit area of the magnetic field. More magnetic field lines imply a stronger magnetic field density and vice versa.

Unit: Tesla (T)

Symbol: B

**Magnetic flux**

Represents the total magnetic field lines passing through a specific (known) area of the magnetic field. Magnetic flux,  $\Phi$  is the product of the magnetic field density, B and the cross-sectional area, A the field lines pass through.

$$\Phi = BA$$

Unit: Weber

Symbol: Wb

**Flux linkage**

Flux linkage defines the link between coil (conductor) and magnetic field density. The magnetic field of the magnet seems cut the windings or loops of the coil as the magnet moves in the coil. As the magnet moves into or from the coil there is a change in the flux linkage between magnetic field and coil,

**AFDELING A**

**Magneetveld**

Die gebied rondom 'n staafmagneet of 'n stroomdraende solenoid waarin magnetiese materiaal 'n magneetkrag sal ondervind.

**Magneetveld-digtheid**

Magneetveld-digtheid verwys na die sterkte van die magneetveld m.a.w. die aantal veldlyne wat deur 'n eenheidsarea van die magneetveld sny. Meer magneetveldlyne beteken 'n sterker magneetveld-digtheid en omgekeerd.

Eenheid: Tesla (T)

Simbool: B

**Magneetvloed**

Verteenwoordig die totale magneetveldlyne wat deur 'n spesifieke (bekende) area van die magneetveld sny. Magneetvloed,  $\Phi$  is die produk van die magneetveld-digtheid, B en die deursnitarea, A waardeur die veldlyne sny.

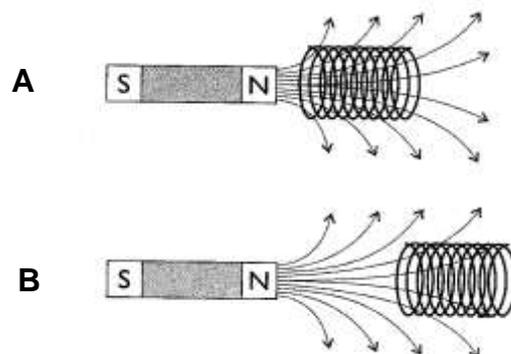
$$\Phi = BA$$

Eenheid: Weber

Simbool: Wb

**Vloedkoppeling**

Vloedkoppeling beskryf die koppeling tussen spoel (geleier) en die magneetveld-digtheid. Die magneetveld van die magneet skyn om die windings van die spoel te sny wanneer die magneet in die die spoel beweeg. Wanneer die magneet in of uit die spoel beweeg, is daar 'n verandering in die vloedkoppeling tussen magneet en spoel.



The same amount of magnetic field density in A and B, but a larger flux linkage in A.

Dieselfde ..... hoeveelheid

**The Right Hand Solenoid Rule** is used to determine the polarity of the electromagnet (solenoid).

If you place your right hand around the solenoid with your thumb outstretched, and

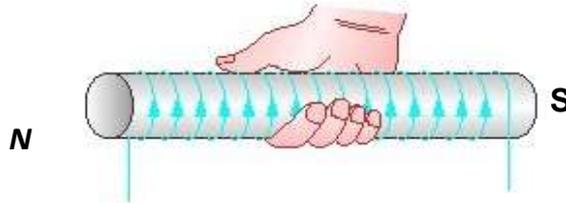
**Die Regterhand Solenoïdreël** word gebruik om die polariteit van 'n elektromagneet (solenoid) te bepaal.

Indien jou regterhand, met jou duim uitgestrek, om die solenoïd geplaas word, met die vingers

your curled fingers pointing in the direction of the conventional current, then your thumb points in the direction of the magnetic field inside the solenoid i.e. in the direction of the north pole of the solenoid.

in die rigting van die konvensionele stroom gekrul, dan wys die duim in die rigting van die magneetveld binne die solenoid dws. in die rigting van die noordpool van die solenoid. .

The fingers indicate the direction of the conventional current.



The thumb points to the N-pole / Die duim wys in die rigting van die N-

### Electromagnetic induction

The phenomenon that an emf (potential difference) and hence a current is induced in a conductor by a changing magnetic field.

#### Emf

The work done per unit charge.  
(1 volt = 1 joule/coulomb).  
OR

The difference in potential that tends to drive an electrical current.

$$Emf (V) = \frac{W}{Q}$$

Emf (V) = potential difference in V  
W = work done in J  
Q = charge in C

### Lenz's Law

The induced current will flow in a direction to produce a magnetic field that will oppose the magnetic field of the magnet that is inducing the current.

### Elektromagnetiese induksie

Die verskynsel waar 'n emk (potensiaalverskil) en gevolglik 'n stroom deur 'n veranderende magneetveld in 'n geleier geïnduseer kan word.

#### Emk

Die werk verrig per eenheidslading  
(1 volt = 1 joule/coulomb).  
OF

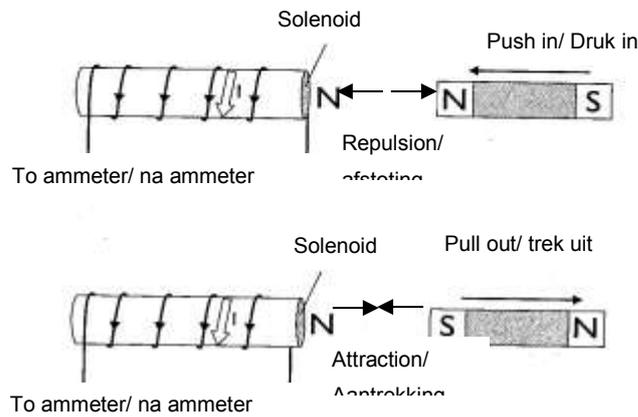
Die verskil in potensiaal wat neig om elektriese stroom te dryf.

$$Emk (V) = \frac{W}{Q}$$

Emk (V) = potensiaalverskil in V  
W = arbeid verrig in J  
Q = lading in C

### Lenz se Wet

Die geïnduseerde stroom sal in 'n rigting vloei om 'n magneetveld te produseer wat die magneetveld van die magneet wat die stroom induseer teen te werk.



## Mutual Induction

- An electric current can produce a magnetic field (electromagnetism).
- A changing magnetic field can induce a electric current (electromagnetic induction).
- When two coils are placed head-to-head against each other they can transfer electrical energy without being electrically connected. A changing current in the first (primary) coil creates a changing magnetic field. The changing magnetic field extends outwards from the primary coil increasingly linking with the secondary coil (flux linkage). The changing magnetic flux in the secondary coil induces an emf which results in current flowing in the secondary coil.
- A changing current can be produced in the primary coil by switching a DC on an off or by using an AC in the primary coil.

Factors that influence the induced emf (hence current) in a coil:

- speed of motion (or change of magnetic field). ( $\Delta t$ )
- the number of turns in the coil ( $N$ )
- the magnetic flux ( $\Phi = BA$ )

## PRACTICAL APPLICATIONS

1. Electromagnetic induction is used extensively in dynamos and generators for the generation of electricity.
2. Electromagnetic induction is of great importance in everyday life, because it forms the basis of electricity generation at power stations.
3. In transformers current flowing in the primary coil induces an emf in the secondary winding

## Handgedrewe Induksie

- 'n Elektriese stroom kan 'n magneetveld produseer (elektromagnetisme).
- 'n Veranderende magneetveld kan 'n elektriese stroom induseer (elektromagnetiese induksie).
- Wanneer twee spoel kop-aan-kop teen mekaar geplaas word, is hulle in staat om elektriese energie oor te dra sonder om elektries aan mekaar gekoppel te wees. 'n Veranderende stroom in die eerste (primêre) spoel veroorsaak 'n veranderende magneetveld. Die veranderende magneetveld vloei vanaf die primêre spoel na buite om toenemend die sekondêre spoel te sny (vloedkoppeling). Die veranderende magnetiese vloed in die sekondêre spoel induseer 'n emk wat veroorsaak dat 'n stroom in die sekondêre spoel vloei.
- 'n Veranderende stroom kan in die primêre spoel aangebring word deur 'n GS aan en af te skakel of om 'n WS in die primêre spoel aan te lê.

Faktore wat die geïnduseerde emk (dus stroom) in die spoel beïnvloed.

- Tempo van beweging ( of verandering in magneetveld). ( $\Delta t$ )
- Aantal windings in spoel ( $N$ )
- Die magneetvloed ( $\Phi = BA$ ).

## PRAKTIESE TOEPASSING

1. Elektromagnetiese induksie word op groot skaal in dinamo's en kragopwekkers vir die opwekking van elektrisiteit gebruik.
2. Elektromagnetiese induksie is van groot belang in ons daaglikse lewe, want dit vorm die basis vir kragopwekking by kragentrales.
3. In transformators induseer die stroom wat in die primêre spoel vloei, 'n emk in die sekondêre spoel.

<b>ACTIVITY EM.5</b> ELECTRICITY AND MAGNETISM	<b>AKTIWITEIT EM.5</b> ELEKTRISITEIT EN MAGNETISME
<b>Electromagnetic induction</b>	<b>Elektromagnetiese induksie</b>

NAME  
NAAM \_\_\_\_\_

DATE  
DATUM \_\_\_\_\_

GRADE  
GRAAD \_\_\_\_\_

**SECTION B**

**List of equipment**

- 2 Coils or solenoids (e.g. 120 T & 360 T)
- 2 Bar magnets
- Iron bar
- Current probe
- DC power supply or 2 size "D" torch cells (approximately 3 V)
- AC power supply (2 – 6 V)

**Precautions**

The current setting of the current probe must be high enough to handle the current flowing in the coil circuit. Max current 0,6 A.

**Preliminary activities**

- Connect a small electric motor (such as found in toys) to a small light bulb. Observe what happens if the spindle of the motor is turned fast.
- Do the electric power generated by the motor (which is now used as a generator) depend on the speed with which the spindle is turned?

**SECTION C**

Executing the experiment

**Experimental set-up of equipment**

**AFDELING B**

**Lys van benodigdhede**

- 2 spoele of solenoïdes (bv. 120 T & 360 T)
- 2 Staafmagnete
- Yster staaf
- Stroomsensor
- GS-kragbron of 2 "D"-grootte flits-selle (ongeveer 3V)
- WS-kragbron (2 – 6V)

**Voorsorgmaatreëls**

Die stroomstelling op die sensor moet hoog genoeg wees om die stroom in die spoel-stroombaan te hanteer. Maksimum stroom 0,6 A.

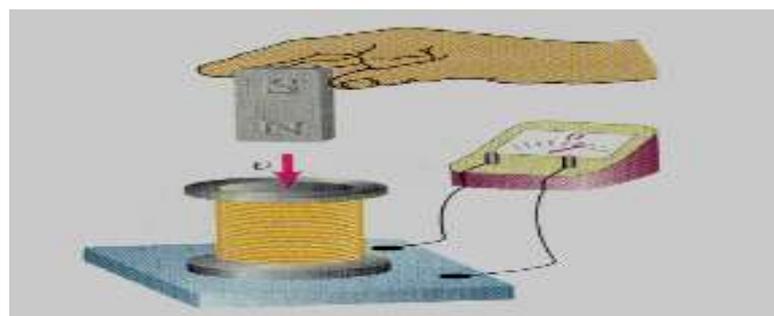
**Inleidende aktiwiteite**

- Koppel 'n klein elektriese motor (soos gevind in speelgoed) aan 'n klein gloeilampie. Neem waar wat gebeur as die spoel van die motortjie vinnig in die rondte gedraai word.
- Hang die elektriese krag wat deur die motortjie (wat nou as 'n opwekker gebruik word) opgewek word, af van die spoed waarmee die spoel gedraai word?

**AFDELING C**

Uitvoer van die eksperiment

**Eksperimentele opstelling van apparaat**



**Fig. 1**  
**Part I**

**Deel I**

## Electromagnetic Induction

- Connect a coil to the current probe.
- Open the file EM.5 LEARNER-PART 1
- Click  to record the current as the magnet is pushed into the coil.
- Repeat the previous step, but this time move the coil while keeping the magnet stationary.
- Repeat above steps, but reverse the poles of the magnet
- Repeat above steps but use different directions and orientations. Try to find out for which direction (of movement) and orientation (of the magnet relative to the coil) the induced current is
  - (a) a maximum,
  - (b) a minimum.
- Repeat the steps but change the following:
  - The speed with which the magnets moved
  - The strength of the magnet
  - The number of turns in the coil
- *Tabulate your results in Table 1 .*

## Elektromagnetiese Induksie

- Koppel 'n spoel aan die stroom sensor.
- Open EM.5 LEARNER-PART 1
- Klik  en neem die stroomlesings wanneer die magneet in die spoel gedruk word.
- Herhaal die vorige stap, maar beweeg hierdie keer die spoel terwyl die magneet stil gehou word.
- Herhaal bogenoemde, maar draai die pole van die magneet om.
- Herhaal bogenoemde stappe, maar gebruik verskillende rigtings en oriëntasies. Vind uit vir watter rigting van beweging en oriëntasie (van die magneet relatief tot die windings) is die geïnduseerde stroom:
  - (a) 'n maksimum,
  - (b) 'n minimum
- Herhaal die stappe, maar verander die volgende:
  - Die spoed waarteen die magneet beweeg word.
  - Die sterkte van die magneet.
  - Die aantal windings op die spoel.
- *Tabuleer jou resultate in Tabel 1.*

Table 1 / Tabel 1

Factors influencing strength of the induced current Faktore wat die sterkte van die geïnduseerde stroom beïnvloed.			
Factor/ Faktor	Symbol/ Simbool		Current / Stroom (Stronger / Weaker) (sterker / Swakker)
Speed with which magnet moves./ Spoed waarteen magneet beweeg.	Longer $\Delta t$	Slow / Stadig	
	Shorter $\Delta t$	Fast / Vinnig	
Strength of magnet./ Sterkte van die magneet.	Weaker $\Phi = BA$	Weak / Swak	
	Stronger $\Phi = BA$	Strong / Sterk	
Number of turns in coil (depending on the available coil)./ Aantal windings in die solenoïd (afhange van die beskikbare solenoïd )	Less $N$	240	
	More $N$	360	

### Question 1

Use the "Examine" button to determine the maximum value. What is the average current in the coil if:

1.1. the magnet is moved?

### Vraag 1

Gebruik die "Examine button" om die maksimum waarde te bepaal. Wat is die gemiddelde stroom in die spoel as:

1.1. die magneet beweeg word?

(1)	
1.2. the magnet is stationary?	1.2. die magneet stil gehou word?
1.3 What conclusion can you come to when you consider the results in 1.1 and 1.2?	1.3 Watter gevolgtrekking kan uit die resultate in 1.1 en 1.2 gemaak word?
1.3.1 Explain your answer in 1.3.	1.3.1 Verduidelik jou antwoord in 1.3.
(1)	
1.4 In what way does the current in the coil change if the poles of the magnet are reversed?	1.3 Op watter wyse verander die stroom in die spoel as die pole van die magneet omgeruil word?
(1)	
<b>Question 2</b>	<b>Vraag 2</b>
2.1. How does the current in the coil change when the magnet is moved faster?	2.1 Hoe verander die stroom in die spoel as die magneet vinniger beweeg word?
(1)	
2.1.1 Use Table 1 and your answer in 2.1 to formulate the mathematical relationship between emf ( $\epsilon$ ) and $\Delta t$ .	2.1.1 Gebruik Tabel 1 en jou antwoord in 2.1 om die wiskundige verwantskap tussen emk ( $\epsilon$ ) en $\Delta t$ te formuleer.
(1)	
2.2 What influence does the strength of the magnet have on the induced current?	2.2. Watter invloed het die sterkte van die magneet op die geïnduseerde stroom?
(1)	
2.2.1 Use Table 1 and your answer in 2.2 to formulate the mathematical relationship between emf ( $\epsilon$ ) and magnetic flux ( $\Phi$ ).	2.2.1 Gebruik Tabel 1 en jou antwoord in 2.2 om die wiskundige verwantskap tussen emk ( $\epsilon$ ) en magneetvloed ( $\Phi$ ) te formuleer.
(1)	
2.3. What influence does the number of turns in the coil have on the induced current?	2.3. Watter invloed het die aantal windings van die spoel op die geïnduseerde stroom?
(1)	
2.3.1 Use Table 1 and your answer in 2.3 to formulate the mathematical relationship between emf ( $\epsilon$ ) and number of windings (N).	2.3.1 Gebruik Tabel 1 en jou antwoord in 2.3 om die wiskundige verwantskap tussen emk ( $\epsilon$ ) en aantal windings (N) te formuleer
(1)	
2.4 Combine your answers in 1.1.1, 2.2.1 and 2.3.1 to formulate Faraday's law.	2.4 Combineer jou antwoorde in 1.1.1, 2.2.1 en 2.3.1 om Faraday se wet te formuleer.
(3)	
2.5 Give the mathematical equation for Faraday's law.	2.5 Gee die wiskundige vergelyking vir Faraday se wet.

(2)

2.6 Use the mathematical equation in 2.5 above and explain how Lenz's law is related to Faraday's law.

2.6 Gebruik die wiskundige vergelyking in 2.5 hierbo en verduidelik die verband tussen Lenz se wet en Faraday se wet.

(2)

**Part II**  
**Mutual Induction**

**Executing the experiment**

Set up the equipment as in the diagram below.

**Deel II**  
**Wedersydse induksie**

**Uitvoer van die eksperiment**

Stel die apparaat op soos in die skets hieronder.

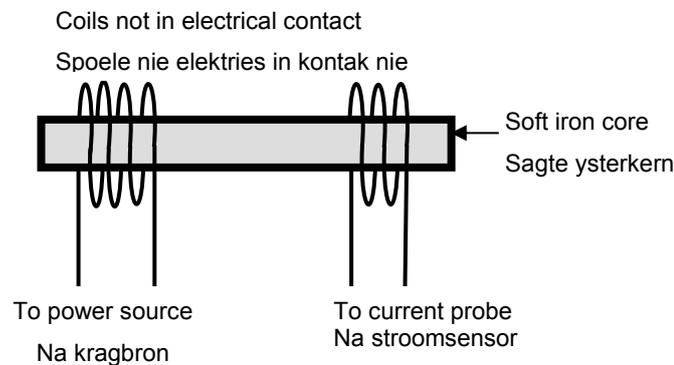


Fig. 2

**Procedure**

- Set up two coils of insulated wire next to each other and connect the one (called the **primary**) to a 3V **DC** power supply.
- Connect the other coil (called the **secondary**) to the current probe.
- Open file EM.5 LEARNER-PART 2
- Click  and switch the current in the primary coil **ON** and **OFF** a few times.
- Sketch the graph of the current vs time in the secondary coil.

**Prosedure**

- Stel die twee spoele van geïsoleerde draad langs mekaar op en verbind een spoel (**primêre** spoel) aan 3V **GS**-kragbron.
- Verbind die ander spoel (**sekondêre** spoel) aan die stroomsensor.
- Open EM.5 LEARNER-PART 2
- Klik  en skakel die stroom in die primêre bron 'n aantal kere **AAN** en **AF**.
- Teken die grafiek van stroom teenoor tyd vir die sekondêre spoel.

**Question 3**

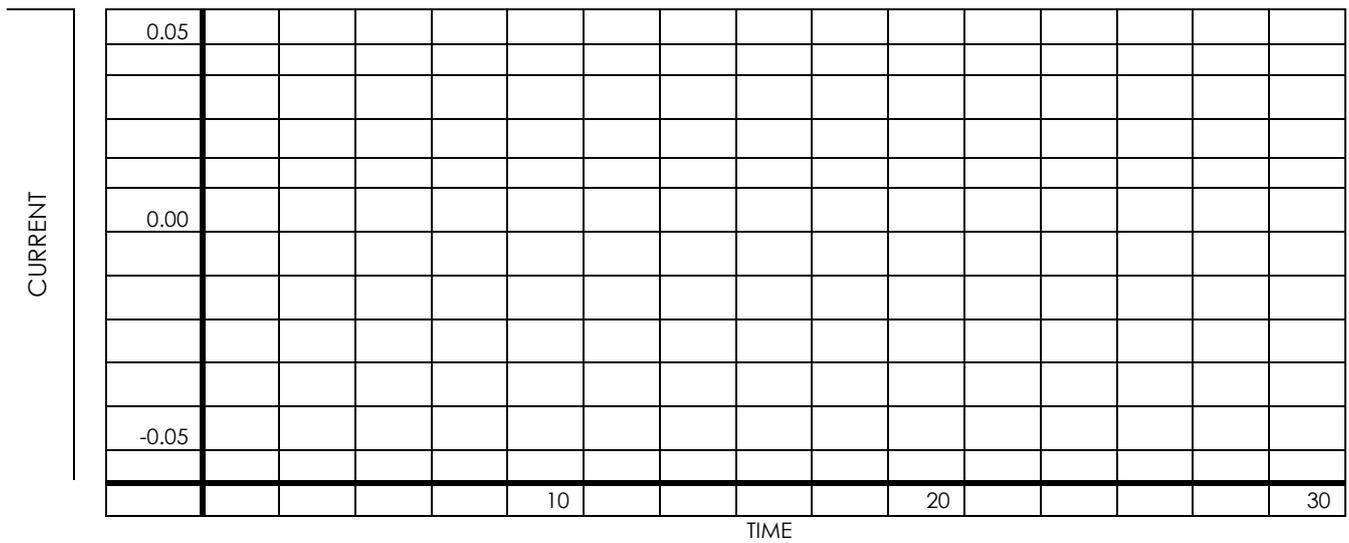
3.1. Sketch the graph of the current vs time for the secondary coil.

**Vraag 3**

3.1. Teken die grafiek van stroom teenoor tyd vir die sekondêre spoel.

Title / Titel

CURRENT vs TIME



**Graph: Assessment rubric**

**Grafiek: Asseseringsrubriek**

	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>X</b>
Graph Plotting Teken van grafiek	<ul style="list-style-type: none"> <li>• Correct title/ Korrekte naam</li> <li>• Both axes labeled/Byskrifte op beide asse</li> <li>• Induced current correctly indicated/ geïnduseerde stroom korrek aangedui</li> <li>• Variables plotted on the appropriate axe/ Veranderlikes op die korrekte asse geplaas.</li> <li>• All units correctly indicated/ Alle eenhede korrek aangedui</li> </ul>	4 of 5	2 – 3 of 5	1 of 5	Not attempted/ Geen poging aangewend  (5)

3.2. When is current induced in the secondary coil?

3.2. Wanneer word stroom in die sekondêre spoel geïnduseer?

(2)

3.3. When is current **NOT** induced in the secondary coil?

3.3. Wanneer word stroom **NIE** in die sekondêre spoel geïnduseer nie?

(2)

- Repeat the previous step, but instead of switching it on and off, connect the primary coil to an **AC** power supply.
- Repeat experiment but insert a soft iron core in the two coils.

- Herhaal die vorige stap, maar in plaas van die bron aan en af te skakel, verbind die primêre spoel aan 'n **WS**-kragbron.
- Herhaal die eksperiment, maar plaas 'n sagte ysterkern binne-in die twee spoele.

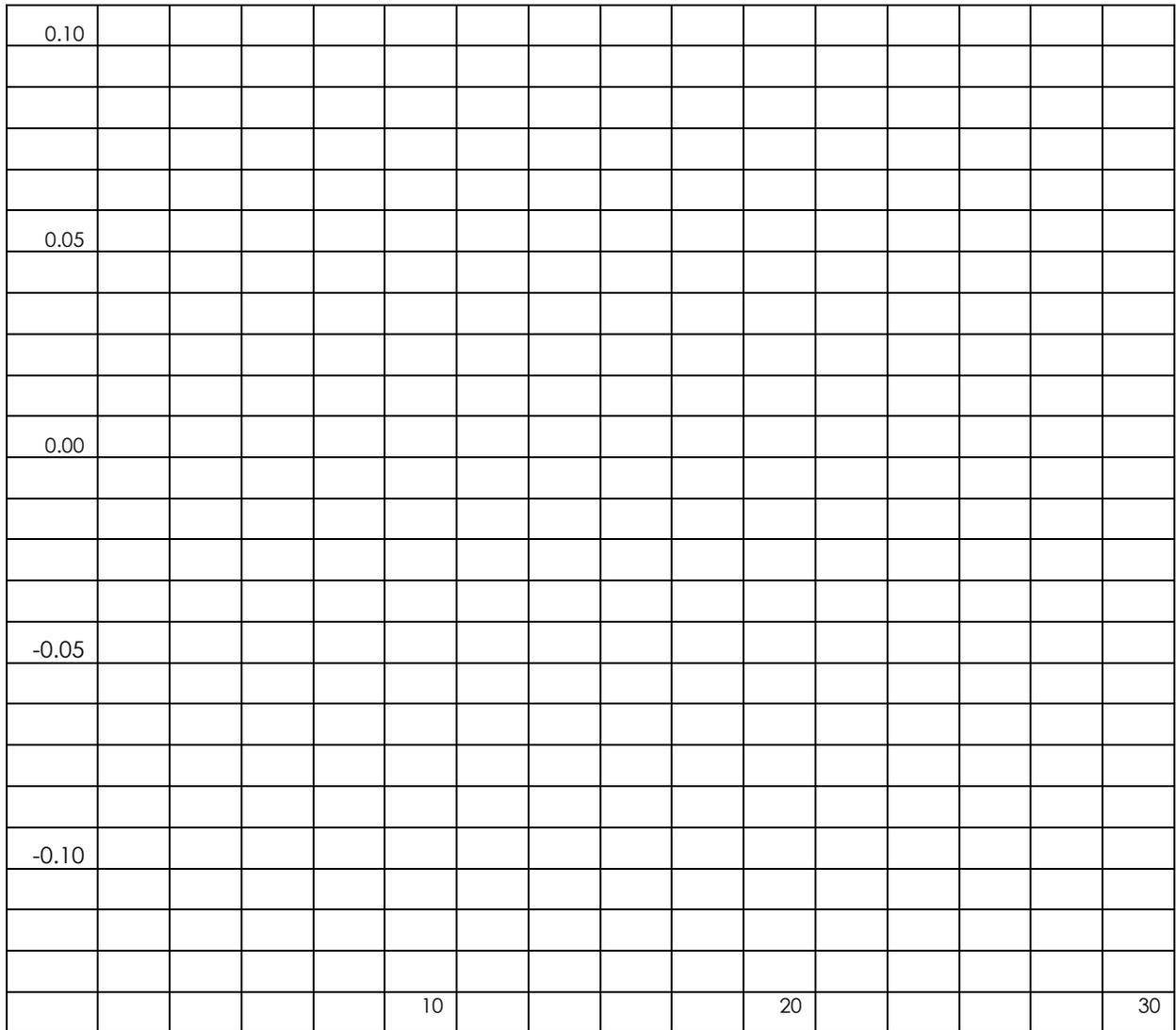
**Question 4**

4.1 Sketch the current vs time graph

**Vraag 4**

4.1. Teken die grafiek van stroom teenoor tyd

Title / Titel



**Graph: Assessment rubric**  
**Grafiek: Asseseringsrubriek**

	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>X</b>
<i>Graph Plotting</i> <i>Teken van grafiek</i>	<ul style="list-style-type: none"> <li>• <i>Correct title/ Korrekte naam</i></li> <li>• <i>Both axes labeled/Byskrifte op beide asse</i></li> <li>• <i>Induced current correctly indicated/ geïnduseerde stroom korrek aangedui</i></li> <li>• <i>Variables plotted on the appropriate axe/ Veranderlikes op die korrekte asse geplaas.</i></li> <li>• <i>All units correctly indicated/ Alle eenhede korrek aangedui</i></li> </ul>	4 of 5	2 – 3 of 5	1 of 5	Not attempted/ Geen poging aangewend  (5)

4.2 Redraw the graph in 4.1 and then show the effect of the iron core.

4.2 Oorteken die grafiek in 4.1 en toon dan die effek van die ysterkern aan.



(5)

5.3. Put forward a reason why it costs more to supply electricity in rural areas.

5.3. Verskaf 'n rede waarom dit duurder is om elektrisiteit aan landelike gebiede te voorsien?

(2)

**SCORING RUBIC**

**RUBRIEK**

NAME / NAAM	
GRADE / GRAAD	
DATE / DATUM	

<b>Assessment Levels Assesseringsvlakke</b>	<b>Mark out of 35 Punt uit 35</b>	<b>Percentage % Gemiddelde %</b>
1	0 – 10	0 – 29
2	11 – 13	30 – 39
3	14 – 17	40 – 49
4	18 – 20	50 – 59
5	21 – 24	60 – 69
6	25 – 27	70 – 79
7	28 - 35	80 - 100

**ASSESSMENT LEVEL / ASSESSERINGSVLAK**

## APPENDIX T: PRE- AND POST-INTERVENTION QUESTIONNAIRES

### **PRE-INTERVENTION QUESTIONNAIRE: THE USE OF PRACTICAL ACTIVITIES TO ADDRESS DIFFICULTIES IN ELECTRICITY AND MAGNETISM.**

Dear Participant

You have been chosen to take part in this research program by the University of Stellenbosch. You are kindly asked to answer the following questions to the best of your ability, following the instructions given. This questionnaire is part of a research study which intends to gather responses from high school learners currently in grade 11 on the Physical Science module Electricity and Magnetism (E&M).

**By completing this form you will be making an important contribution to this study. The results of the study will be used as part of the thesis and copies of the thesis may be made available to the relevant stakeholders in this research.**

Thank you for your participation!

**Surname and Name** :.....

### **GENERAL INSTRUCTIONS**

1. The questionnaire is divided into **seven questions**, answer all questions.
2. The questions require your own answers, so it is to be answered individually and in silence.
3. Please hand back the questionnaire immediately after completion.

### **Question 1: Personal Information**

In this section, you will be asked questions about yourself and your education. The choices for some questions will be written across the page as shown. Tick (✓) the block with the best answer. For the others, you will be expected to fill in the best answer.

- 1.1. In which Grade 11 class are you?                      11b  11c
- 1.2. Please indicate (✓) your age.    16years  17 years  Other (please specify)
- 1.3. Please indicate (✓) your gender.                      male  female
- 1.4. Indicate (✓) the grades attended at Khanyolwethu before grade 11?
- Grade 8                       Grade 9                       Grade 10
- 1.5. From the list below, please indicate (✓), **other than Physical Science**, the subjects

that you are currently taking. If a subject is not listed, fill it in the space provided.

Subject	(✓)	Subject	(✓)
Isixhosa		Computer Applications Technology (CAT)	
English		Life Sciences	
Afrikaans		Hospitality Studies	
Mathematics		Tourism	
Mathematical Literacy		Consumer Studies	
Life Orientation		Accounting	
Agricultural Sciences		<b>Other(s) (please specify below)</b>	
Business Studies			
Economics			
Geography			
History			
Religion Studies			

1.6. Indicate your performance in Physical Science in your last exam.

Rating Code	Description of Competence	Percentage	Indicate (✓)
7	Outstanding achievement	80-100	
6	Meritorious achievement	70-79	
5	Substantial achievement	60-69	
4	Adequate achievement	50-59	
3	Moderate achievement	40-49	
2	Elementary achievement	30-39	
1	Not achieved	0-29	

1.7. Indicate (✓) from which grade have you been doing science.

Grade 8  Grade 9  Grade 10

1.8. Home Language:

.....

1.9. Language in which Physical Science is taught at your school:.....

**Question 2 : Attitude toward science**

Please indicate how much you AGREE or DISAGREE with the following statements about your attitude towards science by ticking (✓) the relevant block.

2.1. Physical Science is my favourite subject.

Strongly Disagree  Disagree  Agree  Strongly Agree

2.2. I sometimes do science-related activities that are not for school work.

Strongly Disagree  Disagree  Agree  Strongly Agree

2.3. I take Physical Science only because I have to.

Strongly Disagree  Disagree  Agree  Strongly Agree

2.4. I take Physical Science only because it will help me in the future.

Strongly Disagree  Disagree  Agree  Strongly Agree

2.5. I take Physical Science because my parents insist on it.

Strongly Disagree  Disagree  Agree  Strongly Agree

2.6. I am good at science.

Strongly Disagree  Disagree  Agree  Strongly Agree

2.7. Science is boring.

Strongly Disagree  Disagree  Agree  Strongly Agree

2.8. How much time in a day, outside of class, do you spend on Physical Science?

Less than 1 hour  1 to 2 hours  2 to 3 hours  More than 3 hours

None (0 hours)

**Question 3: Perceived understanding of Electricity and Magnetism (E&M)**

Tick (✓) the block with the best answer.

3.1. In your science class this year, have you covered the module? Yes  No

3.2. In your opinion, what is your level of understanding of the following topics in E&M?

	Very Low	Low	High	Very High	Not sure
a) Current Electricity	<input type="checkbox"/>				

	Very Low	Low	High	Very High	Not sure
b) Electromagnetism	<input type="checkbox"/>				

3.3. I enjoy this section of science.

Strongly Disagree  Disagree  Agree  Strongly Agree

**Question 4: Practical Work (in general)**

Tick (✓) the block with the best answer. For the others, you will be expected to fill in the best answer.

4.1. In your science class this year, how often have you done science experiments?

- |  | <b>Check<br/>(✓)</b>     |
|--|--------------------------|
| A. Never   | <input type="checkbox"/> |
| B. Once or twice a month   | <input type="checkbox"/> |
| C. Once or twice a week  | <input type="checkbox"/> |
| D. Almost in every science period where experiments are applicable | <input type="checkbox"/> |

**(if your answer to 4.1. is A, move on to question 4.2. and skip 4.3. and 4.4.)  
If your answer to 4.1. is (B, C or D, continue with the rest of question 4)**

4.2. What is/are the main reason(s) given for not doing experiments? Following are possible reasons, please tick (✓) the appropriate box. You may tick more than one box.

- |   | <b>Yes</b>               | <b>No</b>                |
|---|--------------------------|--------------------------|
| A. Not enough time.   | <input type="checkbox"/> | <input type="checkbox"/> |
| B. Lack of the necessary equipment.                               | <input type="checkbox"/> | <input type="checkbox"/> |
| C. Large numbers of learners per class.                           | <input type="checkbox"/> | <input type="checkbox"/> |
| D. Inadequate understanding of practical work.                    | <input type="checkbox"/> | <input type="checkbox"/> |
| E. Disciplinary problems during practical sessions                | <input type="checkbox"/> | <input type="checkbox"/> |
| F. Belief that there is not much to be learnt from the practical. | <input type="checkbox"/> | <input type="checkbox"/> |

Other, please specify: .....  
.....  
.....

4.3. How were the experiments mostly done?

- |  | <b>check<br/>(✓)</b>     |
|--|--------------------------|
| A. Hands-on working in groups  | <input type="checkbox"/> |
| B. Hands-on working individually                                     | <input type="checkbox"/> |
| C. Demonstrations done by teacher                                    | <input type="checkbox"/> |
| D. Sometimes teacher demonstrations, sometimes hands-on by learners. | <input type="checkbox"/> |

4.4. When last did you do a science experiment?

	<b>check</b> (✓)
A. this week	<input type="checkbox"/>
B. last week	<input type="checkbox"/>
C. last month	<input type="checkbox"/>
D. more than a month ago	<input type="checkbox"/>

**Question 5: Practical Work on E&M**

Tick (✓) the block with the best answer. For the others, you will be expected to fill in the best answer.

5.1. In your science class this year, have you done experiments on any of the following topics?

a) Current Electricity (batteries, light bulbs resistors, connectors, circuits, etc)	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
b) Electromagnetism (solenoids, magnets, electric motor, etc)	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>

**(If your answer to 5.1a. is Yes, continue question 5.2)  
(if your answer to 5.1a. is No, move on to question 5.3 and skip question 5.2.)**

5.2. How were the experiments mostly done?

	<b>check</b> (✓)
A. Hands-on working in groups	<input type="checkbox"/>
B. Hands-on working individually	<input type="checkbox"/>
C. Demonstrations done by teacher	<input type="checkbox"/>
D. Sometimes teacher demonstrations, sometimes hands-on by learners.	<input type="checkbox"/>

5.3. Have you ever physically worked with the following components?

<b><u>Component</u></b>	<b><u>Picture??</u></b>	<b><u>Yes</u></b>	<b><u>No</u></b>
Cells (battery)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Connectors / wires	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Light bulbs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Resistors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ammeter	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
voltmeter	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
switch	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	_____	_____	_____
Electromagnet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Solenoid	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Electric motor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AC Dynamo	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5.4. The following are the possible experiments to be done in Grade 11 on the topics specified below. Please tick (✓) Yes or No to indicate whether you have done them or not, this year.

**Current Electricity**

	Yes	No
A. Simple DC Circuit.	<input type="checkbox"/>	<input type="checkbox"/>
B. Cells in series.	<input type="checkbox"/>	<input type="checkbox"/>
C. Cells in parallel.	<input type="checkbox"/>	<input type="checkbox"/>
D. Ohm's Law.	<input type="checkbox"/>	<input type="checkbox"/>
E. Resistors in series.	<input type="checkbox"/>	<input type="checkbox"/>
F. Resistors in parallel.	<input type="checkbox"/>	<input type="checkbox"/>
G. Mixed Circuits	<input type="checkbox"/>	<input type="checkbox"/>
H. Resistance and internal resistance	<input type="checkbox"/>	<input type="checkbox"/>

**Electromagnetism**

	Yes	No
A. Magnetic field associated with current – compass needle and a current carrying straight conductor.	<input type="checkbox"/>	<input type="checkbox"/>
A. Magnetic field associated with a current-carrying loop.	<input type="checkbox"/>	<input type="checkbox"/>
B. Magnetic field associated with a current-carrying solenoid.	<input type="checkbox"/>	<input type="checkbox"/>
C. Factors affecting the strength of the induced magnetic field.	<input type="checkbox"/>	<input type="checkbox"/>
D. Current induced by a changing magnetic field, i.e. what happens when a bar magnet is pushed into or pulled out of a solenoid connected to an ammeter.	<input type="checkbox"/>	<input type="checkbox"/>
E. Determining the direction of the induced current when a N-pole or a S-pole of a magnet is inserted or pulled out of a coil.	<input type="checkbox"/>	<input type="checkbox"/>
F. Determining the factors affecting the induced current.	<input type="checkbox"/>	<input type="checkbox"/>
G. Transformers	<input type="checkbox"/>	<input type="checkbox"/>

5.5. Would you like to do more experiments in E&M?  Yes  No

5.6. What, in your opinion, would be the value of experiments in your understanding of E&M?

.....  
.....  
.....

**Question 6:** Computer Skills

The majority of the experiments that will be done during this research make use of the TRAC program, which is computer based science experiments. Please answer the following questions pertaining to your computer skills.

Please indicate your level of knowledge regarding the following computer skills:

6.1. Understanding the basic components of a computer or laptop (monitor, cpu, mouse, keyboard, etc)?

- |                 |  |
|-----------------|--|
| A. Do not have. | <b>Check (✓)</b><br><input type="text"/> |
| B. Very low     | <input type="text"/>                     |
| C. Low.         | <input type="text"/>                     |
| D. High         | <input type="text"/>                     |
| E. Very high.   | <input type="text"/>                     |

6.2. Using a keyboard

- |   |                      |
|---|----------------------|
|   | <b>Check (✓)</b>     |
| A. I do not know how.                     | <input type="text"/> |
| B. Uncomfortable                          | <input type="text"/> |
| C. Somewhat comfortable but need practice | <input type="text"/> |
| D. Comfortable                            | <input type="text"/> |
| E. Highly comfortable                     | <input type="text"/> |

6.3. Using a mouse to move the cursor

- |   |                      |
|---|----------------------|
|   | <b>Check (✓)</b>     |
| A. I do not know how.                     | <input type="text"/> |
| B. Uncomfortable                          | <input type="text"/> |
| C. Somewhat comfortable but need practice | <input type="text"/> |
| D. Comfortable                            | <input type="text"/> |
| E. Highly comfortable                     | <input type="text"/> |

6.4. Starting or shutting down a computer

- |                       |   |
|-----------------------|---|
| A. I do not know how. | <b>Check (✓)</b><br><input type="text"/><br><hr/> |
|-----------------------|---|

- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

6.5. Using Icons to open a program

**Check (✓)**

- A. I do not know how.
- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

6.6. Using the Start Menu to open a program

**Check (✓)**

- A. I do not know how.
- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

6.7. Using "All Programs" to find and open a program

**Check (✓)**

- A. I do not know how.
- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

6.8. Using "Click & Drag"

**Check (✓)**

- A. I do not know how.
- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

6.9. Using Windows features (minimize, resize and exit buttons)

Check (✓)

- A. I do not know how.
- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

6.10. Using the drop down menu bar

Check (✓)

- A. I do not know how.
- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

6.11. Using the Tool bar icons

Check (✓)

- A. I do not know how.
- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

6.12. How to Scroll

Check (✓)

- A. I do not know how.
- B. Uncomfortable
- C. Somewhat comfortable but need practice
- D. Comfortable
- E. Highly comfortable

**Question 7: Other interventions**

Please answer the following questions regarding other Physical Science interventions you might have been exposed to this year.

7.1. Are there other Physical Science extra classes that you are currently attending or have attended this year? Please indicate (✓).

Yes  No

7.2. If yes, indicate in the space below, how regular? For example, once a week, or twice or during the holidays, etc.

.....  
.....

7.3. If yes, were the following topics covered during these interventions?

a) Current Electricity Yes  No

b) Electromagnetism Yes  No

7.4. Did you do any experiments on E&M during these interventions? Please indicate (✓).

Yes  No

Thank you

**POST-INTERVENTION QUESTIONNAIRE: THE USE OF PRACTICAL ACTIVITIES TO ADDRESS DIFFICULTIES IN ELECTRICITY AND MAGNETISM.**

Dear Participant

You have recently participated in this research program by the University of Stellenbosch, the aim of which was to gather responses from high school learners currently in grade 11 on the difficulties experienced in the Physical Science module Electricity and Magnetism (E&M). You are kindly requested to answer the following questions with regards to your experiences during this process.

Thank you once again for your participation!

**Surname and Name** :.....

**GENERAL INSTRUCTIONS**

1. Answer all questions.
2. The questions require your own answers, so it is to be answered individually and in silence.
3. Please hand back the questionnaire immediately after completion.

**Question 1:**

Tick (✓) the block with the best answer. For the others, you will be expected to fill in the best answer.

1.1. In which Grade 11 class are you?                      11b  11c

1.2. Please indicate (✓) your age.                      16years  17 years  Other (please specify)

1.3. Please indicate (✓) your gender.                      male  female

1.4. Indicate (✓) the grades attended at Khanyolwethu before grade 11?  
Grade 8                       Grade 9                       Grade 10

1.5. Did you attend all the sessions?                      Yes  No

1.6. If your answer to 1.5. is No, how many times were you absent?.....

1.7. How many learners were in your group?.....

1.8. What role did you play in your group? Indicate (✓). You may tick more than one box.

                    Yes                      No

G. Reading instructions.

--	--

H. Setting up apparatus.

--	--

I. Recording observations.

--	--

J. Operating the computer.

--	--

Other, please specify:

.....  
.....

**Question 2**

2.1. What did you enjoy the most about the practical sessions? Describe.

.....  
.....

2.2. What did you not like about these sessions? Describe.

.....  
.....

2.3. After participating in the practical sessions, do you think you would be able to successfully answer questions on E&M?

- A. Yes, very much
- B. Almost
- C. Somewhat
- D. Not at all, its highly ineffective

2.4. Describe which part(s) of the practical sessions did you find easy, which did you find difficult?

.....  
.....

2.5. Do you feel that the experiments done were necessary for your understanding of E&M or not? Explain.

.....  
.....

2.6. What, in your opinion, could be done to improve the practical intervention?

.....  
.....

2.7. Please rate the following exercise as good, adequate **or** poor

- 2.7.1. Practical Sessions: \_\_\_\_\_
- 2.7.2. Worksheets: \_\_\_\_\_
- 2.7.3. Facilitator: \_\_\_\_\_
- 2.7.4. Time allocated: \_\_\_\_\_

2.8. Would you like to do more experiments in future? Indicate (✓).

Yes

No

2.9. If your answer to **question 2.8.** is **Yes**, how often would you like to do experiments?

.....

2.10. Most of the experiments were done making use of computers. What value, if any, did the computers add to your experience of these practical sessions? Describe.

.....

.....

.....

2.11. Please describe any other experiences you might have had while performing these practicals.

.....

.....

.....

Thank you

## APPENDIX U: OBSERVATION SCHEDULES

### OBSERVATION SCHEDULE

#### **The use of practical activities to address difficulties in electricity and magnetism.**

The aim of this observation schedule is to discover any issues connected with or arising from the actual engagement of learners in the practical sessions. Its purpose is to form a clear impression of what actually happens in the sessions where practicals are used to address learner difficulties in electricity and magnetism. Basically the observer is trying to explore the learning experiences the learners are having, which will provide useful details to

- help us understand the contextual factors which might affect the way in which the intervention is viewed by the learners.
- help us to also discover areas of improvement for the study as well as the TRAC program.

#### **Recording the information**

Some of the factual information will be recorded immediately. Some, however, will be in the form of impressions, based upon what is observed. Brief notes will be made at the time, which will then be used at a later stage. A record, of the time and date will be kept. The researcher's thoughts will also be recorded during these observations.

#### **OBSERVATION LIST**

DATE: .....

#### **1. Context: student profile**

- 1.1. Number of students present: .....
- 1.2. Are the learners working individually, in pairs or groups?: .....
- 1.3. Level of student participation and interaction as required by the practical, i.e. are all learners involved OR are learners simply observing others doing the practical, etc? :  
.....  
.....

#### **2. Description of the session and delivery**

This is a description of the way in which:

- 2.1. the facilitator introduces the practical session,  
.....  
.....
- 2.2. offers reasons to learners for learning benefits of the practical session,

.....  
.....  
2.3. clarity of instructions given

.....  
.....

2.4. layout of the room in which the intervention is taking place.

.....  
.....

**3. Technical considerations**

3.1. Resources available to learners during the session:

.....  
.....

3.2. What use is being made of the resources?

.....  
.....

3.3. Possible problems/difficulties experienced during the use of the resource(s) issued.

.....  
.....

**4. THE LEARNER EXPERIENCE**

**4.1. Learner activity**

4.1.1. How easily do learners seem to be working with the equipment? Any problems evident?

.....  
.....

4.1.2. Evidence that learners can or cannot control the equipment.

.....  
.....

4.1.3. Evidence that learners understand the concept being investigated during the practical session.

.....  
.....

4.1.4. Learner ability to correct mistakes made while performing the practical.

.....  
.....

4.1.5. Learners' ability to use the computers, where applicable, e.g. mouse, keyboard, etc. Any variation evident in their competence?

.....  
.....

4.2. **Learner Motivation**

4.2.1. Evidence of how the learners appear to be feeling about the practical session. (Confidence, enjoyment, anxiety, frustration, boredom, etc)

.....  
.....

4.2.2. Are they clear about what they are supposed to do?

.....  
.....

4.2.3. The questions learners ask (about subject content, technical uncertainties, problems with hardware/software?) and to whom do they address these questions? (each other, facilitator, educator)

.....  
.....  
.....  
.....  
.....  
.....

4.3. **Unexpected problems encountered**

4.3.1. Description of the nature of problem.

.....  
.....  
.....

4.3.2. Is it experienced by all learners or a few?

.....

4.3.3. Nature of solution(s) used to solve the problem, if solved. If not, alternate arrangements.

.....  
.....

## APPENDIX V: LETTER OF PERMISSION – DOE



WESTERN CAPE  
Education Department

Provincial Government of the Western Cape

METROPOLE EAST EDUCATION DISTRICT  
METRO OOS ONDERSWYSDISTRIK  
ISITHILI SEMFUNDO IMETRO EAST

[mdiergaa@pgwc.gov.za](mailto:mdiergaa@pgwc.gov.za)

tel: +27 21 900 7021 fax: 086 218 1226

C/o Belhar & Nooiensfontein Road, Kuils River 7580

Private Bag X23, Kuils River 7579

**REFERENCE:** TRAC Research at Khanyolwethu

**ENQUIRIES:** Marius Diergaardt

**PRINCIPAL:** Khanyolwethu Sec.

We hereby want to confirm that after discussions amongst MEED, the Principal of Khanyolwethu and TRAC, we came to the following agreement.

Mrs Kotela will include Khanyolwethu Sec. in her research project which will run during the 2011 and 2012 academic year.

The district gave consent to this intention as it will also benefit the school. The Principal of the above mentioned school also agreed and did commit himself to the cooperation that it might require.

We wish her well with her studies.

Kind regards

B. O. Scherereka

Signed:

A handwritten signature in black ink, appearing to read 'B. O. Scherereka', written over a horizontal line.

The Curriculum Manager

Metro East Education District

11 April 2011

## APPENDIX W: LETTER OF PERMISSION BY PARENTS : ENGLISH VERSION

### PARENT CONSENT FORM FOR LEARNER PARTICIPATION IN THE RESEARCH

**Dear Parent/Guardian**

Your son/daughter has been selected to participate in a research study conducted by Mrs Beauty Kotela (M.Ed), from the Education Department at Stellenbosch University, the results of which will be contributed to a thesis. Your child was selected as a possible participant in this study because he/she is a grade 11 Physical Science learner at Khanyolwethu High School in which the research is to take place.

The purpose of this research study is to investigate the learners' conceptual difficulties in Electricity and Magnetism and to investigate the implementation of a practical activities based approach to addressing these difficulties. We also believe that this study will make a contribution in the conceptual understanding of Electricity and Magnetism of the identified learners.

The proposed study will take place for a duration of approximately four months, resuming in August 2011 and will be taking place after school at no cost to the learners, the parents or the school.

**The following form, if signed, gives your consent for your son/daughter to participate in this research study.**

LEARNER INFORMATION	
Surname	
Name	
Contact Number	
PARENT / GUARDIAN INFORMATION	
Surname	
Name	
Contact Number	

I \_\_\_\_\_, parent / guardian of \_\_\_\_\_ hereby give permission for my child to participate in this research study, conducted by Mrs Beauty Kotela from the Education Department of the University of Stellenbosch and to take part in all educational activities relating to this study.

\_\_\_\_\_  
**SIGNATURE OF PARENT/GUARDIAN**

\_\_\_\_\_  
**SIGNATURE OF LEARNER**

\_\_\_\_\_  
**DATE**

Regards

T.E. Titipana  
Acting Principal

## APPENDIX X: LETTER OF PERMISSION BY PARENTS (ISIXHOSA VERSION)



### KHANYOLWETHU SECONDARY SCHOOL

☎ 021 845 5290

☎ 021 845 9446

✉ [admin@khanyolwethu.wcape.school.za](mailto:admin@khanyolwethu.wcape.school.za)

📮 P.O. BOX 441, STRAND, 7140

📍 Noxolo Street, Lwandle, Strand

**06 May 2011**

Mzali obekekileyo,

Umntwana wakho (unyana okanye intombi) utyunjwe ukuba athabathe inxaxheba kwizifundo zophando (Research) eziqhutywa ngu Nkosikazi Beauty Kotela (M.Ed) kwicandelo lezemfundo kwiDyunivesithi yase - Stellenbosch. Iziphumo zezi zifundo zophando zizakuba yinxalenye yeThesis yakhe.

Umntwana wakho utyunjwe kuba esenza isifundo senzukulwazi (Physical Science) kwibanga leThoba (Gr. 11) apha e Khanyolwethu, kuba kulapho uphando (Research) luzakuqhutywa khona.

Injongo okanye isizathu sokwenziwa kwesi sifundo kukuphanda ukuba bunzima buni abathi abafundi bahlangabezane nabo kwicandelo lezombane (Electricity) namandla (Magnetism) awo, nokuba sisombululo sini na esinokufumaneka. Siyathemba ukuba esi sifundo sophando sizakukhokhelela kulwazi olululo ekuncedeni abafundi.

Olu phando lucetywayo luzakuthabatha iinyanga ezine (4 Months) kususela ku - August ka 2011, yaye luzakuqhubeka emva kokuphuma kwesikolo kungekho nazindleko zamali ezichaphazela abazali nabafundi.

IINKCUKACHA ZOMFUNDI	
Ifani	
Igama	
Iinombolo zomnxeba	
IINKCUKACHA ZOMZALI	
Ifani	
Igama	
Iinombolo zomnxeba	

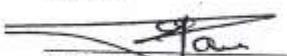
Mna \_\_\_\_\_ Umzali ka \_\_\_\_\_  
 ndigunyazisa ndinika nemvume yokuba umntwana wam angathabatha inxaxheba kwezi zifundo zophando oluqhutywa ngu Nkosikazi Kotela wecandelo lezemfundo kwiDyunivisithi yase - Stellenbosch, kuquka nezinye inkqubo ezihamba nolu phando.

ISignitsha yomzali

ISignitsha yomfundi

Umhla

Enkosi

  
 T.E. Titipana  
 (Ibambela Nqununu)



## APPENDIX Y: SU CONSENT



UNIVERSITEIT • STELLENBOSCH • UNIVERSITY  
jou kennisvenoot • your knowledge partner

### STELLENBOSCH UNIVERSITY CONSENT TO PARTICIPATE IN RESEARCH

---

#### **The use of practical activities to address Grade 11 learners' conceptual difficulties in electricity and magnetism.**

You are asked to participate in a research study conducted by **Beauty Kotela, B.Ed (Hons)**, from the Education Faculty at Stellenbosch University. The results will contribute to a Masters thesis. You were selected as a possible participant in this study because you are a grade 11 Physical Sciences learner at the selected school and will be doing the module Electricity and Magnetism, which is the focus of this research.

#### **1. PURPOSE OF THE STUDY**

To investigate the learners' conceptual difficulties in electricity and magnetism and to investigate the implementation of a practical activities based approach to addressing these difficulties.

#### **2. PROCEDURES**

If you volunteer to participate in this study, we would ask you to do the following things:

- 2.1. Complete a questionnaire**
- 2.2. Attend the science classes**

As a participant in this study you need to attend all the classes taught by your teacher during the normal science period(s) in which the content for the module Electricity and Magnetism (E&M) will be covered at your school. This will be done only theoretically.

#### **2.3. Write pre-test**

After covering the E&M content theoretically, you will be writing a short pre-test which aims to assess your understanding of the concepts. You are expected to adequately prepare for this test as you would for any other test. This test will be written at your school, either during the science period or during the study sessions after school on a day and date agreed upon by the participants, the teacher and the researcher.

#### **2.4. Attend Practical Sessions**

After the pre-test, the same concept will be covered again. This time an experiment or experiments pertaining to it will be done by the participants working in groups. You are expected to attend all the practical sessions. These sessions will be conducted by the researcher during the study sessions in the science lab at your school.

#### **2.5. Write post test**

Soon after the practical session, you will write a short post-test on the same concept to determine whether or not the practical session(s) had any impact on your understanding of that particular concept. This will also be written either during the science period or study session after school.

### **3. POTENTIAL RISKS AND DISCOMFORTS**

There are no risks associated with this study at all. To avoid inconveniences and discomforts, the research process has been structured such that we utilize the study times (14:30 – 15:30) which your school already has in place. This means that, there is no real infringement on your personal time. Due to the nature of practical work however, it might happen in some cases that the practical might take a little longer than an hour, in which case you are asked to stay in order to complete the experiment.

### **4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY**

Following are the possible benefits from participation in this research:

- possible increased understanding of the concepts covered
- an opportunity to experience hands-on the concepts that would only have been done theoretically
- you also get to work with computers due to the nature of the equipment being used, thereby contributing to your computer literacy skills.

### **5. PAYMENT FOR PARTICIPATION**

You, the participant, will not receive any payment for participation in this study.

### **6. CONFIDENTIALITY**

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of utilizing **pseudonyms**. The data collected in the form of hard copies of the tests, will be stored under lock and key at the office of TRAC Western Cape at the University of Stellenbosch, **for a period of 15 years or longer**. Numeric data and electronic copies of information will be kept in the researcher's computer and access will be granted to personnel involved in the study, namely the supervisor, TRAC SA (facilitators of the funding through National Department of Transport), the relevant science educators, school principal and authorized Stellenbosch University staff.

One of the data collection methods to be utilized is the interview method whereby you might be interviewed while you are busy doing the experiments. This content will be audio-taped for use by the researcher. You have the right to review the tapes and this must be done through the school principal. Access to these tapes is also granted to the persons mentioned in the previous paragraph.

The researcher will be publishing this research in the form of a thesis and to maintain confidentiality, your name will not be used but codes. Copies of this thesis will be kept by TRAC SA as well.

### **7. PARTICIPATION AND WITHDRAWAL**

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. The only possible circumstance under which your participation may be terminated without regard to your consent is gross misconduct and/or damage to the equipment utilized during this research.

### **8. IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about the research, please feel free to contact **Mrs Beauty Kotela the Principal Investigator at 021 808 3555, or Mr Nazeem Edwards, the Supervisor at 021 808 2291.**

### **9. RIGHTS OF RESEARCH SUBJECTS**

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

**SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE**

The information above was described to me by *Mrs Beauty Kotela* in *English and isiXhosa* and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

\_\_\_\_\_  
**Name of Subject/Participant**

\_\_\_\_\_  
**Name of Legal Representative (if applicable)**

\_\_\_\_\_  
**Signature of Subject/Participant or Legal Representative**

\_\_\_\_\_  
**Date**

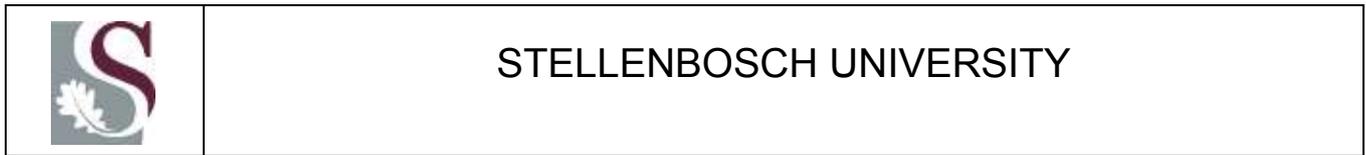
**SIGNATURE OF INVESTIGATOR**

I declare that I explained the information given in this document to \_\_\_\_\_.  
He/she was encouraged and given ample time to ask me any questions. This conversation was conducted in English and Xhosa and no translator was used.

\_\_\_\_\_  
**Signature of Investigator**

\_\_\_\_\_  
**Date**

## APPENDIX Z: MINOR CONSENT



### PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM



**TITLE OF THE RESEARCH PROJECT:**

**The use of practical activities to address Grade 11 learners' conceptual difficulties in electricity and magnetism.**

**RESEARCHERS NAME(S): Beauty Kotela (Mrs)**

**ADDRESS: House # 2, Helderberg College, Annandale Road, Somerset West**

**CONTACT NUMBER: 021 808 3555**

**What is RESEARCH?**

**Research is something we do to find new knowledge about the way things (and people) work. We use research projects or studies to help us find out more about disease or illness. Research also helps us to find better ways of helping, or treating children who are sick.**

**What is this research project all about?**

The aim of this research is to find out what conceptual difficulties are experienced by you, the learner, in the module Electricity and Magnetism (E&M). This will be found out by making use of tests, questionnaires and interviews which you are requested to take. When that has been established, by looking at the test marks and your answers to the questionnaire, we will investigate how the use of practical activities addresses these conceptual difficulties, by actually doing experiments in this module. After this, we will find out, also by using tests, interviews and a questionnaire, if the practical activities based approach does have an effect and how it has enhanced your learning in the module E&M.

## **Why have I been invited to take part in this research project?**

You were selected as a possible participant in this study because you are a grade 11 Physical Sciences learner at the selected school and will be doing the module Electricity and Magnetism, which is the focus of this research.

## **Who is doing the research?**

The research will be conducted by me, **Mrs Beauty Kotela** from the Education Faculty at Stellenbosch University, working for TRAC SA within the university. The results will contribute to a Masters thesis which is utilised by the university and TRAC SA to contribute to the improvement of the teaching and learning of the module Electricity and Magnetism.

## **What will happen to me in this study?**

If you volunteer to participate in this study, we would ask you to do the following things:

### **2.6. Complete a questionnaire**

### **2.7. Attend the science classes**

As a participant in this study you need to attend all the classes taught by your teacher during the normal science period(s) in which the content for the module Electricity and Magnetism (E&M) will be covered at your school. This will be done only theoretically.

### **2.8. Write pre-test**

After covering the E&M content theoretically, you will be writing a short pre-test which aims to assess your understanding of the concepts. You are expected to adequately prepare for this test as you would for any other test. This test will be written at your school, either during the science period or during the study sessions after school on a day and date agreed upon by the participants, the teacher and the researcher.

### **2.9. Attend Practical Sessions**

After the pre-test, the same concepts will be covered again. This time an experiment or experiments pertaining to it will be done by the participants working in groups. You are expected to attend all the practical sessions. These sessions will be conducted by the researcher during the study sessions in the science lab at your school.

### **2.10. Write post test**

Soon after the practical session, you will write a short post-test on the same concepts to determine whether or not the practical session(s) had any impact on your understanding of that particular concept. This will also be written either during the science period or study session after school.

## **Can anything bad happen to me?**

There are no risks associated with this study at all. To avoid inconveniences and discomforts, the research process has been structured such that we utilize the study times (14:30 – 15:30) which your school already has in place. This means that, there is no real infringement on your personal time. Due to the nature of practical work however, it might happen in some cases that the practical might take a little longer than an hour, in which case you are asked to stay in order to complete the experiment.

## **Can anything good happen to me?**

If you participate in this research, the following are the possible benefits you might experience:

- You should gain an increased understanding of the concepts covered.
- You also get an opportunity to experience hands-on the concepts that would only have been done theoretically.
- In addition to the above, you also get to work with computers, due to the nature of the equipment being used, thereby contributing to your computer literacy skills.

### Will anyone know I am in the study?

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of utilizing codes instead of your name. The data collected in the form of hard copies of the tests, will be stored under lock and key at the office of TRAC Western Cape at the University of Stellenbosch. Numeric data and electronic copies of information will be kept in the researcher's computer and access will be granted to personnel involved in the study, namely the supervisor, TRAC SA (facilitators of the funding through National Department of Transport), the relevant science educators, school principal and authorized Stellenbosch University staff.



### Who can I talk to about the study?

If you have any questions or concerns about the research, please feel free to contact me, **Mrs Beauty Kotela the Principal Researcher at 021 808 3555**, or **Mr Nazeem Edwards, my Supervisor at 021 808 2291**.

### What if I do not want to do this?

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind, even if your parents had agreed that you participate. In other words, you can stop being in the study at any time and will not get into trouble.

Do you understand this research study and are you willing to take part in it?

YES

NO

Has the researcher answered all your questions?

YES

NO

Do you understand that you can pull out of the study at any time?

YES

NO

\_\_\_\_\_  
Signature of Child

\_\_\_\_\_  
Date