The Effectiveness of the Use of Practical Work in Teaching Electric Circuits in Grade 11 Physical Sciences

by

Busiswa Xongwana

Submitted in fulfilment of the requirements for the degree of

Masters in Science Education

In the Science Learning Centre for Africa

of the Faculty of Education

at the University of the Western Cape

SUPERVISOR: PROF. M.S. HARTLEY

Declaration

I, Busiswa Xongwana, declare that the work **The Effectiveness of the Use of Practical Work in Teaching Electric Circuits in Grade 11 Physical Sciences** is my own original work and has not been submitted to any other university for a degree. All sources have been fully acknowledged in the text and a list of references have been provided.

Busiswa Xongwana **Date**

Acknowledgements

Firstly, I would like to thank God Almighty for giving me the strength and sustained me throughout the completion of this study.

My special thanks go to my supervisor Professor Hartley for his encouragement, patience, support, motivation, consistent guidance, advice and for his countless efforts of striving to get funding and resources for this course to be a success. Without his efforts through sacrificing holidays, his constructive criticism and even sacrificing his own money, my dream would have never been fulfilled. I am sincerely grateful to you Professor Hartley.

I would also like to extend word of gratitude to Professor Chetty for his assistance and Melissa Petersen who did all the arrangements in the background.

I also acknowledge the support and funding that I received from the Eastern Cape Department of Education.

I am indebted to the education district and the principal of the school where the study was conducted as well as the teachers, learners and parents that were involved.

Lastly, my appreciation goes to my daughter Sibabalwe who never complained when her mommy was always away from home.

Dedication

This study is dedicated to my family. Firstly, my mother, Thenjiwe Sese, who has been constantly praying for me and for the laying foundation for my education. Secondly, my late husband, Simthembile Mzilikazi, who was always my pillar of strength in everything. Thirdly my daughter, Sibabalwe Mzilikazi, who was understanding when I was unable to spend quality time with her during holidays, my niece Thando Xongwana who assisted me with technical aspects and lastly my younger brother, Khulekani “Mr Cools”, who was always there for me when I needed assistance in making drawings.

Glossary

Abbreviations	**Explanation**
DoE	Department of Education
SALT	South African Large Telescope
CAPS	Curriculum and Assessment Policy Statement
NDR	National Diagnostic Report
ECDoE	Eastern Cape Department of Education
LO	Life Orientation
TIMSS	Third International Mathematics and Science Study
LAIS	Learner Attainment Improvement Strategies
HOD	Head of Department
DBE	Department of Basic Education
ICT	Information, Communication and Technology
FET	Further Education and Training

The Effectiveness of the Use of Practical Work in Teaching Electric Circuits in Grade 11 Physical Sciences

Abstract

There is a history of poor results in grade 12 physical sciences in South Africa. This underperformance is particularly evident in the Eastern Cape's rural areas generally and in previously disadvantaged schools in specific. There are several factors that lead to this problem. One factor that has been identified is the lack of practical work in science teaching due to lack of resources for practical work. This study investigated the effectiveness of the use of practical work to teach electric circuits in grade 11. The researcher was prompted by the National Diagnostic Report for grade 12 for the past four years which showed that learners were not doing well on practical-based questions on electric circuits. The case study was conducted in a rural school where the researcher is employed in Dutywa district in the Eastern Cape Province. Two grade 11 classes participated in the research; one as a control group consisting of 60 learners and the other as an experimental group with a total of 65 learners. This study is underpinned by the theory of constructivism. Data was collected using qualitative and quantitative research methods. Two instruments, questionnaires and interviews, were used in the research. The study found the practical approach to teaching electric circuits resulted in learners achieving higher marks in tests compared to the class where purely theoretical approach was adopted. The study also highlighted that learners expressed a greater appreciation for being hands-on in the physical sciences classroom as they perceived that this activity improved their understanding and achievement in physical sciences tests and examinations. The study proposes a greater integration of practical work during teaching which could lead to a positive effect on physical sciences results in the Eastern Cape. Greater involvement of learners through practical work could help learners to understand better practical-based questions on electric circuits and could also serve as a teaching strategy to improve learning in other areas of the curriculum.

Keywords: Science Education, electric circuits, practical work, rural schools, physical sciences

Contents

List of tables

List of figures

CHAPTER 1

Background to the study

1.1 Introduction

South African education is challenged by underperforming learners. This is especially true in the case of grade 12 physical sciences and mathematics results. Science is an important subject in the world as it focuses on developing learners to investigate physical and chemical phenomenon through scientific enquiry, as can be seen in the South African Large Telescope (SALT) project situated in Sutherland. Through the application of scientific models, theories and laws it seeks to explain and predict events in the physical world. This subject also looks at how society can benefit from the environment, care for it and use it responsibly (DoE, 2001). Through science, governments and scientists worldwide, are working to develop affordable and clean energy technologies. Solar energy will provide a practically inexhaustible resource that will enhance sustainability, reduce pollution and lower the cost of mitigating climate change (Quest magazine, 2015). These scientific enquiries can be explored when learners are exposed to hands-on science activities through the effective use of practical work in teaching and learning. This chapter will provide the context and rationale for the study and will highlight the research problem, research question, significance and limitations of the study.

1.2. State of science education in South Africa

This study emerged because of ever-growing deficient performance in science education in rural South African schools. The mediocre performance of South African learners in physical sciences can be observed both nationally and internationally. In 2001 and 2003 the trends in TIMSS were conducted globally and South Africa was part of this study (Howie, 2003). In 2001, 38 countries participated in the study with the view to determining learner performance in sciences; in 2003, a total of 58 countries participated and in both instances South African learners were placed last (Makgato & Mji, 2006). From 2005 to 2007, the number of learners who passed physical sciences at the higher-grade level gradually decreased and this affected their entry into science based programmes at universities (Kriek & Grayson, 2009).

Table 1 shows the percentage of South African learners who passed physical sciences between 2005 and 2007 as highlighted by Kriek & Grayson (2009).

Table 1: Percentage of learners passed physical sciences on HG between 2005 and 2007

Year	Percentage of learners passed physical sciences on HG
2005	29,97
2006	29,78
2007	28,12

The percentages in Table 1 show the findings of research that was conducted ten years ago, by Kriek and Grayson (2009) which indicated deficient performance in South African learners in physical sciences. Clearly South African learners are not performing well in the science field. South Africa is still faced with challenges of underperformance in physical sciences as it was the case ten years ago; as reflected in Table 2 which indicated the performance of learners in physical sciences in the new curriculum called Curriculum and Assessment Policy Statement (CAPS).

Table 2: Overall achievement of grade 12 learners in physical sciences

Year	% achieved at 30% and above	% achieved at 40% and above	% achieved at 50% and above
2011	53.4	33.8	19.6
2012	61.3	39.1	22.2
2013	67.4	42.7	24.7
2014	61.5	36.9	24.6
2015	58.8	36.1	22.7
2016	62.0	39.5	22.5

Out of 53.4% of learners that passed physical sciences in 2011, only 33.8% obtained 40% and above with 53.4% obtaining only 30% pass which is a very poor pass rate. The trend of 30% pass, which is a very poor pass (a level 2 pass rate), increased from 2011 to 2013 and this indicates a drop in learner performance in physical sciences. These results clearly reflecting that learners are struggling to pass physical sciences (NDR, 2014).

1.3 Challenges in Science Education provincially and at the district level

In the Eastern Cape, poor results in physical sciences in grade 12 remain a challenge. Several possible factors which were identified thirteen years ago, by Reddy (2004) are currently contributing to underperformance of learners in physical sciences. Based on my own experience as physical sciences educator over the past thirteen years of teaching, learners underperform due to some of the following factors:

1.3.1 Lack of resources

Inaccessibility of resources in schools contributes to the teaching and learning of physical sciences. Learners understand and learn better when they are given the chance to be hands on with the subject matter. As highlighted by a learner in an interview in research conducted by Makgato (2007) that; it is “better when you are taught about something that you can see” (p 260). It is difficult for a learner to understand when theoretical taught that if you react this substance with that substance will give you that than when doing it practical. Science is much better understood when it is done practical.

Makgato (2007) noted that majority of schools that offer mathematics and physical sciences do not have facilities and equipment to promote effective teaching and learning. The teaching of mathematics and physical sciences remain at a theoretical level without any experiments to enhance understanding and application of knowledge. Though the DoE (2001) has highlighted that there is a lack of resources in schools, this situation remains a problem that leads to deficient performance of learners.

1.3.2 Under-qualified and unqualified educators

Many educators who are teaching mathematics and physical sciences are under qualified to teach these subjects (Makgato, 2007). The findings in the Mathematics and Science Audit in 1999 indicated that more than 50% of mathematics teachers and 68% of science educators had no formal subject training in these subjects (Mangena, 2001). Although they were properly qualified as educators, their training in teaching mathematics and science was insufficient.

1.3.3 Absenteeism by both educators and learners

Researchers reported that some educators and learners especially in remote rural schools were sometimes lazy to attend school. In a few legitimate cases the reasons for absenteeism are that there were no proper access roads to schools, learners had to cross bridges that were not properly built and some were crossing rivers which were not safe during rainy seasons (Musiyoki, Thifhufhelwi & Murungweni, 2016).

1.3.4 Negative attitude of learners towards physical sciences

Some learners have negative attitude towards physical sciences because it is regarded as the most difficult subject. Science seems to be abstract for learners; at times, they find it difficult to understand scientific concepts (Olasimbo & Rotimi, 2012). That is why it is important for educators to do demonstrations when teaching and to involve learners in practical based activities. Science taught at school sometimes contradicts cultural beliefs and backgrounds. For example, in isiXhosa it is believed that lightening can be caused by witch doctors. However, in science at school learners are taught that it is caused by building up of charges in the clouds.

The use of demonstrations and practical work gives a learner the opportunity to understand school knowledge and differentiate between myth and reality. Furthermore, to lessen the negative attitude in learners towards science learners should be introduced to science during their initial stages of development. At Foundation Phase, learners should be given puzzles that could develop their scientific skills like problem solving, observations, identification of variables, data handling and analysis, drawing up conclusions, investigation skills and inquiring skills.

1.3.5 Lack of participation in science activities

Learning of science should be made fun to learners. When the learners are participating in co-curriculum activities they develop the appreciation of science at the same time learning is taking place. Learners need to be exposed in science activities like reading of science magazines and other science related journals, science expos, science festivals, national science week, science clubs and career exhibition in the field of science so that their attitudes would be changed for better. These activities would help them to develop problem-solving skills and scientific enquiry skills that can be applied in answering higher order questions. Educators are reluctant to expose learners in science activities; they find them to be time consuming (Muhammad, 2017). Exposing learners to these activities could have a supportive effect on learners and could serve to address the high rate of failure in physical sciences.

As evidence to this, my learners at school participated in mini-quiz mathematics and science competition in May 2015 and won the third place in a group competition, one of them won the first place in an individual competition; now he is going to represent the province in national minquiz competition (see appendix J). Hartley (2014) in a study of the role of science clubs reported that rural high school learners who were members of a science club that won a science competition were motivated in such a manner that out of nine science club members, four of them enrolled for engineering studies and the others followed science degrees. Exposing learners to science clubs and science-related activities makes learners appreciate science and the positive attitude produces satisfactory results.

1.3.6 Misconceptions of scientific terms

Learners have misconceptions in scientific terms. It has been repeatedly noted in National Diagnostic Report (2014) that learners have misconceptions in using scientific terminology and this result into answering questions incorrectly.

1.3.7 Limited time allocation in the Curriculum and Assessment Policy Statement (CAPS)

Curriculum and Assessment Policy Statement indicates that practical work must not be separated from theory to strengthen the concept being taught. It is stated in CAPS (2010) that the practical work can be in the form of a practical demonstration, an experiment or investigation. This is a proper way of teaching science so that learners could construct meaning in learning. But with the time that is allocated for CAPS in physical sciences, some educators find it difficult to finish the syllabus. And this puts the learners at disadvantage because they will be examined in topics that they did not properly cover (Sibam, 2014).

1.3.8 Socio-economic factors

The background of learners plays a role in deficient performance in physical sciences (DoE, 2001). The impact of violence and HIV/AIDS can also have adverse effects. Some learners are heading their families. Their parents have died due to HIV/AIDS. Inadequacies and inequalities in the education system are most evident in areas which have sustained poverty and notable levels of unemployment. It is difficult for learners to have basic things for learning like calculators and instrument boxes, this contributes negatively to learning. Others come to school with empty stomach; it is gruelling to be taught while you are hungry (DoE, 2001).

1.3.9 Urban-rural differences

There are about 6,239 schools in the Eastern Cape mostly in rural areas compared to Western Cape and Gauteng provinces that have about 1500 schools each (Isaacs, 2007). This gigantic difference contributes to poor service delivery in the Eastern Cape Province. There are ICT projects in Western Cape and Gauteng, projects like Khanya which is based in the Western Cape Province and Gauteng Online Project in Gauteng. The Khanya Project provided almost 24 000 computers in 613 schools and provided infrastructure and training to educators, more than 500 000 learners in the Western Cape are benefiting in this project (Isaacs, 2007). The project is provided with funding by the Western Cape government and other corporate donors. The goal of this project is to have every educator in every school in the Western Cape empowered to use appropriate and available technology to deliver curriculum to each learner. The impact of this project can be associated with the Western Cape grade 12 results which was 82.2% compared to Eastern Cape which obtained the poorest percentage of 65.4 in 2014.

Gauteng Province is also running Gauteng Online Project which is funded by the Department of Education. The programme's access model involves establishing computer laboratory with 25 work stations, Internet and e-mail access, to be used for curriculum delivery in all Gauteng schools (Isaacs, 2007). These intervention programmes also reflect in Gauteng grade 12 results which was the leading province with a percentage of 84.7 in 2014. ICT has a potential to improve the quality of education and training in GET and FET bands when applied effectively as indicated in the outcomes in these intervention programmes. “ICTs have the potential to improve the quality of education and training (Patra, 2014).

These factors that have been highlighted above are highly perceptible in remote rural and previously disadvantaged schools and they have huge contribution in failure rate in physical sciences. Table 3 displays the grade 12 results in physical sciences nationally, provincially and in the district where the research will be conducted.

Table 3: Table showing grade 12 physical sciences results over the past four years

Year	National	Eastern Cape	Dutywa
2013	67.4	64.9	52.8
2014	61.5	51.5	46.3
2015	58.6	49.5	43
2016	62.0	49.6	42.8

There are 38 high schools in the district; about 82% of the schools are in remote rural areas. In 2014 only seven learners in the district managed to obtain level 7 in physical sciences; three schools attained a zero-percentage pass rate and thirteen schools obtained less than 30%. Most schools achieved less than a 50% pass rate of an inadequate quality. There is a serious challenge in physical sciences in the Eastern Cape.

1.4 Intervention Programmes to improve inadequate performance in physical sciences

Due to the major challenge faced by the South African education of not producing anticipated results in grade 12 learners, the DoE introduced intervention programmes with the aim of giving supporting teachers to contribute effectively in the teaching and learning. These intervention programmes had variable impact because of limitations due to funding, lack of proper planning and difficulty to provide for Eastern Cape as it is having the largest number of schools. The following table shows interventions programmes with their limitations.

Table 4: Intervention programmes to improve learner performance

Intervention programme	Limitation
1. Dinaledi Project	To be part of the project, schools must have registered a minimum of 50 learners on in mathematics and physical sciences or the school must have obtained a minimum of 50% pass rate in matric results in both mathematics and physical sciences. The project also caters for 60 schools per provinces. These requirements forbid other schools for getting this opportunity of being part of this project.
2. Incubation classes	These classes were accommodating a maximum of ten learners per school and learners were selected according to their performance. It was only for learners who are performing well in both mathematics and physical sciences.
3. Winter and spring schools	Highly dominated by overcrowded classes with little or no individual attention. Educators are rushing to cover all the challenging topics over a short period leaving behind most learners.
4. Science festivals usually attended in	Not all learners are able to attend those science festivals. Parents must arrange payments for their children to attend festivals. Eastern Cape as one of the provinces with high rate of poverty, it is difficult for some

Grahamstown	parents to cater for their children to attend these festivals.
5. Min quiz and Astro quiz competitions	Most schools do not show any interest in motivating learners to attend these competitions. Schools can register maximum of three learners.
6. Science Olympiads, SAASTA science debate, Eskom Expo, science weeks	Most educators do not show interest in motivating their learners to attend these programmes. In most cases, it is the schools that are already performing that are showing interest in such programmes.
7. NMMU Skills Development Programme for FET mathematics and physical sciences educators	Catered for a limited number of educators. There are about 6500 in Eastern Cape province mostly in rural areas and this makes it difficult for the department to reach out to every educator.
8. Short course for grade 9 natural science educators offered by UWC.	Only limited number of educators was accommodated in the programme due to funding. Not all learning areas were covered because of short period and lack of funds.
9. UWC programme for physical sciences educators	A maximum of 50 educators were taken in the programme from ACE now are currently doing Masters in Science Education. It is not easy for these educators to conduct workshop for other educators in their districts because there is money in the Eastern Cape department of education to support these educators to facilitate workshops in their respective districts.

1.5. Context of the study

The study will be conducted at the researcher’s site at Dutywa district in the Eastern Cape. The school is in a rural area that is about 7km from town. The school is named after the mother of one of former presidents of South Africa as she was honoured as the founder of the school. As a former educator, she played a very active role in developing the school and the community with her creative thinking skills and her love of the community. Through her efforts, the school has well-structured classrooms, with a science laboratory, a computer laboratory and a temporary structured library. But the challenge is that the science laboratory has limited resources which take longer periods for learners to complete one experiment.

The researcher has been teaching physical sciences at this school for a period of nine years. The school has an enrolment of 750 learners with eight physical sciences classes; three grade 10 classes, three grade 11 and two grade 12 classes. The researcher is currently teaching physical sciences from grade 10 to12. There are 165 learners in grade 11 and 93 learners in grade 12. There are 26 educators at school.

The school is in a disadvantaged rural area with different economic categories of people namely wealthy, middle income and unemployed but dominated by unemployed people. Most of the learners in the school are from families where one or both parents are unemployed. These parents depend mainly on social grants and informal jobs to give basic needs to their children. Because of these conditions, some learners struggle to have school basic requirements like a calculator and proper school uniform. Such conditions have major contributions on inadequate performance of learners.

The high rate of unemployment which leads to poverty contributes in an accelerating rate of crime in the school. The school has been vandalised several times resulting in the loss of computers, electric appliances and food. This high rate of crime extended to learners’ boarding houses; burglars would break into the learners’ rooms and demand cell phones and money. Learners are scared to attend evening studies because of crime. Despite of all these challenges, the school managed to attain an overall percentage of 65 in grade 12 results in 2014 with two learners obtaining six level sevens in their matric results. These learners were the top achievers in the district and were both awarded with premier’s bursary (see appendix I).

1.6 Rationale of the study

It has been indicated in Grade 12 National Diagnostic Report in physical sciences (2014) for the past four years that learners have not been performing well in electric circuits, an area in physics component of physical sciences. The report indicates that many learners have misconceptions in electric circuits and are struggling to work out the calculations required in this regard. Learners seem to have difficulty in answering questions that are based on practical work because of lack of exposure to practical work. It was recommended that practical work must be done to improve learner performance (NDR, 2013).

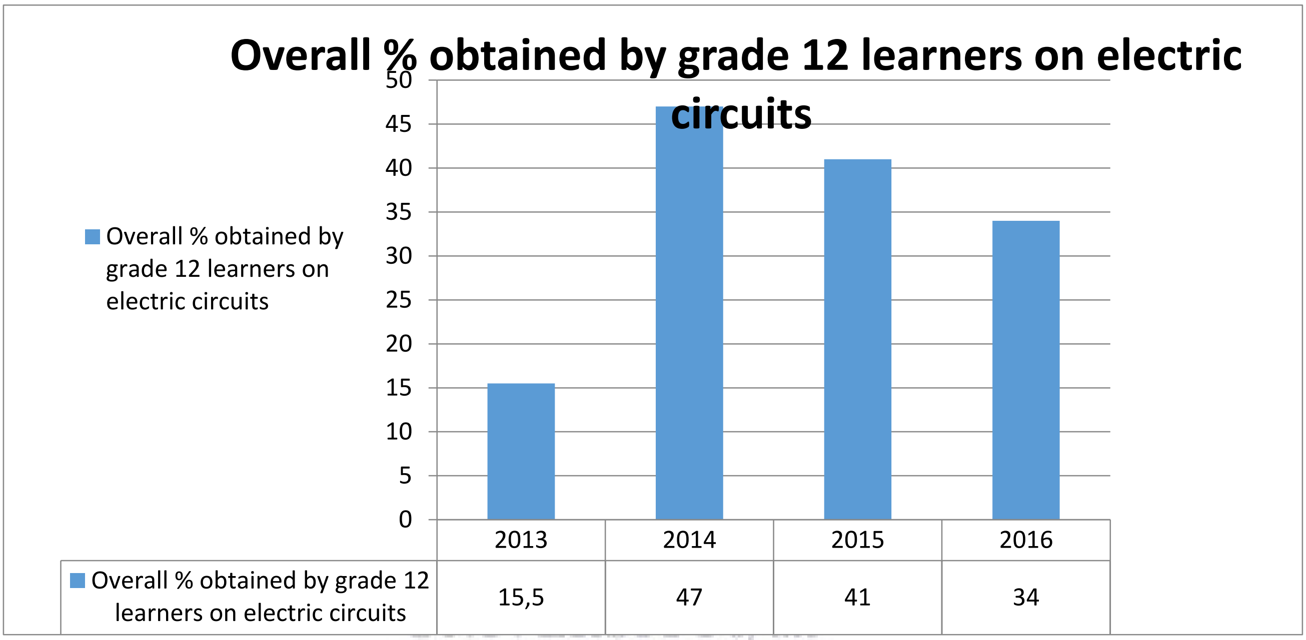


Figure 1: Graph showing grade 12 past results on electric circuits

The learner performance, as depicted in Figure 1 above, served as stimulus to the researcher to investigate possible factors that contribute to this kind of performance in electric circuits and to implement the recommendations by the National Diagnostic Report (2014). The underperformance of learners in practical design questions is not only challenging South African learners, as highlighted by a study conducted by Munikwa, Chinamara & Mukava (2011), also in Zimbabwe learners are performing poorly in examinations when they are assessed in practical design questions.

The study seeks to investigate the effectiveness of the use of teaching electric circuits by means of practical work. As National Diagnostic Report (2014) showed, learners have misconceptions concerning electric circuits; they are struggling to work on calculations. Learners cannot answer questions that are practically based; this indicates that there is a lack of exposure to practical work. It is difficult for learners to understand what happens when voltmeters are closed or open without being exposed to the real objects. It was recommended by the Minister of Education that practical work must be done to improve learner performance. The CAPS document for physical sciences for grade 10-12 portrays a teaching pedagogy that promotes development of critical thinking, scientific reasoning and strategic abilities among learners (DBE 2010). This can only happen when learners are exposed to practical work. The section on electric circuits in high school physical sciences is one of the most important chapters both at high school and tertiary levels therefore it is important that learners get understand of this section especially for those learners that will follow electricity related careers at tertiary level. The knowledge and skills regarding laboratory apparatus are tested in grade 12 examinations and are valued by universities in the engineering field (DoE, 2000). Moreover, in CAPS the topic of Electricity and Magnetism has a weighting of 8.75%, 12.5% and 7.5% in grade 10, 11 and 12 respectively and this shows the significance of this topic in science. Furthermore, CAPS require formal practical work for electric circuits from grade 10-12. And if this topic could be presented properly, learners could be developed enough to be critical thinkers as highlighted by Swain, Monk & Johnson (1999) that practical work aims at seeing problems, seeking ways to solve them and arriving at new conclusions; the challenge of load shedding that South Africa is facing could be improved.

My interest in this study was prompted by reports that indicated inadequate performance in physical sciences grade 12 learners as indicated in Figure 1 and Tables 2 and 3. It is my contention that, from my experience and observation, one of the reasons for the poor pass rate could be that learners lack exposure to hands-on activities which make it difficult for learners to understand and interpret questions; especially during tests and examinations. If, in this case, teaching and learning could be linked with practical activities as stated in CAPS document for physical sciences, the low pass rate could improve (DBE, 2010 p. 11). Although this study focuses on grade 11 in electric circuits, a closer look at grade 12 performance will give a clear picture of the problem. Grade 12 results are good at illustrating problems because analysis is fair, national standards are maintained through the results being examined and moderated externally.

1.7 Problem statement

Learners have the challenge of deficient performance in electric circuits. It has been highlighted in the Examiner's Report of Grade 12 examinations that learners are not responding properly to experiment-based questions in electric circuits (DBE, 2013). Most learners in 2014 physical sciences examination could not recognise that when a bulb burns out there will be no current which results in increased resistance and decrease of current. The reason for this lack of understanding could be a lack of exposure in practical work (NDR, 2013). Also, in 2016 learner performance in electric circuits dropped to 34%, it was then suggested that it is critical that learners must conduct the prescribed experiments in the CAPS document (NDR, 2016)

1.8 Research question

This study responded to the issues raised in the National Diagnostic Report (2014), CAPS document (DBE, 2010) and the appeal by the National Minister of Basic Education that learners are underperforming due to lack of exposure to practical work. The purpose of the study is to explore the use of practical work in teaching electric circuits. To explore the purpose of the study the following research question will be addressed:

> **How effective is the use of practical work to teach electric circuits in grade 11 physical sciences?**

To address this research question, the following sub-questions will be investigated in this study:

1. How were practical and talk-and-chalk lessons implemented to teach electric circuits?
2. What were learners' performance in electric circuits after the practical and talk-and-chalk lessons?
3. How were the practical lessons implemented to the Control Group after their theoretical lesson?
4. To what extent does the use of practical work impact on grade 11 learners' performance in electric circuits?
5. What were learners' perceptions of the practical lesson?

1.9 Significance of the study

The research findings may be beneficial to the teacher in terms of improving strategies for the design of teaching science practical. This could in turn enhance learners' chances of doing well in answering practical-based questions. This could have a positive impact on the physical sciences results in the Eastern Cape. The effective use of practical work will help learners to understand science and appreciate that science is based on evidence. Hands-on skills are of immense importance if learners are to progress in science.

As highlighted by Skamp (2011) and Hartley (2014) the use of practical work creates a vibrant learning environment for teaching and learning of science which could improve physical sciences results. The study is significant because it addresses the practical approach to teaching physical sciences, and specifically the teaching of electric circuits. The outcomes of the study could prove significant for fellow teachers, curriculum advisors and curriculum planners. The results of the study could add baseline data to the limited studies investigating the application of the practical approach to teaching physical sciences in rural schools in the Eastern Cape.

1.10 Limitations of the study

Limitations are conditions beyond the control of the researcher that will place restriction on the conclusion of the study and its application (Best & Kahn, 2006). Being a case study design the study draws conclusions from a single site and participants of that site. The study was conducted in one school in a sample of 125 physical sciences grade 11 learners out of 165. The sample size is not big enough to make general conclusion for the district or the whole country. There were no comparative dimensions in the study since research was in one school.

1.11 Structure of the thesis

This thesis is divided in the following chapters:

Chapter 1: Introduction

The introductory chapter of this study provides the background to this research project. It clarifies the research problem, the aims of the research, the research question, the rationale, the significance and limitations of the study. Importantly, it introduces the succeeding chapters.

Chapter 2: Literature review

The literature review provides the theoretical basis for this study and discusses existing studies related to the topic, and is an attempt to show the relationship between this study and what has gone before. This helps me to place my study in a context and show its relevance by making connections with the body of knowledge.

Chapter 3: Methodology

This chapter discusses procedures which were used to gather raw data, with the aim of answering the research questions of this study. All procedures and techniques which were used in the field are made explicit in this chapter.

Chapter 4: Research findings and discussion

This chapter represents and discusses the findings of the study and serve to represent the data in meaningful and useable formats. This chapter presents a detailed analysis of lesson implementation using talk-and-chalk and practical lesson methods. It also focuses on pre and post-tests analysis, learner performance on practical-based question, analysis of questionnaire and focus group interviews.

Chapter 5: Conclusion and recommendations

Finally, this chapter concludes the study. It includes a discussion of the main findings in terms of effectiveness of the use of practical work, a summary of the study, its conclusions, as well as the limitations of this study and recommendations for future research arising from the findings of the study.

1.12 Conclusion

This chapter provided the background to this research study. It clarifies the research problem, the aims of the research, the research question, the rationale and the significance of the study. It further explains the facts that have limited the study. Importantly, it introduces the succeeding chapters. Chapter 2 will explore the theoretical frameworks that underpin this study as well as how other relevant existing studies relate to this research study.

CHAPTER 2

Literature review

2.1 Introduction

The previous chapter of this study provided the introduction which clarifies the background to the study, rationale for the study, the research problem and the research question of the research project. In this chapter, the researcher will discuss the theoretical framework underpinning the study and review relevant literature of existing studies related to the effectiveness of the use of practical work in teaching electric circuits. The purpose of reviewing relevant literature is to find the relationship between my study and what the other researchers has done before.

2.2 Theoretical Framework

The theoretical framework is the structure that can hold or support a theory of a research study. The theoretical framework introduces and describes the theory which explains why the research problem under study exists (Labaree, 2013). The theoretical framework that underpins this study is constructivism. Constructivism is defined as an epistemological view which sees the learner as an active participant in the teaching and learning process. Constructivist learning theory suggests that learning is a constructive process in which a learner forms an internal picture of knowledge engages in a sense making process where individuals build new knowledge and understanding from the base of existing knowledge and perception (Chalmers & Keown 2006). This theory purports that learners learn better when they construct their own meaning. This is the theory which promotes learning contexts in which students play an active role in learning. In this study, learners will be provided with electricity circuit kit to investigate the relationship between voltage and current when resistance is kept constant. The teacher is going to guide learners to ensure that they are able to connect all apparatus correctly in both parallel and series connections. In constructivism, learners are guided until they understand what they are required to do.

In constructivist classroom, learners play key role in directing learning. The learner comes into a learning situation with prior knowledge on the subject matter. It is based on this prior knowledge that the learner interprets the new situation presented. This means that the construction of new knowledge in science is strongly influenced by prior knowledge. Learning occurs with educator and learner both in the role of co-learners. As such, each has a voice in the learning process. Learning communication is a three-way process, it is teacher-learner, learner-teacher and learner-learner communication, Goals and objectives are established through negotiations with each participant (educator and learners) having a voice in the process. With such an active role in the learning process, learners will also learn new ways to perform. Learners will be independent even after school leaving; there will be lower rate of drop outs in universities because of independency. Learners are prepared for the society and in life.

2.2.1 Role of an educator in a constructivist classroom

The educator's role in a constructivist class is to first demonstrate or model what he would like the learners to adopt. Educator acts as a coach where he had to direct, guide and helps the learners to reach the next level of learning. Learners are helped to develop their own understanding of the content rather than giving them lecture. In this research, discovery method is used so that learners could develop their own scientific reasoning. Higher order thinking is encouraged in a constructivist classroom and this develops learners to be able to answer higher order thinking questions. As noted by Chetty, Hendren and Katz (2015) that the role of educator in teaching-learning assessment process is to monitor learners' knowledge construction.

2.2.2 Limitations of constructivism approach

Though this approach is highly regarded in the literature there are limitations surrounding the proper implementation of constructivism that are put into consideration in this research. Preparing for constructivism classroom is time consuming; it requires proper planning that will accommodate all learners as unique as they are. The training necessary for constructive teaching is extensive and often requires costly long-term professional development. This may be unreasonable to school budgets as well as destructive to the learners' learning. It also requires a reasonable number of learners in a classroom, with many learners in one classroom; educators are unable to adapt the curriculum to each learner as their prior knowledge differs. The constructivism curriculum also eliminates standardized testing and grades. This eliminates grade-centred goals and rewards. Constructivism classroom needs a well-resourced classroom so that learners can be able to work independently. It may sometimes lead to misconceptions if not properly guided.

2.3 Studies based on constructivism

2.3.1 International studies based on constructivism

Zhao (2003) stated that the use of constructivist model in teaching environmental science at Beijing Normal University can improve learner's understanding. Zhao explained that during teaching and learning in environmental science, both the concept map and mind map are useful tools to promote active learning and the students' abilities to integrate knowledge; and that problem-based learning (PBL) and the use of case studies can effectively motivate students' learning curiosity and develop creative abilities. He further explained that constructivism encourages students to confront real world problems which are within their everyday experience. The characteristics of constructivist teaching models include: prompting students to observe and formulate their own questions; allowing multiple interpretations and expressions of learning; encouraging students to work in groups; and in the use of their peers as resources to learning. The researcher in this study, agrees with Zhao's arguments about constructivism as the study tries to find the effectiveness of the use of practical work in teaching electric circuits. In this study, the researcher also believe that constructivist approach can make the learners to develop the scarce skills that are required in the country.

In a study by Anderson (2007) the author reported on one of African countries, Ghana, that has similar related issues to this study in terms of poverty in rural areas and educational issues like lack of teachers in rural areas. The researcher in his study indicated that the learners in rural schools in Ghana have unequal access to science class, lack of resources and the gap between urban and rural schools. Comparable to this study, the researcher's study on Relevance of science education is underpinned by the theory of constructivism. Anderson (2007) believed that the use of constructivism plays a significant role in the teaching and learning of science. As related to Zhao, Anderson also mentioned that through constructivism, learners construct their own meaning in learning and they develop knowledge and understanding of scientific ideas.

According to Asan (2007), constructivism plays a vital role in the science classroom where Robottom (2004) states that learners use their own believes, interpretations and ideas to interpret information conveyed by the teachers. His study is also supported by emancipatory approach which is customized to learners' prior knowledge and emphasized in hands-on problem-solving skills. In this approach, learners are developed to be critical thinkers that are prepared for the society and life.

Constructivism approach can be used in a science class to expose scientific inquiry in learners. Scientific inquiry supports learners to develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world. Melville, Campbell, Fazio, Stefanile, and Tkaczyk (2014) conducted a research study on the practicum experiences of pre-service teachers that are using scientific inquiry in teaching science as required in science education standard document in Australia.

Achimugu (2012) conducted research on strategies for effectiveness of conducting practical chemistry in high school. In his research, learners construct their own meaning in learning through hands-on activities. His study is also underpinned by the theory of constructivism related to Haung and Odegaard (2014) who conducted a study teaching fourth and fifth grades the concept of force using scientific inquiry.

Papadimitriou (2012) wrote about the value of constructivism in a science lesson whereby learners are encouraged to discover, test structure and apply the knowledge obtained to new situation. Using constructivist approach in scenario based learning of electric circuits, he found that learners could discover the formulas and principles of electric circuits.

2.3.2 National studies on constructivism

In constructivism, learners are given skills that will enable them to succeed in a workplace that is characterized by diversity, competition, quality management practices and teamwork. Piaget, in a study piloted by Mpofu (2006) specified that knowledge cannot be given to learners; it is the learner's responsibility to construct it from his or her mental and physical interaction with the environment. Learning is a physical and psychological activity and to be meaningful, one must understand and integrate knowledge into one's cognitive structure. Constructivism approach is linked with the specific aims of physical sciences stated in CAPS document which are as follows:

- Physical sciences promote knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge.
- To make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical phenomena.
- Develop understanding of scientific concepts, principles and attitudes towards life (DBE, 2010, p.8).

The aims that are mentioned above can be achieved when learners are exposed to practical work as they construct their own meaning in learning through hands-on activities. This approach is underpinned by a social constructivist, Vygotsky (1978) who believed that learners have various levels of understanding. Education should be influenced by the principle of scaffolding. Scaffolding is when an educator introduces a concept or a topic and ensures that learners have grasped the concept and thereafter withdraws to allow learners to work independently to increase their capabilities of critical thinking.

In this study, learners will be given support until they can apply new skills and strategies independently and it has been found to be an excellent method of developing learners' higher levels of thinking skills. This process is interested on how learning will be achieved than rushing to finish the syllabus leaving many learners behind. Learners learn better when they construct their own meaning. Learners will be given the opportunity to discover themselves the differences between parallel and series connections using practical work (see lesson plan in appendix E). Moreover, Freire (1972) believed that human beings can take actions in their own lives and world rather than being controlled by political forces. He believed that humans can become aware of the world, reflect on it and act on it to change it. Learners should be involved in two-way communication and reflect in their societies what they have learnt that is linking everyday knowledge with school knowledge which probes critical thinking.

In a study conducted by Dhurumraj (2013) in a school in Pinetown in KwaZulu-Natal province purported that though constructivism had been ignored in teaching of physical sciences, it forms the major role in the teaching and learning of science as implemented in his study. Through constructivism, learners become actively involved in constructing their own meaning in learning which allows them to develop cognitive processes that enables them to question validity and authenticity of work at hand.

Semeon (2014) concur with the above researchers about constructivism approach in teaching science. In his research, he highlighted that learners do not come to school as blank slates but with everyday knowledge through interaction with their environments and societies. The knowledge that the learners bring to school needs to be valued, through practical work and demonstrations; learners can construct their own new meaning in science learning. Practical work helps to resolve any contradictions between school knowledge and everyday knowledge. Constructivism helps learners to develop the ability of making good observations like classifying, measuring, inferring, predicting (etc.). Constructivism approach tends to close the gaps of the past that physical science is meant for highly gifted learners; all learners' abilities are valued in a constructivism classroom.

2.4 Studies of practical work in science education

2.4.1 What is practical work?

Practical work is defined as learning experiences in which learners interact with materials or with secondary sources of data to observe and understand the natural world. The main aim of practical work as suggested by Dillon (2008) is:

- to make phenomena more real;
- to arouse and maintain interest;
- to promote a logical and reasoning method of thought;
- to practice seeing problems and seeking ways to solve them;
- to develop a critical attitude;
- to develop an ability to cooperate;
- To find facts and arrive at new principles.

Physics practical skills are science process skills. Science process skills are cognitive and psychomotor skills employed in problem solving. Science process skills are mental and physical abilities and competences which serves as a tool needed for the effective study of science and technology as well as problem solving, individual and societal development (Nwosu & Okeke, 1995). Practical work helps learners to develop process skills such as observing, classifying, predicting, measuring, drawing, recording data, hypothesizing (etc.). This could not happen if learners are passive, are knowledge absorbers while teacher transmits knowledge to learners.

Practical work arouses and maintains interests and curiosity in science. Science is not stagnant but subjective to change. Learners learn by doing and thinking about what they do (Lowery, 1994). Through practical work learners can be able to verify laws and theories that they have already learnt. Practical work develops learners to be critical thinkers. Learners should be given chance to discover things by themselves by enabling them to practice scientific method (Jenkins & Nelson, 1979), to avoid a science class where learners could end-up be asking ‘what is supposed to happen teacher?

2.4.2 Meaning of an effective practical work

Millar and Abraham (2009) posited that most learners only enjoy doing practical work with little contribution that it has in learning. In a brief period after the learners have conducted practical work, they forget what they learnt from it and what they were doing it for. Osborne (1998) also supported this idea that practical work plays a limited role in science learning and has little educational value. Hodson (1991) claimed that:

> **As practised in many countries, practical work is ill-conceived, confused and unproductive. For many children, what goes on in the laboratory contributes little to their learning of science (p. 176).**

To overcome the challenges that are highlighted by the above researchers, practical work should not only be made fun to learners but it must fulfil educational purpose. For this to happen practical work must be linked with teaching, it must not be done in isolation otherwise learners will only enjoy practical with no link between theories and practical and there will be no impact in learning. And therefore, the recommendation that was made by Minister of Education that learners must do practical work to improve performance will be in vain if practical work is isolated from theory. When planning practical lesson, educators must take into consideration the following objectives of practical work as indicated by Millar and Abrahams (2009) and Achimugu (2012): The main objective of the practical activity is:

(a) To help students develop their knowledge of the natural world and their understanding of some of the main ideas, theories and models that science uses to explain it.

(b) To help learners learn how to use some piece(s) of scientific apparatus and/or to follow some standard scientific procedure(s).

(c) to develop students' understanding of the scientific approach to enquiry (e.g. of how to design an investigation, assess and evaluate the data, process the data to draw conclusions, evaluate the confidence with which these can be asserted).

(d) To verify laws and theories that the students have already learnt.

(e) Leads to fundamental and applied research in chemistry at all levels of education.

(f) It is used to reinforce what is learnt in the theory class and hence encourages the spirit of experimentation.

(g) Arouses and maintains interest and curiosity in physical sciences.

(h) Helps students to develop manipulative skills and proficiency in writing reports.

(i) Enhances students' better understanding of concepts and principles and by so doing, significantly contributes to students' achievements in chemistry.

(j) Encourages students to be active in the class, in other hand, discourages abstraction, rote memorization and inattentiveness in the class.

The following suggestions as identified by Achimugu (2012) should be taken into consideration when an educator wants to conduct an effective practical physical sciences class:

(i) Try out the experiment to ensure problem free practical.

(ii) Teaches the learners necessary precautions.

(iii) Ensure that the laboratory environment is safe, clean and conducive for the learners to work and achieved the desired result.

(iv) The utility services in the laboratory are in good working condition i.e. water, first aid box, fire extinguishers, etc.

(v) All the apparatus and materials required for the practical are provided.

(vi) The reagents required for the practical are prepared in large quantity.

(vii) The entrance and exit routes of the laboratory are free.

(viii) Identify the number of learners that will take part in the practical. Where the number of learners outshoots the available facilities, they should be grouped.

(ix) Prepares practical guidelines or instructions to guide the learners. This could be written on the board or printed out and given to each learner or group.

(x) Works round to assist those learners in areas of identified difficulties.

(xi) Outline the order of reporting practical chemistry i.e. tabular form.

(xii) Learners and laboratory assistants clean up the tables, wash the apparatus and replace them to their respective positions after each practical.

(xiii) Learners leave the laboratory in, an orderly manner.

(xiv) Marks the learners' practical works and makes necessary feedback to the learners.

To make teaching effective, it is first important to think of the meaning of word 'effectiveness' and consider the steps to be followed in developing such activity and monitor what happens when it is used (Millar, Tiberghien & Le Marachal, 2002). Effectiveness of practical work depends on the sequences of lesson activities of which a practical activity is a part of. The following table demonstrates the stages to be followed in developing steps for effective practical activity.

Table 5: Table showing steps in the development and evaluation of teaching and learning when planning practical activity lesson

Step	Activity
1	Educator's objectives (what the learners are intended to learn).
2	Tasks specification (what the learners are intended to do).
3	Learning events (what the learners will do).
4	Learning outcomes (what the learners learn).

In the first stage, when an educator is planning an activity, there are specific goals and objectives that he/she wants the learners to achieve which should be stated by the educator when preparing for a practical activity. Educator's objectives can be influenced by number of factors: what Curriculum Assessment Policy Statement (CAPS) requires; what resources are available; which role is going to be played by the educator, is the lesson going to be a demonstration; what role will be played by learners, is the lesson going to be hands on and minds on activity; how are the learners going to be assessed. Then the educator must compare the first stage with the last stage (stage 4) which shows what the learners have learn in the activity in comparison with what the educator required the learners to learn in stage 1.

If the learners did not achieve what the educator expected them to learn it would be indicating that the outcomes of the lesson were not fulfilled, the educator must consider to re-do the lesson in a different approach or check where the lesson did not go well to improve the lesson design to get the desired outcome. In the lesson preparation, educator has specifications, which is step 2, what he intends the learners to do which should be compared to the actual events, that is what the learners have done (step 3). By so doing, the objectives of conducting practical work would be a success.

The aim of practical work is to help learners to understand some of the ideas that science uses to describe or to explain what they observe. As this study investigates the effectiveness of using practical work to teach electric circuits in this research, learners have to be able: to identify the apparatus that they are going to use in the lesson like voltmeter, ammeter, resistors, switches and batteries; know how are these apparatus connected and how are they used as it is indicated in 2.5.2 (b) that practical work helps learners to understand how to use scientific apparatus and also to follow scientific procedure; learners will also learn what happens to voltmeter and ammeter readings when resistors are connected in series or parallel; when the switch is closed or open what happens to voltmeter and ammeter readings.

Now through the practical activity learners will be able to differentiate between electromotive force (emf) and potential difference which causes much confusion in grade 12 learners when solving electric circuit questions. And without applying their minds and their hands on the task, the activity will not be effective. As the learners are engaged in practical work, they will be enhancing what Dillon (2008) identified about practical work that 'it promotes a logical and reasoning method of thought;

develop critical attitude and practice seeing problems and seeking ways to solve them' (p. 5)

Millar and Abraham (2009) further postulated that for practical work to be considered effective, it must link or address two domains, which are the domain of objects and observables (domain 1) and the domain of ideas (domain 2). In the domain of objects and observables, learners do what was intended with the objects and materials provided and what they were meant to observe. Learners can later recall and describe what they did in the activity and what they observed. In the domain of ideas, during the activity, learners think about what they are doing and observing using the ideas intended. Learners can later discuss the activity using the idea it was aiming to develop and can show understanding of these ideas in the other context. If the lesson only addressed domain 1, learners will not be able to apply what they have learnt in class in another context then there would be a recurring challenge of learners who cannot show understand of ideas in another context. And that would be supporting what was stated by Hodson (1991) in the first paragraph of 2.5.2 of this chapter.

2.4.3 Types of practical work

Wellington (1988) indicated that there are at least six types of activities that take place in school science that could be classified as practical work:

> **teacher demonstrations; class practical's, 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. (p. 12)**

The several types of activity have different purposes (Gott & Duggan, 1995) but, as Wellington (1988) also points out, many 'experiments' are nothing of the sort not least because no new knowledge is being made. Woolnough & Allosp (1985) have suggested three categories which might aid discussion about practical work, namely exercises, experiences and investigations.

School teachers themselves get very keen on innovative approaches which is half the battle won but their eagerness is not untinged with uncertainty about the value of learners finding out for themselves in the laboratory.

The authors of the review of the relevant literature in the Handbook on Research on Science Education, Abell and Lederman, (2007) provide what they call a classical definition of 'school science laboratory activities' (which it notes are called 'practical activities in British Commonwealth parlance'). Such activities are:

> **Learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world (for example: aerial photographs to examine lunar and earth geographic features; spectra to examine the nature of stars and atmospheres; sonar images to examine living systems). (Lunetta et al., 2007, p. 394)**

The Royal Society's stated position on terminology is that '"practical science" is used as shorthand for the full programme of experimental and investigative activities (including fieldwork) conducted as part of science education in schools and colleges' (House of Lords, 2006). However, various terms are in common use in science education to describe different sub-categories of practical work. For example, the Student Review of the Science Curriculum, reported findings of an online questionnaire survey which asked students aged 16-19 what they thought about different methods of teaching and learning in school science (Cerini, Murray & Reiss 2003). However, when asked to choose the three methods that were most useful and effective in helping them to understand school science, 32% of respondents chose 'doing a science investigation' and 38% chose 'doing a science experiment in classes. Does separating experiments and investigations clarify or confuse? The report begs the question, how many of the respondents chose both 'doing a science investigation' and 'doing a science experiment in classes and how many of them thought they meant the same thing (Cerini et al 2003). More importantly, for those advocating practical work, the two approaches that were regarded as being most useful and effective were 'having a discussion/debate in class' (48%) and 'taking notes from the teacher' (45%).

In an experiment, learners were testing a hypothesis by following instructions given by educator. Kim and Tan (2010) posited that such experiments are designed for learners to follow instruction for implementation procedures handed down by educators without much thinking and purpose. Experiments add little value in learning because learners are just using their hands without applying their minds. In an experiment, learners are told the aim of the experiments, apparatus to be used, the method to be followed; all they are doing is to put the pieces together it is like playing puzzle and then conclude. The following example shows how an experiment is conducted:

Aim: To verify Ohm's law

Apparatus: Voltmeter, ammeter, two resistors, connecting wires, three cells and a switch.

Method: Connect the apparatus as shown in the diagram. Then record ammeter and voltmeter readings in a table.

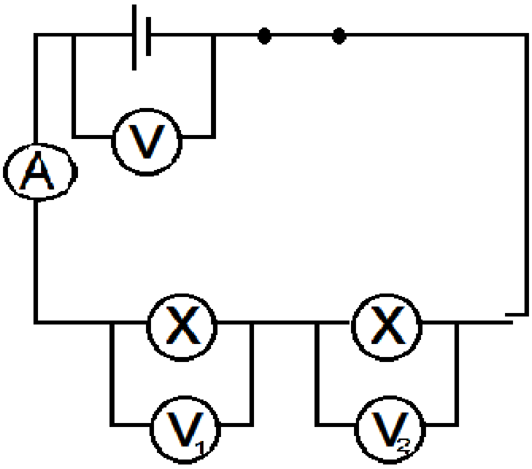


Diagram 1

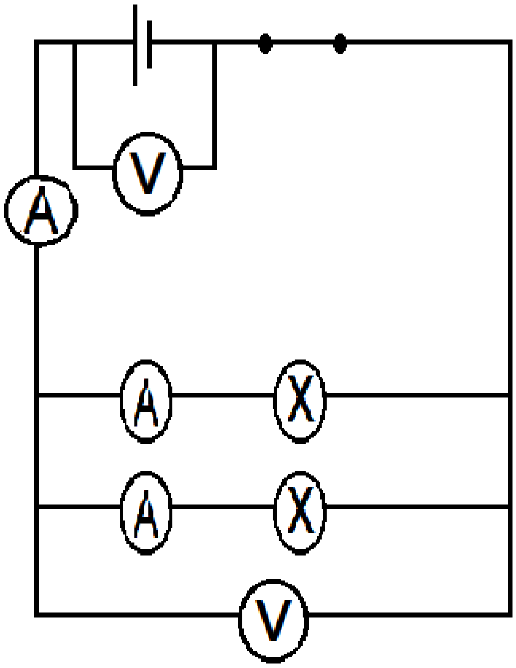


Diagram 2

Analysis: Analyse your results.

Conclusion: Write conclusion.

Practical investigation differs from an experiment because it gives the learners the opportunity to design, plan, organize data, collect information, analyse and draw their own conclusions based on their findings. In a practical investigation, learners are given chance to develop critical thinking skills and scientific inquiry. Practical investigations usually follow the following steps:

1. Learners are given a scenario that leads to investigation.
2. Learners must develop the aim of the investigation.
3. Make a hypothesis.
4. Classify the apparatus that will be used.
5. Identify the dependent, independent and control variables.
6. Learners must formulate their own method that they will follow when conducting the investigation.
7. Then they can record their observations and findings.
8. The next steps would be analysis of results.
9. Then conclusions will be drawn from their findings.

Practical investigations enable learners to have better understanding of what science is. With practical investigations, learners can verify scientific laws.

2.4.4 Learners' attitude towards practical work

Attitudes and beliefs of learners are important in the teaching and learning of science. Learners develop an idea about what science is all about, how scientists are as persons, what they do and how this relates to society, the environment and other people. Learners' attitudes to learning are more influenced by the way they are taught. Learners will not be able to obtain enough science learning experience when educators themselves are not pleased with science teaching (Simpson & Oliver, 1990). The significant role that educators play in learners' attitudes formation towards science has been confirmed by several studies; Ebenezer and Zoller (1993) who studied attitude towards science with American grade 10 learners between ages 15 and 16; Sundberg, Dini and Li (1994) who studied attitudes towards science of 2965 United States college pupils; Hendley, Parkinson, Stables and Tanner (1995) who studied gender differences in pupils' attitudes.

This study focuses on how effective is the use of practical work in teaching electric circuits. Therefore, it is vital to look at how educators and learners' attitude affect teaching and learning of science using practical work. Educators must consider what it really means when learners claim to enjoy practical work. Do the learners enjoy practical work because they are acquiring learning and can be able to prove scientific theories or it is only better because it is giving them the opportunity to avoid writing? Are the learners enjoying practical work because it gives them the freedom to chat with their friends? (Sharpe, 2012). Educators should examine learners' attitude when doing practical work if it is working towards the goal of conducting practical work. Sometimes educators have a tendency of using practical work to manage learners' discipline. Educator would threaten to stop doing practical work if learners are not behaving well and threaten learners that they will learn only from textbooks (Sharpe, 2012).

2.4.5 Integrating Practical Work with Theory

The importance of using a laboratory is that it helps improve learners' higher order learning skills such as analysis, problem solving and evaluating (Makgato & Mji 2006). One of the challenges that are a contributing factor in deficient performance in physical science, in South Africa, is that the teachers are unable to take learners through practical sessions. Achimugu (1997) noted that teachers cannot display correct understanding of science processes.

Teachers should constantly model how they teach practical work in science (Coleman, Holcomb & Rigden 1997). Physics can be best taught through experiments, demonstrations and visualizations which help the learners understand physical phenomena conceptually (DiSessa, 2001). According to Concari, Giorgi, Camara & Giacosa (2006), Physics being an experimental science, observation, measuring and theoretical speculations are processes that cannot be separated from the physical knowledge construction, even in the classroom. Many authors agreed that the results of practical work in science focuses on the strengthening of the understanding of scientific concepts and principles; the development of practical work; teaching the processes of science and arousing learner's interests (Van der Linde, Van der Wal & Wilkinson, 1994; Bradley & Maake, 1998; Treagust & Thair, 1999; Abrahams, 2009).

2.4.6 Learners as critical thinkers

The aims of practical work are to encourage accurate observations and descriptions; to make phenomena more real; to arouse and maintain interest and to promote a logical reasoning method of thoughts. According to Swain, Monk & Johnson (1999), practical work aims at seeing problems and seeking ways to solve them; to develop critical attitude; to develop an ability to cooperate, finding facts and arriving at new conclusions. Also, the Science Curriculum statements of Curriculum 2005 in South Africa emphasize experimentation and problem solving that is 'doing science'. Doris

(1991) in his book believed that science is a way of reasoning and acting, not just a body of knowledge to be acquired by memorizing facts and principles.

Applying what we know about child’s development contributes to science teaching. Understanding how children at different ages think and work is important in planning, interpreting and responding to children's science work. Children learn through their own activity. The weighting of practical work in the current curriculum, Curriculum and Assessment Policy Statement (2010) is 25% of learners’ continuous assessment; this indicates the vital role of practical work in the teaching of Physical Science. Practical work assesses performance at different cognitive levels and a focus on process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological environment and everyday contexts (DBE, 2010, p151).

2.4.7 Learners as constructors of meaning

Social constructivists’ theory stated that learners come to class with everyday knowledge which serves as a baseline for the active construction of knowledge as the learner interacts with the teacher and peers (Driver, Asoko, Leach, Mortimer & Scott, 1994). The way learners understand and interpret the material presented to them in a Physics class mostly depends on the experiences they bring to class (Redish & Steinberg, 1999). Other researcher has studied that the lack of practical work in physical sciences is a contributing factor in the inadequate performance of learners (Hodson 1992).

2.5 Conclusion

This chapter provided theoretical basis of the study and discussed international and national studies related to effectiveness of the use of practical work for teaching and learning. The views of other researchers helped me to place my study in a context and showed its relevance by making connections with the body of knowledge. The following chapter will discuss methodology that will be used in conducting this research.

CHAPTER 3

Research Methodology

3.1 Introduction

Chapter two presented the theoretical bases and reviewed relevant literature to this study. This chapter clarifies step-by-step processes of the overall research design and method used in the study to find the effectiveness of the use of practical work to teach Electric circuits in grade 11. The aim of achieving the purpose of the study, this chapter provides detailed justification of implementation of the instruments, site selection, sampling, population, participants, trustworthiness, reliability and ethical considerations. The process of data collection and analysis are also discussed in this chapter.

3.2 Research design

This study used a mixed methods design which includes both qualitative and quantitative approaches. The purpose of using both methods is to acquire richer, in-depth and wider data from the participants. Johnson and Christense (2012) define a mixed methods research approach as one in which the researcher uses a combination of qualitative and quantitative methods. The usage of qualitative elements would give a fuller meaning to the quantitative data. This validates the views of many researchers who believe mixed methods have more advantages over the onetime quantitative versus qualitative positions (Johnson et al. 2012). The strength of the other method can add insight and understanding that might be missed when only a single method is used. In this study a questionnaire is used for quantitative data and is strengthened by focus group interviews which is qualitative data to acquire richer data.

It was highlighted by Mouton and Marais (1994) that the use of the qualitative approach gives rich deep data but integrating the approaches gives more valid data. The qualitative method on its own is a systematic and empirical strategy for answering questions about people in a social context (Locke, Spirduso & Silverman, 2010). This can be associated with respondents’ descriptions and understandings of their experiences. Respondents indicate their perceptions in a qualitative form as interviews will be used in this study.

When participants express their feelings, beliefs and explanations such responses can be treated as a valuable reality. In this study, views of the learners are surveyed and explored in both qualitative and quantitative data that they provide. Interview transcripts, field notes and documents are primary forms of information in qualitative data according to Locke et al. (2010). Interviews were used in this study as a primary form of acquiring qualitative data.

Locke et al. (2010) argue that qualitative research is naturalistic: the researcher enters the world of the participant as it exists and obtains data without any deliberate intervention designed to alter the setting. In this study, participants were approached in their natural environment to ensure their surroundings could allow the most authentic responses to emerge naturally without any alien elements intruding. The researcher ensured that the learners are interviewed in an environment where they were comfortable with for example the researcher avoided interviewing learners in the staffroom where there will be other teachers that will make them uncomfortable or in front of other learners.

In applying qualitative research, there is the advantage that probing can take place which results in a wealth of detailed information when using semi-structured interviews. This enhances the depth of data and reliability for thorough analysis and interpretation. Henning, Van Rensburg and Smit (2004) characterise qualitative research as understanding and in-depth inquiry.

3.3 Case study

The focus of this section will be on the definition and the explanation of the reasons for the study to be classified as the case study. A case study was the choice of research strategy for exploring the effectiveness of the use of practical work in science class as one school will be involved during the data collection process. Atkins and Wallace (2012) state that the case study strategy can go beyond the ‘how’ and ‘why’ questions: it offers a way of investigating connections, patterns and context, and of reflecting on the details and the bigger picture. The case study strategy was an acceptable approach to capture an in-depth understanding of practical work issues and its complexities within a natural context. A descriptive case study design presents an in-depth description of a phenomenon within its context. The case study allows thick description as the researcher is teaching in that school, to spend time with the participants to gather data through different teaching methods, assessing learners through tests, questionnaires and interviews. A defining characteristic of this case study was its intensive investigation of a single unit (Yin 2009). As a physical sciences teacher with an interest in academic support for science learning, a practical decision based on easy access was taken to focus the case within a rural school. The case study assisted the researcher to identify, understand and gain insight of the effective use of practical work in teaching electric circuits.

There are advantages and disadvantages of choosing to do a singular case study. Rule and John (2011) provide an indication of the advantages:

- The case is a good example of its kind
- It can be studied in great depth
- The researcher has easy access to the case
- The researcher has experience of the case and ‘insider knowledge’

The disadvantages of selecting a singular case study are:

- The findings cannot be generalised to other cases with coherent academic conviction
- There is no comparative dimension in the study.
- The bias of the researcher might restrict or distort the findings.

In considering the advantages and disadvantages of selecting a case study, the advantages outweigh the disadvantages. The issue of bias is considered on ethical terms and influences the validity of the data.

3.4 Sample

The research was conducted over a period of three months with the purpose of having enough time to collect data. The study was conducted in a rural school in the

Eastern Cape where the researcher is currently teaching. The research sample of the study comprised of 125 physical sciences grade 11 learners out of a population of 165 learners. Two grade 11 classes out of three classes doing physical sciences were selected purposively; 60 in the control group (group C) and 65 in the experimental group (group E) as presented in table 6. Both classes are taught by the researcher. Purposive sampling was used to select the two classes to ensure validity. The third class had 40 learners; the difference in number of learners could limit the outcomes of the research. The reason for choosing this sample size is to acquire as much data as possible.

Table 6: Table of sampling for the study

Sample	Class 1 Control group (group C) Sample 60 learners	Class 2 Experimental group (group E) Sample 65 learners
Focus group	12 learners (Four groups with three members in each group)	12 learners (Four groups with three members in each group)
Grade 11 Life Orientation educator	Conduct interviews	
Grade 11 Language educators	Verification of language in instruments	
Grade 11 physical sciences learners from neighbouring school	50 learners Language testing of instruments	

3.5 Data collection plan

In the first step, a lesson on electric circuits was presented to both groups (C and E) (refer to Appendix F). Only theoretical presentations were made to the group C but theoretical and practical presentation was provided to the group E. Both lessons were videotaped to reflect on learner involvement and teacher interaction with learners. Step two occurred after the presentation where both groups were given the same control test (see Appendix G) to measure the level of understanding. The test findings were recorded in a table and compared (see Appendix L). In the third step, the same lesson was then repeated in the group C with both theory and practical work.

The purpose of using practical work as a teaching strategy is that it is a valuable tool to help learners learn meaningfully and to help teachers become more effective educators. During the lesson presentation, learners compared the theoretical knowledge with the experimental findings, constructing their own meaning about electric circuits. In step 4 the control group was given a similar post-test (see Appendix H) for evaluation. The results were recorded in a table and compared with the pre-test results (refer to Appendix M).

Table 7: Methodological framework that was followed in data collection

Steps	Research question: How effective is the use of practical work to teach electric circuits in grade 11?	Control group (group C)	Experimental group (group E)
Step 1	How were practical and talk-and-chalk lessons implemented to teach electric circuits?	Theoretical lesson on electric circuits ($\mathbf{L_t}$)	Theoretical and practical lesson on electric circuits ($\mathbf{L_p}$)
Step 2	What were learners' performance in electric circuits after the practical and talk-and-chalk lesson?	Control test ($\mathbf{T_1}$)	Control Test ($\mathbf{T_1}$)
Step 3	How were the practical lessons implemented to the Control Group after their theoretical	Theoretical and practical lesson on electric circuits ($\mathbf{L_p}$)	

	lesson?		
Step 4	To what extent does conducting of practical work impact on Control Group's ' performance in electric circuits?	Control Test ($\mathbf{T_2}$) [similar to $\mathbf{T_1}$]	
Step 5	What were learners' perceptions of the practical lessons?	1. EPReQ to obtain learners' perception on lesson implementation 2. Focus group interviews	1. EPReQ to obtain learners' perception on lesson implementation 2. Focus group interviews

In step 5, both groups were given the questionnaire called the Electricity Practical Reflection Questionnaire (EPReQ) to obtain learners' perception on lesson implementation. The researcher used questionnaires in this research to prompt learners to think and reflect on the lesson and examined their perceptions of what they believed is the effect use of practical work in the lesson. EPReQ was composed of both closed ended and open-ended questionnaires to obtain both quantitative and qualitative results for the research. Focus group interviews were conducted to obtain learners' views of the practical lessons. Table 7 above represents a summary of the data collection plan.

3.6 Research instruments

Research instruments are a way of gathering data concerning the research focus. The researcher must ensure that instruments are valid and reliable to acquire the expected results. The instruments that were used were an interview schedule and a questionnaire.

3.6.1 Questionnaires

Questionnaires provide information about thoughts, feelings, perceptions beliefs and values (Johnson et al. 2000). The researcher developed a questionnaire called the Electricity Practical Reflection Questionnaire (EPReQ). Questions were developed in a way that learners could reflect on how they perceive the use of practical work in teaching and learning. The EPReQ was used to probe learners to think and to reflect on the lesson on electric circuits and to examine their perceptions on what they believed the application of practical work had contributed in the improvement of their results. Furthermore, Ackroyd and Hughes (1981) stated the following advantages and disadvantages of questionnaires:

- The use of questionnaires enables the researcher to acquire large amount of information from many learners in a brief period.
- Questionnaires can be carried out by the researcher or by any other number of people with limited effect to its validity and reliability.
- Questionnaires can be analysed more scientifically and objectively than other forms of research.
- The results of questionnaires can usually be quickly and easily quantified by either a researcher or using software package.
- Questionnaires are practical.
- When data has been quantified, it can be used to compare other research and may be used to measure change.

Disadvantages of using questionnaires:

- Is argued to be inadequate to understand some forms of information
- People may read differently into each question and therefore reply based on their own interpretation of the question
- There is no way of telling how truthful a respondent is being
- Lacks validity
- There is no way of telling how much thought a respondent has put in
- The respondent may be forgetful or not thinking within the full context of the situation

In validating the questionnaire, the researcher pilot tested it in grade 11 learners in a neighbouring school as indicated in section 3.7. 50 Grade 11 learners in the neighbouring school were requested to read and explain the questions in the questionnaire to show that their understanding of what is asked so that the researcher could pick up if the language was clear for the learners (See appendices P &Q).

3.6.1.1 Development of Electricity Practical Reflection Questionnaire (EPReQ)

The EPReQ consisted of twelve closed-ended questions and three open-ended questions (refer to Appendix D). To give respondents a range of responses to the statements, the Likert scale was used which consisted of five categories ranging from strongly agree (5); agree (4); not sure (3); disagree (2); and strongly disagree (1). The reason for using a five-point scale is that participants are required to decide on the statement. To give respondents an opportunity to voice their opinions/concerns an open-ended question was provided at the end that requested learners to respond to their experience of practical lessons in electricity. Data collected from the questionnaire was primarily used to complement the qualitative part of this study. Data was captured and analysed on excel spread sheet. Data was represented visually in a form of graphs and tables.

3.6.2 Interviews

Interviews are mainly useful for getting a better story behind a participant's experiences. The researcher decided to implement the semi-structured interview technique. In this type of interview, the sequence of usually open-ended questions is determined in advance. Respondents are asked the same basic questions in the same order, which provides consistency. An interview schedule (refer to Appendix E) was used. Four discussion questions were asked in the interview which focused on the involvement of practical work in teaching and learning of electric circuits. The questions were designed in a way that will probe the learners to give a thick reflection of the lesson presentation.

The interviewer can pursue in-depth information around the topic. Interviews were used as a follow-up to certain respondents to questionnaires. Interviews are a systematic way of talking and listening to people. It is a method of collecting data from individuals through conversations and gain knowledge from individuals (Kvale, 1996). Interviews were conducted in isiXhosa as Morse (1998) mentioned that interviews can use the language that is best known to the respondents so that they can understand what is being asked. This had enabled the researcher to extract as much data as possible. Focus group interviews were conducted with the control and the experimental group respectively.

The aim was to draw deeper understanding on the effectiveness of the use of practical work in teaching electric circuits. The focus groups of learners were coded as F1, F2, F3 and F4 respectively. Each focus group had three members from both control and experimental group. A total of twenty-four learners was selected according to their performances in the tests, with twelve members from each group.

Each line in the transcription for interview is numbered to be able to go deeper in any response that seemed to be stimulating. To avoid biasness, the researcher asked Life Orientation educator to conduct the interview. The researcher provided her with audio tape to record the interview. This is supported by Walford (1998) who claims that tape-recorded conversations are highly reliable records that could be presented. The researcher played the tape and wrote down the conversations then translated them into English. The researcher highlighted and analysed the important data then cleaned the data that was not be relevant to the study.

3.7 Pilot study

The research instruments were pilot tested in 50 grade 11 learners in a neighbouring school comparable to the school where the research was conducted in terms of relevant characteristics such as geographical location, the level of equipment for science class and past performance in official examinations. This was done to test the questionnaire's relevance, suitability and accuracy of questions sample and language appropriateness and those findings can be analysed. Two grade 11 language educators were also requested to look at the level of language of the instruments (See appendix O).

3.8 Data analysis

The data analysis process involves understanding data and what information it conveys relating to effectiveness of the use of practical work. Because the study was set in an experimental method, interpretation was achieved through data analysis. Rule et al. (2011) argue that data analysis and interpretation constitute a critical stage in the research process which allows the researcher to construct thick descriptions, identify themes, generate explanations of thought and action evident in the case, and theorise the case. The research question of the study determines the analysis process.

Before the researcher could start data analysis, she had to prepare data by organising it for analysis. The organising process involved having the interviews transcribed and questionnaires analysed. She spent time reading transcripts and listening to audio recordings to familiarise herself with data and remind herself of the context of the interviews. This was the phase before the actual analysis of results.

Analysis of data was non-computerised in order not to restrict the scope of the interpretation process. Grbich (2013) posits that data analysis software has the capacity to distance and limit perspective of researchers thereby providing a too narrow interpretation. The researcher used a selective coding and categorisation approach, four focus groups codes as F1, F2, F3 and F4 for learners to analyse the focus group interviews and learners were coded as Learner 1, Learner 2, Learner 3 up to Learner 12.

The following are the stages followed when the data was analysed.

Stage 1: First test results

Test (**T_1**) results in Step 2 for the theoretical lesson (**L_t)** and the combined theoretical and practical lesson (**L_p)** were compared and analysed in Table 5.

Stage 2: Tests results

Test results in step 2 (**T_1**) and step 4 (**T_2**) were compared and analysed in Table 5.

Stage 3: Questionnaire

Data was captured and analysed on excel spread sheet. Data was represented visually in a form of graphs or tables.

Stage 4: Interviews

Audio tape was used to record the interview. The interview was conducted in isiXhosa; the researcher transcribed the conversation then translated it into English. The interview was conducted by a Life orientation teacher other than the researcher to maintain validity. Any data that is not relevant to the study was erased: what was important was highlighted and analysed. Interview was conducted once. A total number of twenty-four learners was interviewed, twelve from control group and twelve from experimental group. Learners were grouped according to their performance in the test results.

3.9 Validity (trustworthiness)

Validity refers to the degree to which the interpretation and concepts have mutual meanings between the participant and the researcher (McMillan & Schumacher, 2001). The researcher ensured that the aims and research questions were clear and focused and that they were linking well with the instrument. Sampling was done to ensure that there was a good representation of respondents in the study. Two instruments were used (a questionnaire and interview schedule) to triangulate the results, which is a good strategy to ensure validity. The researcher requested two grade 11 language teacher colleagues and she also used 50 grade 11 physical science learners from a neighbouring school to review instruments to ensure that they are valid. Learners from neighbouring school were asked to read the questions and explain the questions with their understanding and this was done to detect whether the language used was clear. The two language educators were requested to read the questions to check if the questions will not be ambiguous to learners.

When considering the validity of data in action research, researchers need to consider the accuracy of what is collected and used as evidence. Koshy (2010) posits that we should be aware that the conclusions are based on the quality of what we gather as data. Interpretation of the same observations can vary between different people and this can affect the validity of data presented. The researcher triangulated the instruments to gather and interpret data from two different points of views. According to Rule et al. (2011) triangulation refers to the process of using multiple sources and methods to support provisions or findings generated in a case study.

3.10 Reliability

Reliability is the degree to which an instrument produces stable and consistent results (Phelan & Wren, 2005). Parallel forms reliability was used to measure reliability obtained by administering different versions of an assessment tool to the same group of individuals. The scores from the two versions were then correlated to evaluate the consistency of the results across alternate versions. The researcher piloted the instrument; respondents who were not part of the sample were requested to complete the questionnaire. Then the researcher detected if the language was clear, the items were understood and unambiguous and ensured that there were no biases in the instrument.

The respondents completed the questionnaire in the absence of the researcher with the aim of obtaining consistent results and to ensure that the participants will not put the researcher in a good light. Quantitative approach gave the researcher the opportunity to analyse the data using mathematically based method that gave better reliable outcomes (Aliaga & Gunderson, 2006). To avoid biasness, the researcher requested Life Orientation educator to conduct the interview.

3.11 Ethical considerations

Rule et al. (2011) stated that conducting research ethically will improve the quality of the research and contribute to its trustworthiness. The public has a right to know and the participants have the right to privacy and protecting their identity. The researcher first requested for consent form from the University of the Western Cape which she gave to the principal (Appendix A). She then asked permission from the principal to conduct the research at the school (Appendix B). In seeking permission from the learners, parents and Life Orientation educator for their voluntary contribution in the study she wrote consent letter to Life Orientation educator and to both parents and learners (Appendices C & N). The consent form to parents was translated to isiXhosa to ensure that they understand my request clearly. The researcher obtained approval from the Eastern Cape Department of Education (ECDE) as well as from the Ethics committee of the University to undertake the research since the intended study took place in a public school. The researcher held an initial briefing session with the learners about the research study. During the consultation, she was intentional watchful not to provide details which could later impact the participant’s responses.

The ethical classroom research was considered since the research was conducted in the classroom. Classroom research was tied to the class topic and content which was on electric circuits and I believed it enhanced the learning experience to both the researcher and learners. In a classroom research, learners learn by doing this is known as experiential learning. Learners in this research were hands-on in practical work. The research was worth the time of learners because it was in line with the work that is expected in grade 11 during the period of the research, learners were not treated as guinea pigs; this is referred to as fidelity in classroom research. Debriefing was done to the participants. Debriefing is the communication the researcher shares with the participants upon the completion of the study. The type of debriefing in study was a double-loop communication, both participants and the researcher learnt from the research. Participants were given feedback on the research outcomes. For research ethics to be valid there were three standard principles to consider as indicated by Rule et al. (2011):

- Autonomy – The researcher needs to ensure that respondents' privacy, confidentiality and anonymity are adhered to. The researcher needed to gain permission from the authorities (ECED) and obtain informed consent from respondents. There should be no deception in securing participation of the respondents.
- Non-maleficence (do no harm) – The researcher needed to ensure that, throughout the research process, neither respondents nor the institution were harmed in any way.
- Beneficence – This principle relates to the duty of the researcher to serve the public good. Such duties include meeting obligations: providing feedback, follow-up or intervention if this was part of the negotiation agreement.

The researcher had abided by these principles to validate the study.

3.12 Conclusion

This chapter looked at the research design methodology applied and gave a description of how the data was analysed in the study. The data collection methods were also described as well as data analysis and ethics statement. The next chapter will discuss the findings and represent the data collected in various forms.

CHAPTER 4

Findings and Discussion

4.1 Introduction

The previous chapter gave a description of methodology used in this study and focused on how the research was approached and coordinated. The aim of the research was to investigate the effectiveness of the use of practical work to teach electric circuits in grade 11. In this chapter, all data collected represented to understand the phenomenon of the effective use of practical work to teach electric circuits is captured and analysed. This chapter looked at detailed analysis of lesson implementation on electric circuits using talk-and-chalk method and practical work method. This chapter also looked at analysis of pre and post test results, how learners have performed specifically in practical-based questions, analysis of questionnaire and focus group interviews. The data collected responded to the following main and research sub-questions:

> **How effective is the use of practical work to teach electric circuits in grade 11 physical sciences?**

To address this research question, the following sub-questions will be looked at:

1. How were practical and talk-and-chalk lessons implemented to teach electric circuits?
2. What were learners' performance in electric circuits after the practical and talk-and-chalk lessons?
3. How were the practical lessons implemented to the Control Group after their theoretical lesson?
4. To what extent does the use of practical work impact on grade 11 learners' performance in electric circuits?
5. What were learners' perceptions of the practical lesson?

4.2 Teaching strategies used in both groups

The research was conducted in two comparable physical sciences grade 11 classes, group E (the experimental group) with 65 learners and group C (the control group) with 60 learners. Both groups were taught the same lesson, which was on electric circuits, using different approaches, namely the traditional telling method and the practical approach. The talk-and-chalk approach was the approach that was generally used in everyday classes no matter what the content. The lesson was more teacher-centred in group C (talk-and-chalk approach) and in group E it was learner-centred (practical approach). Both presentations were videotaped so that the researcher would be able to reflect on each lesson.

4.2.1 Talk-and-chalk lesson presentation (teacher-centred approach) in Group C

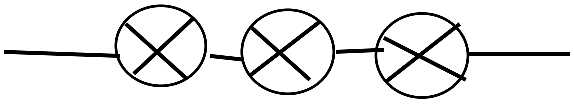
Step 1: The lesson aimed at teaching learners to be able to solve electric circuit based problems at different cognitive levels. The teacher introduced the lesson by asking questions that are in the grade 10 syllabus on electric circuits to determine learners' level of understanding of the topic (electric circuits were introduced in grade 10). Learners' previous knowledge was used as the raw material for the new knowledge that they would learn in the new lesson. The teacher asked the following questions with selected responses from learners:

> *Which instrument is used to measure current and how is it connected in the circuit*?
>
> Response 1: Ammeter is connected in parallel [Learner 1]
>
> Response 2: An ammeter and it is connected in series [Learner 2]
>
> *Yes, this is correct, an ammeter is an instrument that is used to measure current and is always connected in series.* [Teacher explained]
>
> *What is the function of a voltmeter and how is it connected in the circuit?*
>
> Voltmeter is used to measure voltage and is connected in parallel [Learner 3]
>
> *Voltmeter measures voltage and is connected in parallel*. [Teacher added]
>
> *What happens in the circuit when the switch is opened?*
>
> Response 1: All the bulbs switch off [Learner 4]
>
> Response 2: Current does not flow [Learner 1]
>
> *What happens in the circuit when the switch is open?*
>
> No current flow [Learner 5]
>
> *What happens to the other bulbs when one bulb burns out in series connection?*

There was no response at first, some learners looked at the teacher with blank faces which made the teacher think that maybe they did not understand the question or they were not sure of the answer. One learner frowned as if she was trying to figure out exactly what the teacher was asking.

The teacher repeated the question with the aid of a diagram on the chalkboard, and asked:

> *Let say you have three bulbs connected in series and one burns out or is removed what will happen to the remaining two bulbs?*



Three bulbs in series connection drawn on the chalkboard

> This was the response after the illustration
>
> Response 1: Other bulbs will be dimmer [Learner 6]
>
> Response 2: All bulbs will not light [Learner 7]
>
> Response 3: Um……! (hesitating) The other bulbs will also not light because there is one path for current [Learner 1]
>
> *There is only one path for current when bulbs are in series, if one burns out the others will not light because the current path will be obstructed in the bulb that has burnt out.* [Teacher]

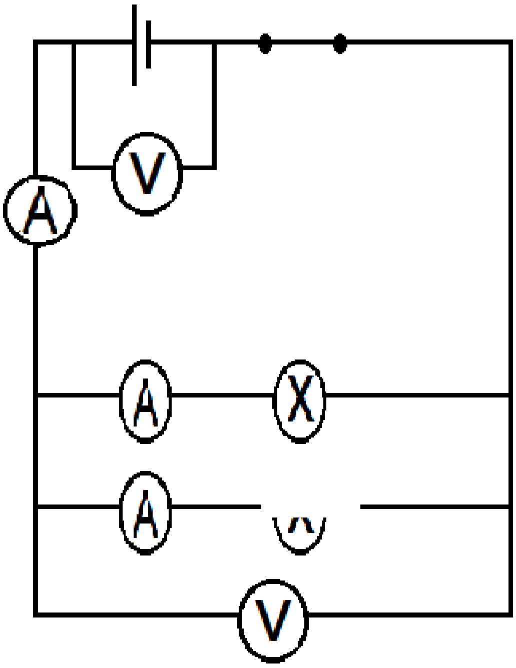
Some of the learners could correctly respond to these questions from their grade 10 knowledge of electric circuits although some had misconceptions.

Step 2: The teacher further explained the difference in voltage, current and total resistance when resistors are connected in series and when they are in parallel. The following diagrams were drawn on the chalkboard to explain the differences in parallel and series connections:

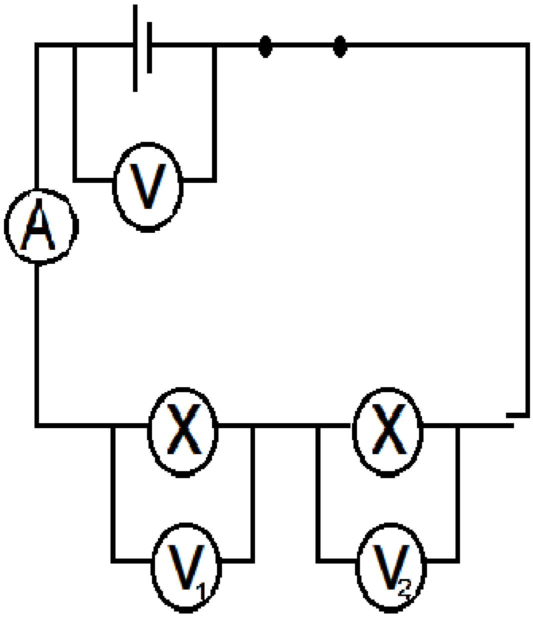
Parallel connection	**Series connection**
Resistors in parallel are current dividers ($I_T = I_1 + I_2 + I_{3\ldots\ldots\ldots}$) example, If I_T is 5A, 5A= 3A + 1.8A + 0.2A	Current is the same throughout the resistors in series ($I_T = I_1 = I_2 = I_{3\ldots.}$) example 5A = 5A = 5A
Voltage is the same across the resistors	Resistors in series are voltage dividers

in parallel ($V_T = V_1 = V_2 = V_3$……) example, if R_T is 8V, 8V =8V=8V	($V_T = V_1 + V_2 + V_3$….) example 8V = 5V + 2V + 1V
$1/R_{//} = 1/R_1 + 1/R_2 + 1/R_3$……example, resistors with resistance of 6Ω, 10Ω and 4Ω, 1/6 + 1/10 + ¼	$R_{total} = R_1 + R_2 + R3$….example 6Ω + 10Ω + 4Ω

Formula for calculating total voltage is $V_T = I_T.R_T$



Parallel connection



Series connection

The explanations were followed by circuit diagrams and calculation that were done by the teacher on the chalkboard. The following were some of problems that were solved by the teacher which were calculated on the chalkboard:

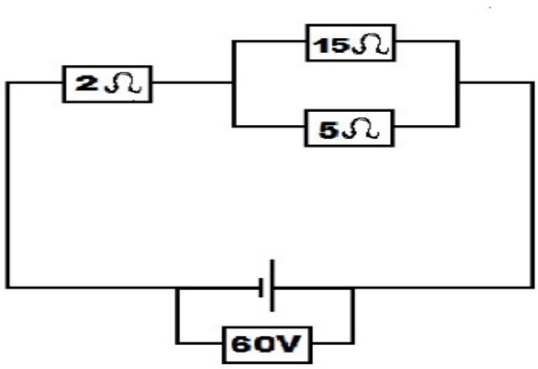


Diagram 1

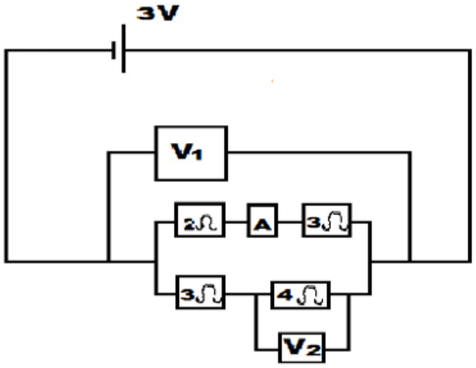


Diagram 2

In diagram 1, calculate:

1. The current.
2. The potential difference across 15Ω resistor.

The teacher engaged learners in solving these problems. (Diagram 1)

> *Which type of circuit in diagram 1?* [Teacher]
>
> It is a mixed circuit because it has two resistors in parallel and one in series. [Learner 2]

The teacher explained that the formula for calculating total current is I= V/R then first the teacher calculated total resistance:

1. $1/R_{//} = 1/R_1 + 1/R_2$ (Teacher explained that the first step was to get the total parallel resistance)

=1/15 + 1/5

= 3.75Ω

$R_T = R_{//} + R_{series}$ (Teacher: to get R_T, R_{series} must be added to $R_{//}$)

= 3.75 + 2Ω

= 5.75Ω

I = V/R (To get the total current flowing in the circuit, V_T is divided by R_T)

=60/5.75

= 10.43A

The teacher proceeded to the second part of the question which was to calculate the potential difference across 15Ω resistor):

$V_{15\Omega} = I_{15\Omega}.R_{15\Omega}$ (potential difference (voltage) across the 15Ω resistor is given by the current and voltage across the 15Ω resistor)

What is the current passing through the 15Ω resistor? [Teacher]

The responses from learners:

10.43A [Learner 5]

There is only a current for the total circuit which is 10.43A, I don't know how to get current in 15Ω resistor [Learner 1]

This is correct, we need to first get the current passing through the 15Ω resistor as it is connected in parallel to the 5Ω resistor [Teacher]

As it was stated that resistors in parallel are current dividers, current is inversely proportional to resistance which meant that if the resistor has high resistance then that resistor will have lesser current, current is divided equally only when resistors are having equal resistance.

Which resistor has more resistance? [Teacher]

"Teacher let me try to answer though I am not sure, 15Ω resistor has more resistance than 5Ω resistor, more current will go to the 5Ω resistor and there will be less current on the 15Ω resistor" [Learner 6]

The teacher further explained that the resistance in the15Ω resistor is three times greater than the 5Ω resistor therefore the current in the 5Ω resistor will be three times the current in the 15Ω resistor. The teacher used ratio to calculate the current:

Ratio: 5:15

1:3 ¼*10.43 =2.6A, the current in the 15Ω resistor 2.6A in the 5Ω resistor is 10.43A-2.6A=7.83A

Step 3: Learners were given classwork for evaluation which was then completed as homework due to ending of the period. The aim of giving learners classwork was to check whether the outcome of the lesson was achieved. The teacher checked the homework on the following day and most of them had correctly done it but it was not a reliable way of testing learners' level of understanding as there are more chances of copying homework. Then the learners were given a control test.

4.2.2 Practical lesson presentation (Learner-centred approach) in Group E

The same lesson was presented in group E but with practical approach. Learners were exposed to practical activity lesson where they had to use their hands for connecting electric circuits, use their eyes to observe what happened then apply their minds on the phenomenon. The following are the steps that were administered during lesson presentation:

Step 1: The lesson was introduced by the teacher by asking the following questions:

> *As you studied electric circuits in grade 10, what is voltmeter and how is it connected in the circuit?* [Teacher]

No one appeared to be ready to respond the teacher assumed that the question was not understood or they were trying to recall. The teacher repeated the question the same way. Five learners' hands were up ready to respond. They responded as follow:

> Response 1: It is used to measure current and is connected in parallel [Learner 5]
>
> Response 2: It is connected in parallel and it measures voltage [Learner 6]
>
> Response 3: It measures voltage and I think ……uh… (hesitating) is connected in parallel [Learner 7]

Learner 7 responded correctly but was doubting. The teacher connected a circuit and showed the learners how the voltmeter is connected in the circuit.

The teacher asked again holding up the circuit so that all learners could see:

> *How is the voltmeter connected and what does it measure?*
>
> Voltmeter is connected in parallel and it measures voltage [All the learners]

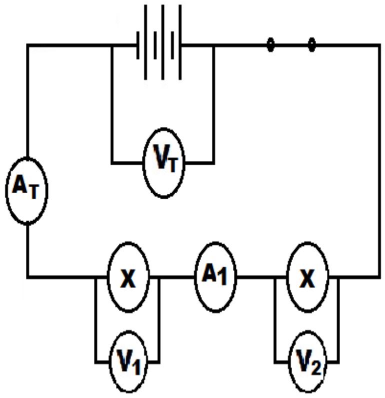
The teacher randomly formulated six groups; five groups with eleven members each and one group with ten members as there were only seven available electric circuit kits. One kit was used by the teacher for demonstration. Teacher also showed the leaners what happens to the ammeter and voltmeter needles if connected wrongly. Each kit consisted of 2 voltmeters, 2 ammeters, 2 bulbs, 3 cells in a cell holder, two switches and connecting wires. The following were the objectives of the lesson:

- Learners must be able to identify the differences in voltage, current and resistance when resistors are in parallel and when they are in series.
- To solve questions that are based on electric circuits at different cognitive levels.

Step 2: Groups were provided with worksheets with instructions of what the learners were required to do:

Stage 1: Connect an electric circuit with two bulbs connected in series, a voltmeter across each bulb and a voltmeter that will measure the total voltage, connect ammeter that will measure the total current and current across each bulb as seen in the diagram below.

As the lesson was videotaped, teacher moved around the groups to observe what the learners are learning during practical lesson. With the intention of discovering learning processes that take place during practical lesson, it would be best if learners are operating in their mother tongue which is isiXhosa.



Connection in series

Measure the total current in the circuit and the current passing through each bulb, record your results in a table. Measure the total voltage in the circuit and the voltage across each bulb, record your results in a table.

Voltage in series		**Current in series**	
V_{total}		I_{total}	
V_1		I in bulb 1	
V_2		I in bulb 2	

> Teacher can you please check if our ammeters are correctly connected, they are not showing any reading. [group 1]
>
> *Negative terminal of ammeter which is represented with the black nob is connected to the negative side of the battery and the red nob is connected to the positive side of the battery.* [Teacher explained by showing them in the circuit used for demonstration]

There were lot of discussions and trial and error that were taking place in the groups. The following were some of the arguments from the groups as they struggled to assembly their connections:

“Hayi fondini bekuthwe unegative ngulo ufakwa apha….” (pointing at the ammeter) translation: Negative is connected here [Learner 1 from group 1]

“…sifake ndawoni ke ngoku apha kwiammeter” translation: where should we connect in the ammeter? [Learner 3 from group 1]

“Bekuthwe senza njani kanene when we connect parallel bulbs? Translation: what did the teacher say about how bulbs are connected in parallel [Learner 1 from group 2]

“Okay makhe senze kanje…masijonge nalapha kwiworksheet uba le diagram imi kanjani [Learner 4 from group 2 demonstrated for the group] translation: lets’ do it this way

Learners were instructed to observe and record ammeter and voltmeter readings on the table, then the findings would be discussed by the whole class. Figure 2 is showing learners’ interaction during electric circuit practical lesson approach.

Figure 2: Practical approach lesson on electric circuit

Table 8 shows the voltmeter and ammeter readings that were obtained by group 3 learners.

Table 8: Group 3 presentation of findings

Voltage in series (in V)		**Current in series (in A)**	
V_{total}	4.4	I_{total}	0.6A
V_1	2.2	I in bulb 1	0.6A
V_2	2.2	I in bulb 2	0.6A

> There were lot of disagreements in our group on how voltmeters should be connected when resistors are in parallel, we tried many ways, we finally got assistance from our teacher. In our group (group 3) we noted that as we connect the voltmeter across the battery the reading was 4.4V, then in bulb 1 the reading was 2.2V and in bulb 2 the reading was also 2.2V. [Learner 4 from group 3]

> *Thank you group 3 for your presentation. From these findings, what can be observed in the relationship between V_{total} and V_1 and V_2?* [Teacher]

> We observed that if bulbs are connected in parallel the voltage across every point in the circuit is the same. [Learner 5 from group 3]

> We also got the similar readings in our group. We noted that if add the readings of V_1 and V_2 you get the reading on V_{total} ($V_1 + V_2 = V_{total}$ .2V + 2.2V=4.4V) [Response from a learner from group 5]

There was less assistance that was required in group 5 as they did not struggle much to connect. The teacher encouraged the group members to all participate in the making a circuit connection.

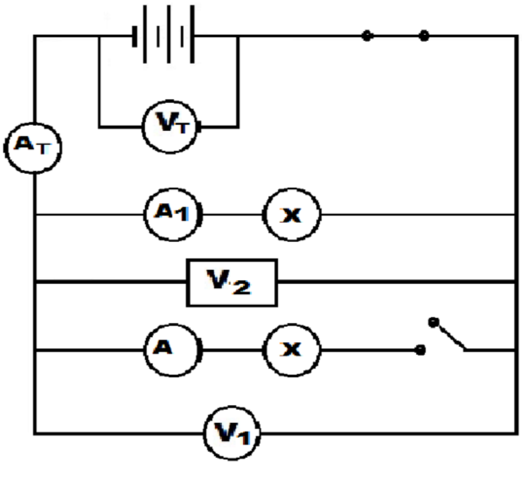
Group 6 presented their results on ammeter and voltmeter readings as indicated in table 9.

Table 9: Group 6 presentation of findings

Voltage in series (in V)		Current in series (in A)	
V_{total}	4.4	I_{total}	0.6A
V_1	2.2	I in bulb 1	0.6A
V_2	2.2	I in bulb 2	0.6A

> We also struggled first to connect ammeters, the needle was moving anticlockwise, our teacher showed us how to connect correctly. We decided not to use the scale in mA as we would have to convert mA to A, we therefore measured current in Amperes. We could not see the exact position of the ammeter needle as it was slightly below 0.6, we agreed on writing the approximate value of 0.6A. We also observed that the ammeter reading is the same throughout the circuit. [group 6 representative]

Stage 2: Method in stage 1 was repeated by in parallel connection. Connect an electric circuit with two bulbs connected in parallel, a voltmeter across each bulb and a voltmeter that will measure the total voltage. Close the main switch and open the switch across one bulb as indicated in the diagram, record the readings of A_1 (ammeter which measures total current) and the ammeter readings across each bulb.



Connection in parallel

Record the readings of V_T, V_1 and V_2. Close both switches, measure the total current in the circuit and the current passing through each bulb, record your results in a table. Measure the total voltage in the circuit and the voltage across each bulb, record your results in a table. Tables 10 and 11 show the results that were obtained by group 2.

Table 10: Group 2 presentation of results

Readings when one switch was closed

Voltage in parallel		**Current in parallel**	
V_{total}	4.5V	I_{total}	0.7A
V_1	4.5V	I (A) in bulb 1	0 A
V_2	4.5V	I (A_1) in bulb 2	0. 7A

Table 11: Readings when both switches were closed

Voltage in parallel		**Current in parallel**	
V_{total}	4.5V	I_{total}	0.8A
V_1	4.5V	I (A) in bulb 1	0.4A
V_2	4.5V	I (A_1) in bulb 2	0.4A

[Report from group 2 representative] We first struggled to connect a circuit, since it was our first time to deal with electric circuits, it was difficult to open crocodile clip. Our teacher showed us how to connect resistors in series and in parallel. In our group, we observed that when the switch across bulb two was opened the readings on voltmeter and ammeter across bulb two were zero, V_{total} equal to V_2 and I_{total} equal to I_1. When both switches are closed, the reading in the voltmeter across the battery is the same as the readings across the bulbs, the voltage across the battery was

4.5V. There was a debate in our group as we were observing the exact position of the voltmeter needle across bulb one, others said it was slightly below 4.5V, others said no it was exactly at 4.5V, we then agreed on the approximate value which was 4.5V. As we were having two ammeters, the first ammeter measured the total current, we recorded the reading which was 0.8A, then connected another ammeter across the first bulb which showed the reading of 0.4A. We removed the ammeter from the first bulb and connect it on the second bulb, the reading was 0.4A.

Looking at the observations and results, what could you say about voltage and current when resistors are in parallel and in series? [Teacher]

In parallel I_{total} is the sum of current across bulbs, in series I_{total} is the same as current across bulbs. V_{total} is the same as voltages across the bulbs in parallel, in series V_{total} is the sum of voltages across bulbs. [Learner from group 1]

The teacher summarized by explaining to learners that in a series connection current is the same across all the resistors, the total current is the same as the current across the resistors. Resistors in series divide the voltage across the resistors and are known as potential dividers or voltage dividers. The total voltage is the sum of the voltages across the resistors. In parallel connection, voltage is the same across the resistors and current is divided across the resistors. If the resistors have the same resistance, current will be divided equally but the bigger the resistance in a resistor the lesser the current. When a switch is open, current does not flow.

Step 3: Same calculations which were done in Step 2 (page 60) of group C were also administered in group E.

Step 4: Both groups were given the same control test (see Appendix G) at the same time. Test results were analysed in 4.2.3

4.2.3 Findings of test after lesson implementation

The aim of using different methods was to compare the effectiveness of the use of practical approach to theoretical approach to teach electric circuits as these methods were administered to both classes. The objective of this research was to investigate the effectiveness of the use of practical work on teaching electric circuits. After the lesson presentations, both groups were given the same control test which added up to 60 marks (refer to appendix G) and the results were compared and analysed (refer to appendix L). In the test, three categories were evaluated in the test which was recalling in question 1 (out of 12 marks), application in question 2 (out of 30 marks) and practical based questions in question 3 (out of 18 marks). Table 12 indicated comparable percentages obtained in both groups in the total for pre-test.

Table 12: Table showing percentages of test categories in the pre-test

Category	**Total marks for each category**	**Percentage achievement of Group C learners per category**	**Percentage achievement of Group E learners per category**
1. Recall (Question 1)	12	70	75
2. Application (Question 2)	30	29	49
3. Practical based questions (Question 3)	18	07	28
Total group %	60	35	51

According to the results in the table, both groups were effectively able to answer recall questions, group C obtained an overall of 70% in recall questions with group E obtaining 75%. This showed that reproducing type of questions such as stating, naming and describing are not much thought-provoking to learners as reflected in question 1 in the test. Challenge could be noted in the application type of questions (question 2) as group C acquired only 29% with group E obtaining 49% of the questions. In question 2, learners were to answer questions based on given circuit diagrams. Question 3 was addressing the practical part of electric circuits, group C and group E attained 7% and 28% in this question respectively.

Both groups performed fairly in questions one and two which were based on recall and calculations. There was a notable drop of performance in question 3 which was based on practical specifically in group C. As it was indicated in 4.1.2 of chapter 4 that group C, which is the group that was taught with theory only, performed poorly with an attainment of only 7% of practical-based questions and in group E, 28% of the learners managed to get these questions correctly.

In question 3.1.1, learners were given a circuit diagram with three bulbs (X, Y and Z respectively) connected in parallel, bulbs Z burned out. Learners were to describe the readings ammeters across each bulb when bulb Z has burned out, only two of those learners that were exposed in practical managed to get correct answers and none in the theoretical group. Most learners chose option A and some chose option B which had a total current of 2.5A which was the total current before Z burns out. From these responses, it could be observed that learners appeared not to understand that when bulb burned out in parallel increases the total resistance which result in the decrease in current. Learners also assumed that all light bulbs are identical and simply splitting current equally which was the reason for choosing option A which had equal values of current. This question was the same as the question that was asked in question 1 in the final examination of grade 12 in 2014. It was distinguished in National Diagnostic Report that most learners in this question failed to understand that when Z burns out no current will pass through ammeter 3 which was the ammeter across bulb Z and the total resistance will increase and therefore the current will increase. And this was also the case with the learners in this study. It was recommended that teachers should expose learners in experiments so that learners could be able to analyze practical-based questions.

In question 3.2.1 learners were required to identify the terminal of the ammeter that was represented by letter E, none of the learners got the answer correct in group C five in group E succeeded to answer correctly. Learners seemed to be confused about relating the term terminal to an ammeter. The following are some of their misconceptions:

> “E represents a conductor”
> “E is the symbol of ammeter”
> “Positive”

The use of experiments helps learners to understand why a component must be connected in a certain way, learners that are exposed to practical would be able to identify the correct terminal of connecting an ammeter. This misunderstanding was also distinguished in question 8.2.4 of November 2014 in grade 12 where learners got confused to identify device Z in the circuit. It was suggested in National Diagnostic Report of 2014 that teachers should perform experiments to explain why each component is connected in a particular way for example negative terminal of ammeter or voltmeter is always connected to negative terminal of the battery and positive to positive (NDR, 2012). This misconception was also the case in question 2 of grade 12 final examination of 2011, as it was reported in the National Diagnostic Report of 2011 that learners did not know that an ammeter must be connected in series and voltmeter in parallel. In the report, it was believed that learners performed poorly in that question because of lack of practical work (NDR, 2011). The poor test outcomes of group C echoed the remarks that were made by Minister of Education as emphasized in chapter 1 of this study that learners are underperforming in physical sciences because of the lack of exposure to practical work.

> ‘Learners seem to have difficulty in answering questions that are based on practical work because of lack of exposure to practical work’ (NDR, 2013).

Four learners got correct answers in question 3.2.2 and only one got the answer correct from group E and group C correspondingly. The question required learners to calculate the total resistance in the circuit, some learners seem not to understand any differences in resistance when switches are opened or closed. Another remarkable misunderstanding was noted in 3.3 whereby learners were to explain how does the burning out of bulb Z affect the reading of voltmeter and emf. The following are the common incorrect misinterpretations that were made mostly by group C in question 3.3:

Response 1: The reading of V will decrease and emf will increase.

Response 2: Both readings V and emf will remain the same.

Response 3: V will decrease and emf will remain the same.

Response 4: Reading of emf will increase and the reading of V will also increase.

Response 5: V will remain the same and emf will increase.

Responses 2 and 4 appeared to have no understanding of the differences between emf and external voltage. A related question to this was asked in grade 12 final examination in question 10.4 in 2011, learners were required to explain what would happen to external voltage when a headlamp burns out. Learners could not identify emf and external voltage in the provided diagram, they incorrectly assumed that the internal resistance was changing. The involvement of practical work was the first suggestion to solve this challenge. (NDR, 2011).

This study is focusing on how effective is the use of practical work to teach electric circuits in grade 11 therefore it is essential to show the number of learners that could correctly answer each sub-question in this section. The following table (table 13) breaks down the comparable performance of learners in question 3 which was practical based to clearly show the performance of learners in this question.

Table 13: Learner performance analysis in question 3 (practical-based)

Question	Number of learners that obtained correct answer in each sub-question (Group C)	Number of learners that obtained correct answer in each sub-question (Group E)
3.1.1	0	2
3.2.1	1	5
3.2.2	1	4
3.2.3	1	2
3.3.1	0	2
3.3.2	0	1
3.4	1	2
Total number of learners	4 out of 60	18 out of 65

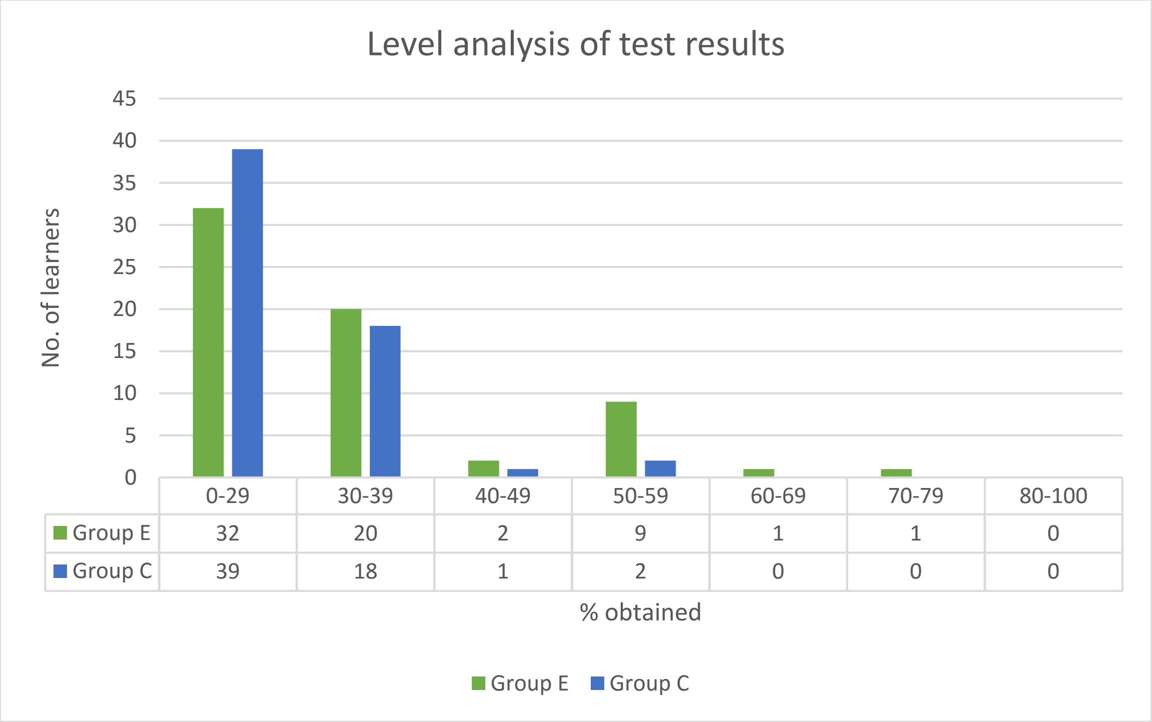
As highlighted in the table, only a total of 4 and 18 learners from group C and group E respectively that succeeded in answering practical based questions on electric circuits correctly. Not a single learner in group C managed to answer question 3.1.1 correctly, two learners in group E got the answer for 3.1.1 correct. One and five from groups C and E respectively correctly attempted question 3.2.1. Group C learners struggled to answer practical based question as the table indicated 1 out of 60 learners obtained question 3.2.2 and 4 learners in group E managed to get correct answers. In question 3.2.3 only 1 learner and 2 learners in group C and group E correspondingly who prospered to get correct answers. Most learners could not answer 3.3.1 and 3.3.2, none of the learners attained these questions in group C and only 2 learners and 1 learner in group E respectively got the questions correct. In the last question, which was 3.4, one learner got the correct answer in group C and two in group E got the question correct. Furthermore, it is also crucial to understand and analyse the performance of learners in terms of their performance level categories as the levels are shown in table 14.

Table 14: Table showing level categories

Level	**% range**	**Achievement description**
1	0-29	Not Achieved
2	30-39	Elementary Achievement
3	40-49	Moderate Achievement
4	50-59	Adequate Achievement
5	60-69	Substantial Achievement
6	70-79	Meritorious Achievement
7	80-100	Outstanding Achievement

A level below 30% is regarded as not achieved or fail. Pass rate for physical sciences is beginning from level 2 which is a very poor pass rate and seldom considered as an entry requirement in universities especially in science related fields. Figure 2 shows the level category analysis of test results for both groups.

The figure (figure 3) below indicates that in the experimental group (group E), 33 out of 65 learners who wrote the test passed, with 20 learners obtaining only level 2 pass, thirteen learners achieved above 40% and with zero distinctions. This indicated that though 51% of group E learners have passed, the quality of results was not good. In group C, out of 60 learners who wrote the test, 21 learners passed the test with 18 learners attaining only level 2 pass and three learners obtained 40% and above but with no distinctions.



	0-29	30-39	40-49	50-59	60-69	70-79	80-100
🟩 Group E	32	20	2	9	1	1	0
🟦 Group C	39	18	1	2	0	0	0

Figure 3: Graphic representation of test results after lesson implementation

4.2.4 Practical teaching approach in the Control Group

With the purpose of finding the effectiveness of use practical work, the lesson was repeated in group C using the same method which was applied in group E which was the practical approach. The principle of scaffolding was used, the teacher helped the learners to develop their own understanding of the lesson. The following observations and comments that were raised by learners during practical lesson presentation indicate that use of practical work stimulated scientific inquiry in learners:

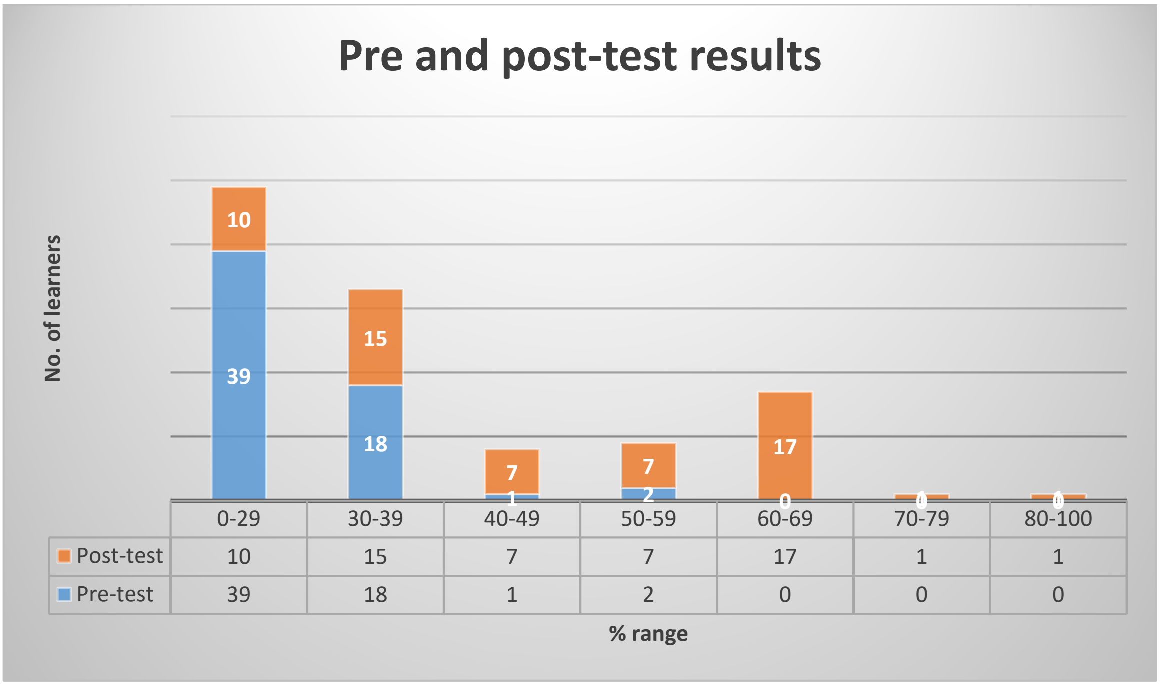
> Remark 1: Now I understand that the negative terminal of an ammeter is connected to the negative terminal of the battery and positive to positive. I did not know it when it was asked in a test. [Learner 2 from group 3]
>
> Remark 2: I also did not understand the question in the test that was asking what would happen to the voltmeters when one switch is open and one closed. Now through this experiment I could observe what happens to voltmeters when switches are closed or open. [Learner 1 from group 1]
>
> Remark 3: "Look at this mfethu (my brother), the value of emf is not affected when one bulb burns out" [remark from learner 1, group 2]

Each group was given an opportunity to present its findings on parallel and series connections. After the practical approach presentation, group C was given a similar control test to the pre-test (see appendix J). The results were compared to the previous test results. The structure of the test was in the following manner, Question 1 (recall type questions) was out of 12 marks, question 2 (Application) out of 22 marks and question 3 (Practical based) out of 26 marks. Table 15 shows comparable question by question percentage results obtained by group C in the pre-and post-tests.

Table 15: Question by question analysis of results in the pre-and post-tests

Category	Total marks for each question (pre-test)	% obtained in the pre-test	Total marks for each question (post-test)	% obtained in post-test
Recall (Question 1)	12	70	12	95
Application (Question 2)	30	29	22	88
Practical-based (Question 3)	18	07	26	65
Total % obtained	60	35	60	83

The results indicate an improvement in learner performance, there was a percentage increase of 25% in the first question. In question 2 (out of 22 marks) which was categorized as application, there was a considerable progress of 59% from 29 to 88%. The results illustrate that the use of practical work helps learners in answering practical based questions, after the practical lesson learners could achieve 65% of the questions in the post-test compared to 7% that was attained in the pre-test. Overall percentage obtained in the post-test was 83% compared to 35% acquired in the pre-test, there was a distinguished enrichment of 48%. The following figure further demonstrates an evaluation of group C post and pre- test results in terms of quality of results.



	0-29	30-39	40-49	50-59	60-69	70-79	80-100
🟧 Post-test	10	15	7	7	17	1	1
🟦 Pre-test	39	18	1	2	0	0	0

Figure 4: Group C pre-test and post-test results

4.2.5 Learners' achievement after the practical approach in Group C

As the results were indicated in figure 4, there was an improvement of 48% in the post test results (after practical approach) in Group C. It was notable that the use of practical approach had a positive impact on improving learner performance in electric circuits. Out of 58 learners who wrote the test, 48 learners passed the test with only 15 learners who attained lowest level 2 pass and 33 learners obtained above 40% with at least one distinction. There was a remarkable improvement in quality results obtained by learners, in the first test the highest percentage was 58% and in the second test the highest percentage obtained was 80%.

An improvement of percentage levels was also noted; the number of lowest level 2 percentage passes decreased from 18 to 15 in the post test, more learners attained percentages above 40. It is also in the interest of the study to compare the pre-and post-test results that were obtained by the learners in question 3 which was based on practical. The following table (table 16) shows results obtained by group C in the practical based question.

Table 16: Pre-and post-test practical based results analysis (question 3)

Pre-test results for practical based question (question 3) in Group C		**Post-test results for practical based question (question 3) in Group C**	
Question	**Number of learners that obtained correct answer in each sub-question**	**Question**	**Number of learners that obtained correct answer in each sub-question**
3.1.1	0	3.1	10
3.2.1	1	3.2.1	2
3.2.2	1	3.2.2	10
3.2.3	1	3.2.3	2
3.3.1	0	3.2.4	6
3.3.2	0	3.2.5	6
3.4	1	3.2.6	2
Total number passed in this question	4 out of 60	Total number passed in this question	38 out of 58

As specified in the table, a total number of 38 out of 58 learners performed well in a practical based question. This data showed significant improvement when it was compared to question 3 of the test after the theoretical lesson. Possible assumptions on the improved performance of learners could be based on the notion that the same lesson was repeated on the same group of learners as this was indicated in the limitations of this study and there were also two learners who were absent during the post-test. But the use of practical approach played a significant role in the improvement of learner performance as 100% of the learners in the questionnaire indicated that they enjoyed doing practical work.

4.3 Learners’ perceptions of practical work

4.3.1 Questionnaire data (closed-ended questions)

Data was collected from 123 respondents out of 125 learners, two learners were absent on that day. 18 respondents were destroyed as they were spoilt, 105 respondents were analyzed (see appendix G). The following was the likert scale that was used in the questionnaire 5- Strongly agree, 4- Agree, 3- Sometimes, 2- Seldom, and 1- Disagree

4.3.1.1 Doing practical work

Table 17: Learners’ perception on doing practical work

Responses	%
Strongly agree	96
Agree	04

According to the responses in table 17, enjoying doing practical work had its popularity as all the learners noted that they enjoy doing practical work with 96% of strongly agreed responses and 4% of the learners also agreed that they enjoy doing practical work. This suggested that learners enjoy most when they are actively involved in science lessons.

4.3.1.2 Learning from practical work

The figure below (figure 5) indicated that most of the learners (95%) believed that they learned from doing practical work on electric circuits. This is highly replicated on the improvement of their performance in the second test, more learners could solve problem-based questions compared to their first test. The use of practical work helped the learners to understand practical-based questions. A composition of only about 2% of learners felt that they were not very sure if they learn from practical work this could be because of large group size depending on one kit.

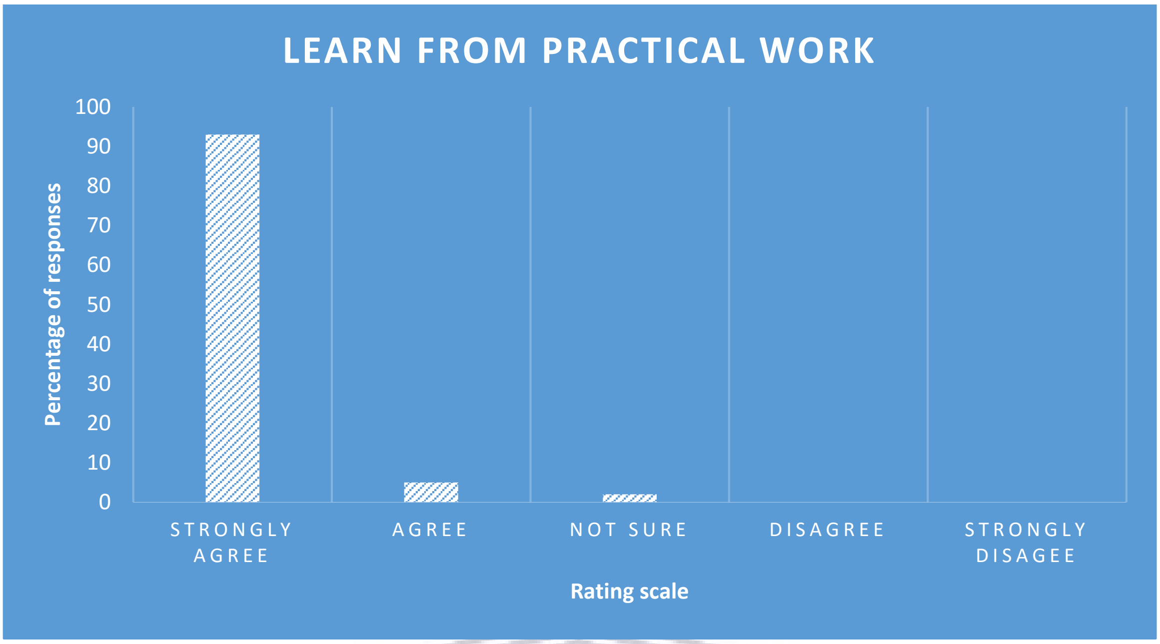


Figure 5: Learners learn from practical work

4.3.1.3 Practical work enriches understanding of physical sciences

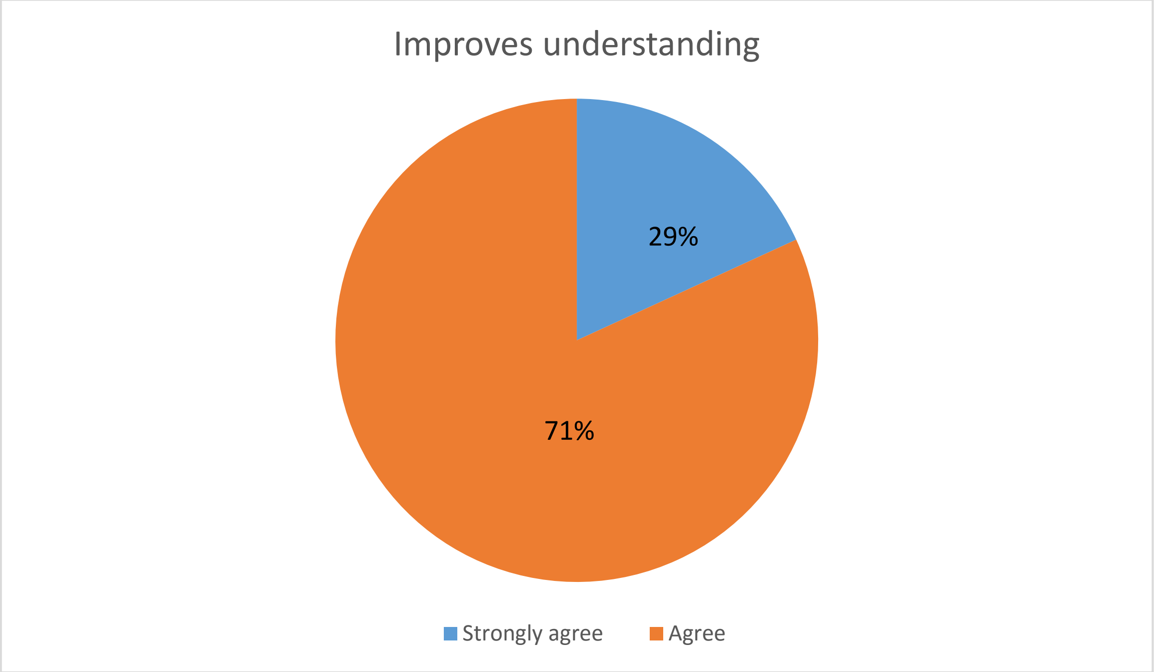


Figure 6 Practical work improves learners’ understanding

It is distinguished from figure 6 that learners felt that the use of practical work in learning electric circuits helped the improvement of their understanding, with 71% of learners strongly agreed that their understanding improved through practical work. And 29% of learners agreed that being able to connect circuit practically and correctly, compare voltage and current in series and parallel connections improved their understanding of the topic.

4.3.1.4 Learners prefer doing practical work to learn science

The responses in table 18 indicate that 78% of the learners strongly agreed that they prefer doing practical work, 14% of the responses also agreed that they prefer practical work as a way of learning electric circuits. Out of a composition of 105 respondents, 8% was not sure if practical work could assist in learning science.

Table 18 Table showing percentage of responses who prefer doing practical work

Prefer doing practical work	Strongly agree	Agree	Sometimes
	78	14	8

4.4.1.5 Practical approach develops understanding of science

Table 19 Responses of learners according to the rating scale

I need more practical work in science lessons	Strongly agree	Agree	Sometimes	Disagree	Strongly disagree
	95	5	0	0	0
To learn science, I need practical work	85	5	10	0	0

It is notable from the learners' responses, (see table 19) that there is a need for practical work in physical sciences lessons as 95% of the learners strongly agreed and 5% of respondents also supported that the need for hands-on science lessons. According to the response from learners, 85% of respondents specified that practical work is necessary for learning science. 5% of learners also supported that science needs practical work. Few respondents (10%) was not sure if practical work would have any positive impact in their science learning.

4.3.1.6 Practical work develops confidence is solving electricity related questions

When learners were asked if the involvement of practical work developed their confidence in solving electricity related questions, 48% significantly noted that their confidence have developed. This is supported by a remarkable improvement of 48% in the second test after practical approach. 32% of respondents purported that the use of practical approach has developed their confidence in science. 15% stated that they were not sure if involving practical work developed their confidence. A limited number of 5% disagreed that their confidence has developed, this is also observable in the test results that some few learners who failed in the first test had shown slight improvement in the second test.

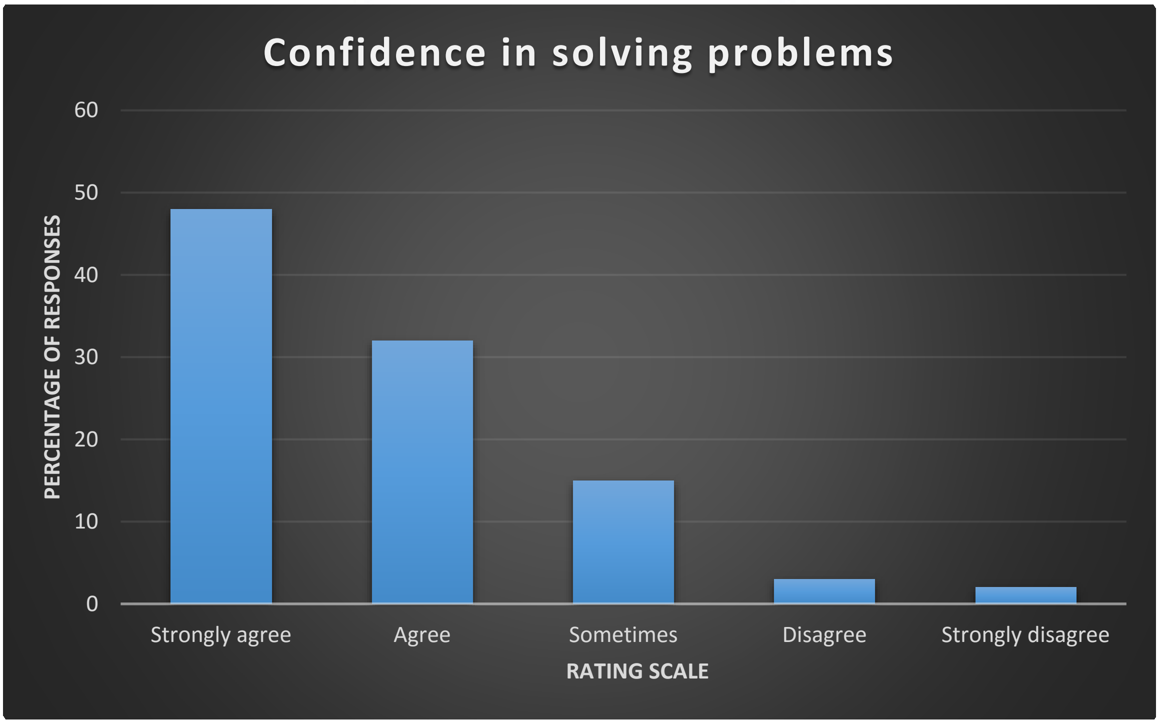


Figure 7 The use of practical work helps learners to gain confidence

4.3.1.7 Relating school knowledge on electric circuits with everyday knowledge

As shown in figure 8, the information gathered from questionnaire exhibited a limited number of respondents (12%) who can relate the knowledge they have gained in class with their everyday knowledge. 10% of learners agreed that the knowledge that they gained in electric circuits can be able to relate it to everyday knowledge. Half of the respondents were not sure that they could be able to integrate the knowledge they gained in electric circuits with their everyday knowledge. 27% of respondents disagreed that what is learnt in electric circuits can be related to everyday knowledge.

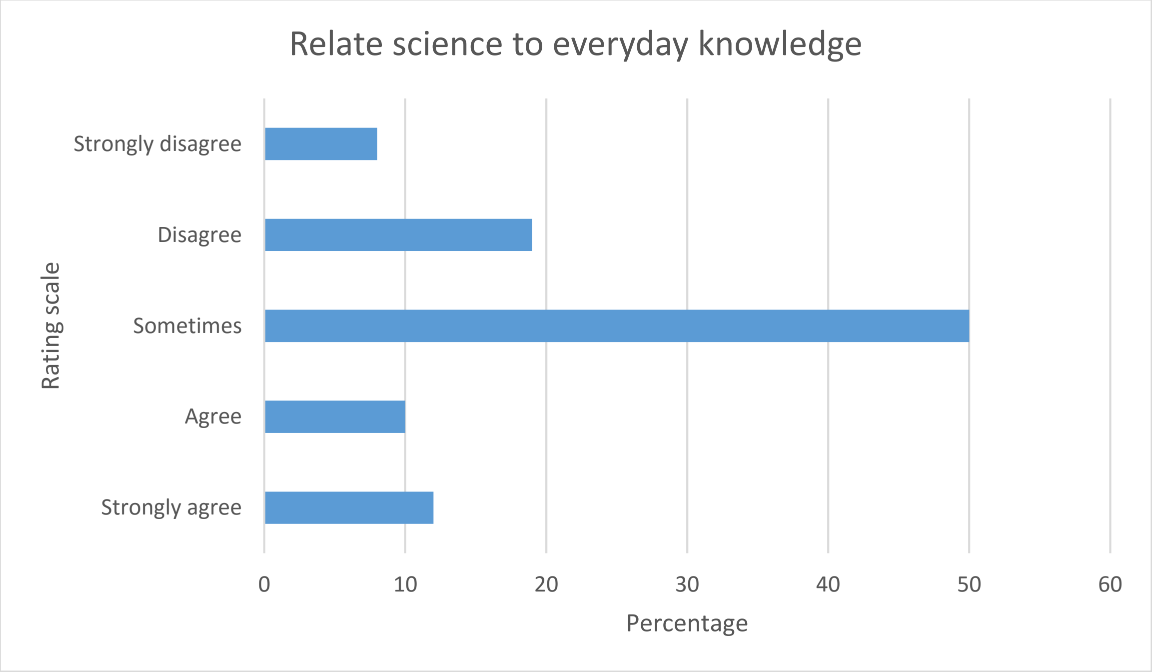


Figure 8 Relating classroom knowledge with everyday knowledge

4.3.1.8 Science as a career after school leaving

A concerning evidence collected from the data captured indicated that there is little interest shown in science related careers, 7% of learners did not consider science as useful after school leaving, this could be the effect of lack of career guidance in rural areas (refer to figure 9). Most learners (83%) were not sure if they would study science related careers after school leaving. Followed by 5% who completely disagreed to consider science as a career.

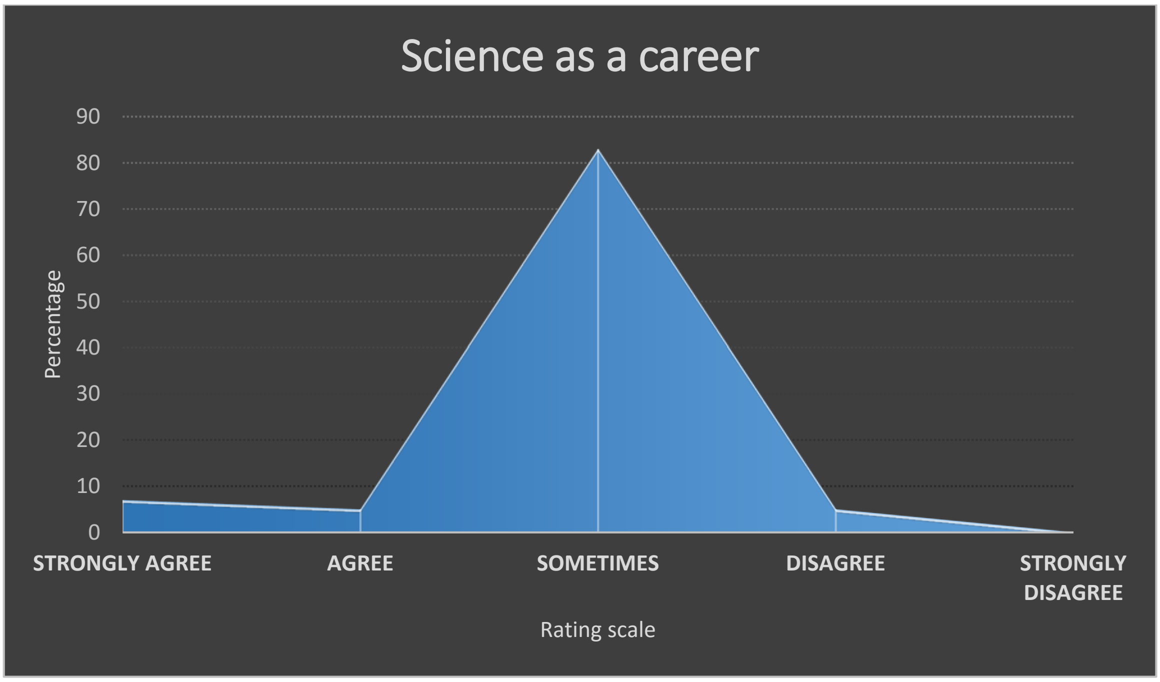


Figure 9 Science as useful career after school leaving

4.4 Questionnaire analysis of open-ended questions

Learners were asked to write their suggestions and comments on the lesson on electric circuits. Majority of learners (about 96%) indicated that it was difficult to understand electric circuits without practical, the lesson become clearer when it was repeated with a practical approach. The following are some of the comments that were made by learners as they were reflecting on the lesson and its impact on test results:

> I suggest that physical sciences lessons must be taught with experiments. [L 1]
>
> I like experiments. [L 2]
>
> I suggest that our teacher must give us a chance to do experiments. [L 3]
>
> I gained better understanding of electric circuits when we were doing experiment. [L 4]
>
> It surprised me to observe that there is no change in voltmeter reading across resistors in parallel and in series each resistor has its voltage. [L 5]

Most responses highlighted that doing practical work was interesting, they could connect parallel and series connections. Learners specified that they could observe the voltmeter and ammeter readings when resistors are in parallel and in series. 100% respondents agreed that they wish physical sciences could be taught with practical approach.

4.5 Learners' responses in the focus group interviews

As all learners were exposed to theoretical and practical approaches, it was of researcher's interest to find out their opinions on practical approach. During the interview, learners were asked to freely express their views on the practical approach to which they were exposed to. Focus group interview of four groups labelled as F1 to F4 was analyzed. The themes identified after coding the learners' responses pointed to their satisfaction with the practical approach.

4.5.1 How do learners think of practical approach?

Learners indicated that they enjoyed the practical lessons and wanted more of these types of lessons. They pointed out that working on the practical aspects of the lessons through the hands-on approach helped them to understand their work and made them experience the theory. Some of the learners indicated that:

> It was difficult for me to understand electric circuits [F1:L1]
>
> Through practical work I gained better understanding of electric circuits [F1:L2, F1:L6, F4:L5, F3:L3]
>
> In physical sciences, sometimes we are thought think that are complex to understand, for instance we were once taught that a stone and feather can hit the ground at the same time in the absence of air resistance, it is difficult to believe this but we accepted because that was what we were taught. Now having an opportunity to do prove a theory really excites me. [F1:L7]

4.5.2 Practical approach as a preferable method for teaching physical sciences

Most of the learners indicated that they would prefer practical approach to be used in all physical sciences topics.

> I think if we can do practical also in the other topics that we have already covered, I believe we could understand better. [F2:L7, F1:L8, F3:L1]
>
> I wish all lessons in physical sciences can involve practical work. [F3:L1, F1:L2, F1:L7, F4:L6]

4.5.3 Practical approach improves understanding

Learners indicated that the use of practical approach in electric circuits improved their understanding of the lesson.

> The use of practical work improved my performance, I was 31% in the first test and in the second test I got 64%. [F2:L1]

> I had no problem with calculations, I passed the test with 50%, my challenge was on interpretation of questions based on investigation, I was getting confused to explain what happens to voltmeters when this switch or that switch is open or closed through experiment I now understand. [F1:L5]
>
> Physical science is not the subject that I like because it is difficult but at least I am happy that I got 38% pass in the second test. This is very promising to me because in the first test I got 10%, I think my performance improved because of experiment.
> F3:L2]

4.6 Learners as constructors of meaning

After the analysis of group C and group E pre-test results, the same lesson on electric circuits was now presented with a different approach in group C which was the practical approach. Then after the introduction of the lesson, learners were provided with electric circuit kits and were constantly guided by the teacher on what they were expected to do. It was noted during the practical lesson presentation that learners could discover by themselves the errors that they made during the pre-test. The use of practical work seems to enhance students' better understanding of concepts and principles of electric circuits as the learners showed the following during practical approach lesson:

> Remark 1: "I did not understand the question in the test that was asking what would happen to the voltmeters when one switch is open and one closed. Now through this experiment I could observe what happens to voltmeters when switches are closed or open." [Learner 1 from group 1]
>
> Remark 2: "Now I know how to connect voltmeter and ammeter, positive terminal of the ammeter or a voltmeter must be connected to the positive terminal of the battery and likewise with the negative terminal." [Learner from group 2 remarked]
>
> Remark 3: "I was confused when it comes to emf and potential difference, I could not distinguish between the emf and potential difference readings when a bulb burns out. Now I observe that emf is not affected by the decrease or increase in the number of bulbs as it measures the total amount that a battery can supply. Potential difference increases if one bulb in parallel burns out" [Learner 2 from group 1]
>
> Remark 4: Learner 1 from group 3 removed one bulb in a parallel circuit with three bulbs and observed the reading in the ammeter. After their observation,

> he concluded by saying “in parallel if resistors are decreased total resistance increases” Now I have better understanding why the reason the current decreased from 2.5A to 1.5A in the test. [Learner 1, group 3]
>
> Report from learner 1, group 1: In our group, we struggled to connect parallel connection especially connecting bulbs in parallel through the support of our teacher we managed to connect correctly. We observed that in parallel, voltage is the same, we got the reading of 2.1V through all the parallel points in the circuit.

This is supported by Jenkins (1979) who indicated that learners should be given a chance to discover things by themselves by allowing learners to practice scientific method to avoid a science class where learners would ask “what would happen?” The use of practical approach in teaching electric circuit in grade 11 helped the learners to construct their own meaning in learning as it was stated in 2.4.2 of this study that learners will be given a chance to distinguish between parallel and series connections. This study agrees with several studies that believed that through constructivism learners develop knowledge and understanding (Anderson, 2007; Zhao, 2003 & Robottom, 2004). Also, Millar (2004) and Maselwa & Ngcoza (2003) as cited by Accom (2011) discovered that finding out things for yourself through your own effort help you to remember them better.

4.7 Impact of practical work on learner performance in electric circuits

After the practical lesson, group C learners were given a similar control test to compare the results with pre-test results. A total number of 38 learners answered practical-based questions correctly, a notable improvement of 34 learners was observed as there were only 4 learners that performed well in question 3 in the pre-test. In question 3.1, learners were to indicate the changes in the ammeter and voltmeter readings when a resistor is added in parallel. 10 out of 58 learners chose option D of four provided solutions and could correctly explain that when resistors are increased in parallel, total resistance decreased, current increased and voltage remain the same.

In question 3.2.1, two learners obtain correct responses, learners were to explain what would happen to the readings of voltmeter V and V_1 when the switch S is open, the following are some of the responses from learners:

Response 1: Both V and V_1 will read 0

Response 2: No reading

Response 3: There will be no emf and V_1 will have no reading

Response 4: Since the switch is open, there will only be a reading for emf and V_1 will be zero.

It can be observed from learners' remarks during practical work that there was learning that was taking place during practical lesson as the learners could identify the mistakes that they did during the first test. The outcomes of this lesson are contrary to the remarks that were made by Hodson (1991) as indicated in chapter 2 of this study, that practical work that is conducted in many schools is ill-conceived, confused and unproductive. If learners are guided by the teacher through practical lesson, learners learn through constructing their own meaning in learning. Figure 10 shows how physical sciences lessons should be conducted for learning to be effective.

4.8 Summary

This chapter looked at detailed analysis of data collected through the use a practical teaching approach. The researcher analyzed the findings collected from teaching approaches, tests, questionnaire and interviews and discussed the impact of these on learners' achievement. Learners perceptions of the practical; approach was also examined and discussed. The results indicated that learners in this study have common misunderstanding when it comes to answering practical-based questions on electric circuits. The involvement of practical work could bring out a reasonable performance in learners that were taught with practical approach compared to the group that was taught using a traditional approach. The next chapter will deal with conclusion and recommendations of the study.

CHAPTER 5

Conclusion and recommendations

5.1 Introduction

This chapter presents overview, implications, limitations and recommendations of the study.

5.2 Overview of the thesis

The first chapter looked at the overview of current state of physical sciences in South Africa, in the province and as well as in the district where the study was conducted. There was an evidence that South Africa is poorly performing in subjects like physical sciences and some of the contributing factors to underperformance have also been highlighted. One of the factors that have been emphasized is lack of practical work in teaching and learning of physical sciences. The study was stimulated by the report stated in National Diagnostic Reports in the past four years that many learners have misconceptions in electric circuits and are struggling to answer questions that are based on practical work due to lack of exposure to practical work. This chapter also gave problem statement, research question, current physical science intervention programmes, breakdown of the study, rationale and context of the study.

The second chapter looked at literature review. It examined what other researchers have discovered about the use of practical work in teaching and learning of physical sciences. The aim of reviewing the relevant literature was to find the relationship between what other researchers have done before and this research study. The study is underpinned by the theory of constructivism. The study looked at what other researchers think about constructivism. Current national and international literature on constructivism have been discussed in depth.

The third chapter presented the methodology of the research. The aim of the study was to investigate the effectiveness of the use of practical work in teaching electric circuits in grade 11. In this case study a mixed method design was used which included both qualitative and quantitative approaches. Two grade 11 classes with a total of 125 learners were used, one as a control group with 60 learners and an experimental group with 65 learners. The research instruments used were questionnaires and interviews. Also, validity, reliability and ethics were put into consideration.

Chapter four presented the findings and discussion of the research by looking at comparable teaching strategies which was teacher-centred in the control group and learner-centred in the experimental group. The lesson aimed at teaching learners to be able to solve questions based on electric circuits at different cognitive levels. After the lesson presentation, both groups were given same control test. The test covered all cognitive levels and question 3 was practical-based question. The test results were recorded and analysed. After the analysis of results, the lesson was then repeated in the control group with the same method that was used in the experimental group. Steps for effective teaching of practical work that were suggested by Millar and Abrahams (2009) and Achimugu (2012) which are discussed in chapter 2 of this study were considered during the practical lesson implementation.

The experimental group was then given a similar control test after the lesson. Results of the first and the second test in the experimental group were recorded and analysed. After the test results both groups were given questionnaires which was later analysed. Focus group interviews were conducted after the questionnaire.

The concluding chapter provides the main findings and the implications of the study. Recommendations for future studies are also provided.

5.3 The main findings of the study

The sub-research questions were asked in this study to unpack the main research question:

How effective is the use of practical work to teach electric circuits in physical sciences in grade 11?

5.3.1 How were practical and talk-and-chalk lessons implemented to teach electric circuits?

Lessons on electric circuits was presented in two groups of learners, control and experimental group. In the control group lesson was presented in a traditional way of teaching, which was a theoretical method. There was little contribution that came from learners, most of the talking was done by the teacher though learners were participating when asked questions. It was found that this method did not develop learners to be critical thinkers as they depended on the teacher for information. This method resulted in learners who struggled to answer practical-based questions due to lack of exposure to the real objects as shown in the pre-test results. In the other group, experimental group, practical approach was used. Learners were provided with electric circuit kits to work on electric circuits. Teacher constantly guided the learners as they interacted with the resources provided as well as with each other and the teacher. In the practical lesson, learners were getting the opportunity to explore on their own, learn to assist each other and they become independent. Practical approach helped learners to answer practical-based questions as this has been a concern in the physical sciences that lack of exposure to practical work resulted in learners who could not answer questions that need exposure to practical activities.

5.3.2 What were learners' performance in electric circuits after the practical and talk-and-chalk lessons?

The impact of teaching electric circuits using practical work was noticed in the tests administered in the control group. An overall difference of 16% was observed in the group that was taught using practical approach from the group that was taught with traditional approach. Learners' performance in practical-based questions (question 3) in the post-test increased from 7% to 66%, there was a perceptible improvement of 59%. 90% of the learners believed that the use of practical work improved their performance as they indicated during an interview that the use of practical work improved their performance. One student was exceptionally vociferous about this change as he attained 31% in the first test and in the second test he got 64%. The study found that practical work helped learners to improve understanding as observed during practical lesson implementation that learners could identify their own mistakes and misconceptions that they did in the first test. This could be observed in some remarks that were made by learners:

Remark 1: "I did not understand the question in the test that was asking what would happen to the voltmeters when one switch is open and one closed. Now through this experiment I could observe what happens to voltmeters when switches are closed or open." [Learner 1 from group 1]

Remark 2: “Now I know how to connect voltmeter and ammeter, positive terminal of the ammeter or a voltmeter must be connected to the positive terminal of the battery and likewise with the negative terminal.” [Learner from group 2]

The use of practical work appeared to enhance better understanding of concepts and principles of electric circuits.

5.3.3 How were the practical lessons implemented to the Control Group after their theoretical lesson?

For practical work to be effective, learners were guided towards obtaining the results by discovering the answers through their interactions in the class. The study found that it was important for teachers to first demonstrate what the learners were expected to do as it was elucidated in this study. During practical lesson on electric circuits, the teacher moved around the groups to ensure that learners are given all the necessary support. Learners were assisted on how to connect apparatus like voltmeters and ammeters and the teacher also checked if the learners could correctly connect bulbs in series and in parallel. It was also important to listen to the talks that the learners were doing during practical lesson as the study found that for an effective practical lesson, learners must have the chance discuss their activities with the group, the following are some of the talks that were made by learners during the lesson. “*Hayi fondini bekuthwe unegative ngulo ufakwa apha*….” (pointing at the ammeter) translation: Negative is connected here [Learner 1 from group 1]

“…*sifake ndawoni ke ngoku apha kwiammeter*” translation: where should we connect in the ammeter? [Learner 3 from group 1]

“*Bekuthwe senza njani kanene when we connect parallel bulbs*? Translation: what did the teacher say about how bulbs are connected in parallel [Learner 1 from group 2]

These talks assisted the teacher to see if there was any learning that was taking place during practical work and if there were any problems encountered by learners.

5.3.4 To what extent does conducting of practical work impact on grade 11 learners’ performance in electric circuits?

The use of practical enabled learners to recognize misconceptions in science lessons. As it was observed in the practical lesson approach that learners could notice the mistakes that they did in the test after the theoretical lesson. When learners were exposed to practical lesson, they could apply that knowledge in a similar context as it was observed in the improvement in the practical-based question in the post test.

5.3.5 What were learners' perception of the practical lesson?

The study found that 96% of learners showed that they enjoyed doing practical work. Learners were not only enjoying practical work on electric circuits but were also learning from activity, this is supported by 95% of learners who strongly agreed that they learnt from doing practical work. The use of practical work helped learners' improvement in answering practical-based questions as observed in practical based questions in the post test results. The results showed that 71% of learners strongly agreed that their understanding of electric circuits improved through practical approach. Most of the responses, 78%, specified that practical work is the most preferred method in learning of physical sciences. 95% of learners showed that there is a need for hands-on activities as they noted an improvement in their performance in electric circuits.

Learners' responses in questionnaire and interviews indicated that they are enjoying doing practical work as it helps to improve their understanding of science. Learners also indicated that they could be content if all physical sciences lessons could be taught with practical work as it is a complex subject to understand.

5.4 Implications of the study

The research findings may be beneficial to the teacher in terms of improving strategies for effective teaching of electric circuits. This could in turn enhance learners' chances of doing well in answering questions that are practical-based in electric circuits. This could have positive impact on the physical sciences results in the Eastern Cape province. The effective use of practical approach could help learners to understand science and appreciate that science is based on evidence and this could develop learners that are critical thinkers. Hands-on skills are immense importance if learners are to progress in science.

If practical approach can be implemented by other fellow physical sciences educators, this could add value in the understanding of electric circuits. And this could lead to positive impact in physical sciences results in the district, in the province and the whole of the country. Likewise, if the Curriculum advisers could use this practical approach when conducting physical sciences content workshops that could bring positive outcomes in physical sciences. Physical science is a practical subject, without practical work it would be difficult for learners to understand science therefore the schools must have science laboratories for practical work. Some teachers are unable to conduct experiments, regular workshops on practical work should be done. Practical work should not be done for formal tasks but should be part of teaching and learning, the Department of Education must organise in-service training for physical sciences educators where they will be taught effective ways of integrating practical work in everyday teaching.

Some teachers were trained as teachers during that time when practical work in science was not prioritised, in-service training on practical work would be helpful in such cases. Teachers must not only focus on experiments that are prescribed on CAPS document but must be the part of teaching and learning of physical sciences. Physical sciences require more time for practical activities, the curriculum must increase time allocation for physical sciences. Practical work must also be included and ensured that it is implemented in the curriculum for Natural sciences.

5.5 Limitations of the study

The case study was administered in two grade 11 classes only in one school and the results cannot be generalized. Due to a limited number of resources, learners had to be grouped in large group of eleven members. The fact that the researcher was also the one who was teaching could also have affected the performance of learners. For ethical considerations, the researcher requested someone else to do the interviews and administer the questionnaires, Learners might have responded in a way that they would think the interviewer would have wanted to hear.

5.6 Recommendations for future study

This study examined the effect of the practical approach to teach electricity in one class. Future studies could look at bigger samples and include more schools. It is also recommended that studies be done on other concepts in the Physical sciences curriculum as well as other science subjects.

Another useful study could consider how this approach could be implemented on a large-scale study of one or more education districts.

5.7. Conclusion

From the analysis of research findings, practical work plays a vital role in the teaching and learning of science. Involvement in meaningful practical work contributed to improved learner performance in electric circuits. Practical work made the learners keener on the content. Conclusions were drawn from data collected than relying only on theory. Physical Sciences can be taught and learned most effectively if teaching involves active participation of learners with their minds and hands on, rather than transmission method which is a teacher-centred approach, where the teacher is doing most of the talking.

References

Abell, S.K. & Lederman, N.G. (2007). Handbook of research on Science of Education. Mahwah, N.J.: Lawrence Erlbaum Associates.

Abrahams, I. (2009). A study of effectiveness of practical work and teaching and learning methods in school science. *International Journal of Science Education*. 30 (14), 1945-1969.

Accom, G. (2011). An investigation of learning process that takes place during practical work activities when using electric circuit board in grade 8: Case study. *Science Education.* Rhodes University, South Africa.

Achimugu, L. (1997). Organizing and conducting Senior Secondary Certificate Examinations Chemistry Practical. Proceedings of Kogi State Third Annual STAN Workshop, held at FCE, Okene, October, 13-16.

Achimugu, L. (2012). Strategies for Effective Conduct of Practical Chemistry Works in Senior Secondary Schools in Nigeria. *Journal of the Science Teachers' Association of Nigeria.* 47(1), 126-136.

Ackroyd, S., & Hughes, J.A. (1981). *Data Collection in Context*. City Longman

Aliaga, M., & Gunderson, B. (2006). *Interactive Statistics*. Upper Saddle River, N.J.: Pearson Prentice Hall.

Anderson, R. D. (2007). Inquiry as an organizing theme for science education. In S. K. Abell & N. G. Lederman (Eds), (2007). Handbook of Research on Science Education (pp. 807–830).

Asan, A. (2007). Concept mapping in Science Class: A Case Study of fifth grade students. *Educational Technology & Society*. 10 (1), 186-195.

Atkins, L., & Wallace, S. (2012). *Qualitative Research in Education Research Method in Education*. Sage Publications Ltd.

Best, J. W., & Kahn, J. V. (2006). *Research in education.* United States of America: Pearson.

Bradley, J., & Maake, P. (1998). *Research Report on Practical Work in Colleges of Education*. Pretoria: National Research Foundation.

Cerini, B., Murray, I., & Reiss, M. J. (2003). *Student Review of the Science Curriculum: Major Findings.* London: Planet Science; Institute of Education, University of London; Science Museum.

Chalmers, L., & Keown, P. (2006). Communities of practice and professional development. *International Journal of Lifelong Learning*. 25(2): 139–156.

Chetty, R., Hendren, N., & Katz, L.F. (2015). The Effect of Exposure to Better Neighbourhoods on Children: New Evidence from the Moving to Opportunity Experiment. NBER Working Papers 21156, National Bureau of Economic Research, Inc.

Coleman, L.A., Holcomb, D.F., & Rigden, J.S. (1997). The introductory university physics project 1987–1995: What has it accomplished? *American Journal of Physics*. 66(2): 124–137.

Concari, S., Giorgi, C., Camara, C., & Giacosa, N. (2006). Didactic strategies using simulations for Physics teaching. *Departmento de Fisica, Facultad de Exactas*. 1552, (3300). Argentine.

Department of Basic Education. (2010). *Curriculum and Assessment Policy Statement grade 10-12.* Department of Basic Education Publishers. Republic of South Africa.

Department of Basic Education. (2013). *Examiner's Report for grade 12*. Department of Basic Education Publishers. Republic of South Africa.

Department of Education. (2000). *Norms and standards for educators*. Pretoria: Government Printer.

Department of Education. (2001). *National Strategy for Mathematics, Science and Technology Education in General and Further Education and Training*. Pretoria: Government Printer.

Dhurumraj, T. (2013). *Contributing factors to poor learner performance in Physical sciences in KwaZulu-Natal Province with special reference to schools in the Pinetown district* (Unpublished Master's thesis). University of South Africa.

Dillon, J. (2008). *A Review of the Research on Practical Work in School Science*. King's College, London.

DiSessa, A.A. (2001). What changes in conceptual change? *International Journal of Science Education.* Vol 20(10), 1151-1191.

Doris, E. (1991). *Doing what Scientists Do: Children Learn to Investigate their World.* Portsmouth, N. H: Heinemann.

Driver, R., Asoko, H., Leach, J., Scott, P. & Mortimer, E. (1994*). Constructing Scientific knowledge in the classroom.* Educational researcher *23(7*): 5-12. Available at: http://cepa.info/3999

Ebenezer, J.V., & Zoller, U. (1993). Grade 10 students' perceptions of and attitudes towards science teaching and school science. *Journal of Research in Science Teaching.* 30, 175-186.

Freire, P. (1972). *Pedagogy of liberation*. Malabar, FL: Krieger Press.

Gott, R., & Duggan, S. (1995). *Investigative work in the Science Curriculum*. Buckingham, Philadelphia. Open University Press.

Grbich, C. (2013). *Qualitative data analysis: an introduction.* Thousand oaks, California, London, Sage publications.

Hartley, M. S. (2014). Science clubs: An underutilised tool for promoting science communication activities in school, In L.T.W. Hin & R. Subramaniam (Eds), *Communicating Science to the Public Opportunities and Challenges for the Asia Pacific Region*. The Netherlands Springer.

Haung, B.S., & Odegaard, M. (2014). From words to concepts: Focusing on word knowledge when teaching for conceptual understanding within an inquiry-based science setting. *Research in Science Education*. 44:777-800. Australia.

Hendley, D., Parkinson, J., Stables, A., & Tanner, H. (1995). Gender Differences in Pupil Attitudes to the National Curriculum Foundation Subjects of English, Mathematics, Science and Technology in Key Stage 3 in South Wales. *Educational Studies.* 21(1): 85-97.

Henning, E., Van Rensburg, W. & Smit, B. (2004). Finding your way in qualitative research. Van Schaik Publishers. Pretoria. p. 19-22.

Hodson, D. (1991). Practical work in science: Time for a reappraisal. *Studies in Science Education.* 19, 175-184.

Hodson, D. (1992). Re-thinking old ways: Towards a more critical approach to practical work in school science. *Studies in Science Education*. 22, 85–142.

House of the Lords. (2006). *Science and Technology - Tenth report.* Retrieved December 21, 2009, from Parliament: http://www.publications.parliament.uk/pa/ld200506/ldselect/ldsctech/257/25702.htm.

Howie, S.J. (2003). Language and other background factors affecting secondary pupils' performance in Mathematics in South Africa*. African Journal of Research in Mathematics, Science and Technology Education.* 7:1-20.

Isaacs, S. (2007). Survey of ICT and Education in Africa: South Africa Country Report ICT in Education in South Africa. South Africa.

Jenkins, E., & Nelson, N.W. (1979). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science and Technological Education.* 23(1), 41-57.

Johnson, B., & Christensen, L. (2000). *Quantitative and Qualitative Approaches.* (1st ed.). University of South Alabama.

Johnson, B., & Christensen, L. (2012). *Educational Research: Quantitative, qualitative and mixed approaches.* (5th ed.). Thousand Oaks, CA: Sage.

Kim, C., & Tan, K.C. (2010). The value simulation-based learning added to machining technology in Singapore. *Educational Media International.* 48(2): 127-137.

Koshy, V. (2010). *Action Research for Improving Educational Practice. A Step-by-step guide.* Sage, London. Second Edition. ISBN 0 978 184860 159 8.

Kriek, J., & Grayson, D.J. (2009). Initial Development of a holistic model for Physical science teacher development. *Paper represented at the 3rd conference on Science, Mathematics and Technology Education.* East London, South Africa, 11-14 January.

Kvale, S. (1996). Qualitative Inquiry: Dominance Through Interviews and Dialogues. *SAGE Publications*. Vol. 12(3), 480-500.

Labaree, R. (2013). Bildungsgeschichte. *International Journal for the Historiography of Education.* 3:1, 46-59.

Locke, L.F., Spirduso, W.W., & Silverman, S.J. (2010). *Reading and understanding research,* 3rdEd. Thousand Oaks. Sage Publications.

Lowery, L.F. (1994). Inquiry: The Emphasis of a Bold, New Science Curriculum. *Educational Technological Horizons in Education*. 21(8): 50-52.

Lunetta, V.N., Hofstein, A., & Clough, M. (2007). Learning and Teaching in the School Science Laboratory: An analysis of research, theory and practice. In S. K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education*. (pp. 393-442). Mahwah: Lawrence Erlbaum Associates.

Makgato, M., & Mji, A. (2006). Factors associated with high school learner's poor performance: a spotlight on Mathematics and Physical science. *South African Journal of Education.* 26(2), 253-266.

Makgato, M. (2007). Factors associated with poor performance in learners in Mathematics and Physical sciences in secondary schools in Soshanguve, South Africa. *Africa Education Review*. 4:1, 89-103.

Mangena, M. (2001)*. Science, Engineering, Technology and our environment: How can we take it to our schools, particularly in rural schools?* A paper presented by deputy minister of education to Limpopo Province Council of Churches school support programme seminar in Pietersburg. Pretoria: Department of Education.

Maselwa, M., & Ngcoza, K.M. (2003). 'Hands-on', 'Minds-on' and 'Words-on' practical activities in electrostatics: Towards conceptual understanding. In D. Fisher & T. Marsh (Eds). Proceedings of the Third International Conference on Science, Mathematics and Technology Education, (pp. 649-659), January 15-18, East London, South Africa.

McMillan, J.H., & Schumacher, S. (2001). *Research in Education: A conceptual Introduction.* (5th Ed.). New York: Longman.

Melville, W., Campbell, T., Fazio, X., Stefanile, A., & Tkaczyk, N. (2014). Problematizing the Practicum to Integrate Practical Knowledge. *Research in Science Education.* 44: 751-775. Australia.

Millar, R., & Abrahams, I. (2009). Practical work: making it more effective. *School Science Review*. 91(334), 59-64.

Millar, R. (2004). *The role of practical work in the teaching and learning of science*. Retrieved January, 3, 2014, from University of New York: http://www7.nationalacademies.org/bose/Millar_draftpaper_Jun_04.pdf.

Millar, R., Tiberghien, A., & Le Maréchal, J.F. (2002) Varieties of lab work: a way of profiling lab work tasks. In Teaching and learning in the science laboratory, ed. Psillos, D. & Niedderer, H. pp. 9–20. Dordrecht: Kluwer.

Morse, J.M. (1998). Validity by committee. *Qualitative Health Research.* 8(4), 443-445.

Mouton, S., & Marais, H.C. (1994). *Basic concepts in the basic concepts in the methodology of the social sciences.* HSRC Press, Pretoria, South Africa. http://dx.doi.org/10.1375/ajgc.17.1.8.

Mpofu, E. (2006). *Theories and Techniques for Counsellors Applied to African Settings,* Zimbabwe: College Press Publishers.

Muhammad, R. (2017). A Survey of Availability, Utilization and Maintenance of Biology Laboratory Equipment and Facilities in Secondary Schools in Sokoto State, Nigeria. *International Journal of Science and Technology.* Vol (6), 1, 662-668.

Munikwa, S., Chinamasa, E., & Mukava, M. (2011). A Study for Teaching Advanced Level Physics Practical and Solution approach to Practical Questions (pp. 36-48). *Journal of Innovative Research in Education.* Vol 1(1) 36-48.

Musyoki, A., Thifhufhelwi, R., & Murungweni, F.M. (2016). The impact of and responses to flooding in Thulamela Municipality, Limpopo Province, South Africa. *Jamba: Journal of Disaster Risk Studies.* 8(2), Art # 166, 10 pages. Retrieved from

http://dx.doi.org/10.4102/jamba.v8i2.166.

National Diagnostic Report Grade 12: National Senior Certificate Examination. (2011). Department of Basic Education Publishers. Republic of South Africa.

National Diagnostic Report Grade 12: National Senior Certificate Examination. (2012). Department of Basic Education Publishers. Republic of South Africa.

National Diagnostic Report Grade 12: National Senior Certificate Examination. (2013). Department of Basic Education Publishers. Republic of South Africa.

National Diagnostic Report Grade 12: National Senior Certificate Examination. (2014). Department of Basic Education Publishers. Republic of South Africa.

National Diagnostic Report Grade 12: National Senior Certificate Examination. (2015). Department of Basic Education Publishers. Republic of South Africa.

National Diagnostic Report Grade 12: National Senior Certificate Examination. (2016). Department of Basic Education Publishers. Republic of South Africa.

Nwosu, A.A., & Okeke, E.A.C. (1995). The effect of teacher sensitization on the acquisition of science process skills. *Journal of Science Teachers Association of Nigeria.* 30(1 &2), 39-45.

Olasimbo, S., & Rotimi, C.O. (2012). Attitudes of Students towards the Study of physics in College of Education. *American international Journal of Contemporary Research.* Vol. 3 (12). Nigeria.

Osborne, J. (1998). Attitude towards science: a review of the literature and its implications. *International Journal of Science Education.*

Papadimitriou, A. (2012). A Scenario-Based Learning on Electric Circuits. *Journal of Education and Practice, Vol 3 (7).* Greece.

Patra, N.J. (2014). The role of ICT in improving the Quality of School Education in *India. International Educational E-Journal.* Vol 3, Issue 2, April-June. ISSN 2277-2456.

Phelan, C., & Wren, J. (2005). Exploring reliability in academic assessment. Retrieved from: https://www.uni.edu/chfasoa/reliability and validity. htm. process. Cambridge, MA: Harvard University Press.

Quest magazine, Science for South Africa. Vol (11). 2015.

Reddy, C. (2004). Democracy and in-service processes for teachers: A debate about professional teacher development programmes. In Waghid, Y. and Le Grange, L. (Eds), *Imaginaries on Democratic Education and Change.* Pretoria. South African Association for Research and Development in Higher Education.

Redish, E.F., Steinberg, R.N., & Saul, J.M. (1999). On the effectiveness of Active-Engagement Micro-computer based laboratories. *American Journal of Physics*. Vol (65), 45-54.

Robottom, I. (2004). Constructivism in Environmental Education: Beyond Conceptual Change Theory. *Australian Journal of Environmental Education*. 20 (2), 93-101.

Rule, P., & John, V. (2011). *Your guide to case study research*. Van Schaik, Pretoria.

Semeon, N. (2014). Investigating South African grade 12 Physical sciences learners' meanings of everyday words when used in the science context. A Research Report submitted to the Faculty of Science. University of the Witwatersrand. Johannesburg. Settings. Zimbabwe: College Press Publishers.

Sharpe, R.M. (2012). Secondary school students' attitudes to practical work in school science. Education. University of New York.

Sibam, Z. (2014). An investigation in the time allocation in the Curriculum and Assessment Policy Statement (CAPS) for grade 10 Physical sciences. *Paper represented at the 1st conference on South African Association for Science and Technology Educators (SAASTE)*, Umtata, South Africa, 11-12 July.

Simpson, R.D., & Oliver, J.S. (1990). A summary of major influences on attitude towards and achievement in science among adolescent students. *Sci. Educ.* 74(1): 1-18.

Skamp, K. (2011). Teaching primary science constructively. South Melbourne, Vic,: Cengage Learning.

Sundberg, M., Dini, M., & Li, E. (1994). Decreasing course content improves student comprehension of science and attitude towards science in freshman biology. *Journal of Research in Science Teaching.* Vol 31(6), 679-693.

Swain, J., Monk, J., & Johnson, S. (1999). A comparative study of attitudes to the aims for practical work in science education in Egypt, Korea and UK. *International Journal of Science Education*. 21(12), 1311-1324.

Treagust, D.F., & Thair, M. (1999). Teacher training reforms in Indonesian secondary science: The importance of practical work in physics. *Journal of Research in Science Teaching.* 36(3): 357–371.

Van der Linde, H.J., Van der Wal, R.W.E., & Wilkinson, A. (1994). Practical work in science teaching in developing communities. *South African Journal of Education.* 14(1), 48–52.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Walford, G. (1998). Reading and writing the small: The fate of sponsored grant-maintained schools. *Educational studies*. 26(2), 113-118.

Wellington, J. (1988). *Practical work in school science: Which way now?* London: Routledge.

Woolnough, B., & Allosp, T. (1985). *Practical Work in Science*. Cambridge University Press.

Yin, R.K. (2009). *Case Study Research. Design and Methods*. 4th Ed. Thousand Oaks, CA. Sage Publications. pp 240.

Zhao, Y. (2003). *The use of a constructivist teaching model in environmental science at Beijing Normal University.* People's Republic of China.

APPENDIX A: CONSENT FORM FROM THE UNIVERSITY OF THE WESTERN CAPE

UNIVERSITY OF THE WESTERN CAPE

FACULTY OF EDUCATION

CONSENT FORM

NOTE: This consent form is to be retained by the teacher and school principal and kept in a secure location. The student may be required to represent the original copy to the University of the Western Cape Ethics Committee as evidence that consent has been granted to conduct research at your school or institution.

I, ______________________________ hereby give permission for Busiswa Xongwana who is a MEd in Science Education student at the University of the Western Cape and is involved in the planning and implementation of this research project permission to use the material which has been obtained during the research.

I understand that the above research project has been explained and specified and those involved tend to share the research in the form of publications.

I also understand that:

- My participation is a personal decision and entirely voluntary.
- There are no rewards for granting permission.
- I will not be penalized for granting permission.
- I have a right to withdraw my permission at a later stage.
- The content obtained through the interview and questionnaire will only be used for the purpose of this research project.
- My own identity shall remain anonymous.

My signature below indicates my permission to use the material for research.

Signature ______________________________

Date __________________

APPENDIX B: CONSENT FORM TO PRINCIPAL

Consent letter to principal

P. O. Box 1036

Butterworth

4960

The Principal

Nomaka Mbeki T.S.S.S.

P. O. Box 2055

Dutywa

5000

Dear Sir/Madam

Permission to conduct research

I, Miss Busiswa Xongwana, MEd student at the University of Western Cape hereby request permission to conduct research at school in grade 11 Physical Science learners. The study researches effectiveness of the use of practical work on teaching electric circuits.

Confidentiality is guaranteed and no harm to the learners participating in the research. I will ensure that there will be no disruptions or interference during contact time or teaching time at school.

I hope that my proposal meets with your approval and that it will receive the necessary approval to conduct my research.

Yours in Education

Miss Busiswa Xongwana

APPENDIX C: CONSENT FORM TO PARENTS AND LEARNERS

Consent form to parents and learners

Parent consent form

I……………………………………, herewith grant permission that my child/ guardian,

(Parent/Guardian’s surname and name)

……………………………………., a learner at Nomaka Mbeki T.S.S.S. may participate in a research study conducted by Miss B. Xongwana in partial completion of her M.Ed degree. I am aware that the participation in this study will not influence my child/ guardian’s results at school.

Signed: Parent/guardian…………………………………..

Date………………………….

Learner consent form

I………………………………., a learner at Nomaka Mbeki T.S.S.S. in Grade……

(Learner’s surname and name)

Herewith grant permission to be a participant in the research study of Miss B. Xongwana. I am aware that my participation in this study will not influence my results at school.

Signed: Learner………………………….

Date

Appendix D

Instrument design for electricity practical reflection questionnaire

Instruction LEARNER'S QUESTIONNAIRE: VIEWS ON PRACTICAL WORK IN ELECTRIC CIRCUITS

This questionnaire is looking into your views on practical work within physical sciences. You need to read the questionnaire and decides if you:

5- Strongly agree

4- Agree

3- Not sure

2- Disagree

1- Strongly disagree

Tick the number that best fits your own view. This questionnaire is divided into closed and ended questions.

Description	Rating				
	5	4	3	2	1
1. I enjoy practical work in electric circuits					
2. I am able to learn from practical work					
3. I prefer practical work to non-practical work					
4. Doing practical work is my favourite part of physical sciences					
5. Practical work helps me understand electric circuits					
6. I find practical work in physical sciences easy to do					
7. What I do in physical sciences practical work will be useful when I leave school					

8. I find practical work a way of seeing how Physicists work in the real world					
9. I think we should do more practical work in physical sciences lesson					
10. For me to learn physical sciences lessons, I need to do practical work					
11. I have gained confidence on solving electricity related questions					
12. I can relate what I learnt with everyday knowledge					

Open-ended questions

1. What are your suggestions and comments for the lesson on electric circuits? explain?...
....
....
....
....

2. What surprised you as you were conducting this experiment?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
………

3. How do you wish physical sciences should be taught?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
………

APPENDIX E

Interview Schedule

Group code --------------------------------

Grade: ____________________

Date: ____________________

Interview Questions

1. Describe the challenges you have found during the lesson on the topic of electric circuits.
2. You wrote the test for the second time after you went through the same topic with your teacher. How did you find the second test?
3. Was the score obtained in the second test better than the first test?
   What do you think was the reason for that?
4. In what ways did practical work help you to understand electric circuits?

APPENDIX F: LESSON PLAN

Lesson plan

Grade 11: Electric circuits

Objectives of the lesson: Learners must be able to differentiate between emf and voltage.

Learners must be able to differentiate between parallel and series connections.

Teaching approach: Discovery method

Learners are instructed to conduct the following method during lesson presentation

1. Aim: To verify Ohm's law

2. Apparatus: Voltmeter, ammeter, two resistors, connecting wires, three cells and a switch.

3. Method: Connect the apparatus as shown in the diagram. With a switch open, measure and record voltmeter reading. Close the switch, then record ammeter and voltmeter readings in a table.

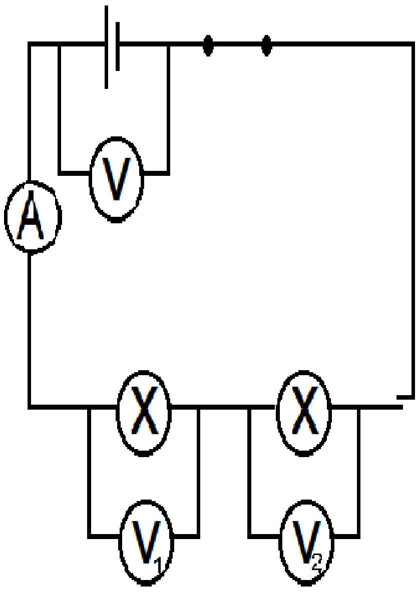


Diagram 1

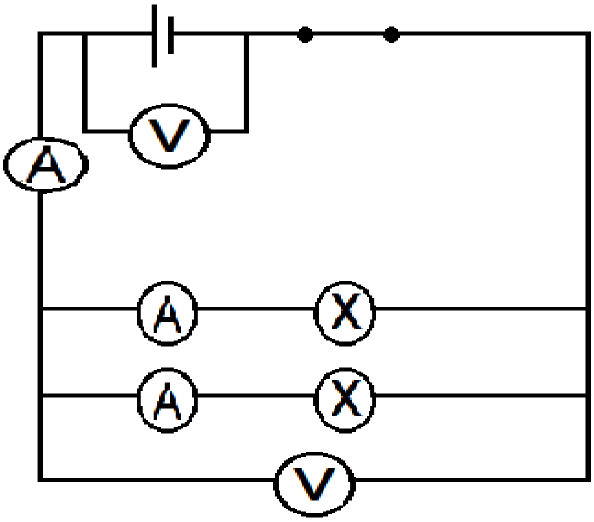


Diagram 2

4. Analysis of results

5. Write your own conclusion.

APPENDIX G: PRE-TEST

Test 1 (Pre-test)

Grade : 11

Duration : 60 minutes

Total : 60 marks

Question 1

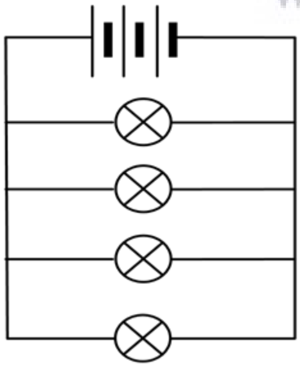
1. Give one word for each of the following explanations:
   - 1.1 At constant temperature, voltage is directly proportional to current provided that the temperature is kept constant.
   - 1.2 Unit of resistance.
   - 1.3 Potential dividers.
   - 1.4 Maximum voltage that a battery can supply.
   - 1.5 Work done per unit charge.
   - 1.6 The rate at which charges pass a given point.

[12]

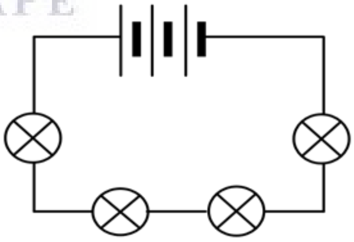
Question 2

2.1 Four identical bulbs are connected in different methods as shown in the diagrams, which bulbs which glow the brightest?

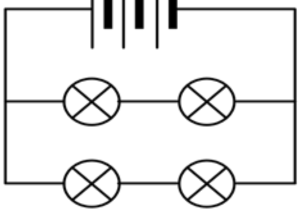
A



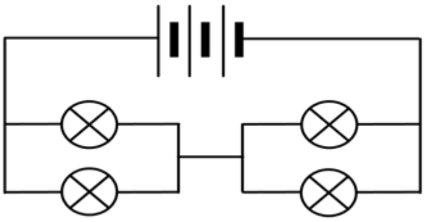
B



C



D



(2)

2.2 In the circuit below, the resistance of the battery, ammeter and connecting wires can be ignored.

The power of the 8 Ω resistor is 0, 5 W.

Calculate the reading on the:

2.2.1 Voltmeter (V) (8)

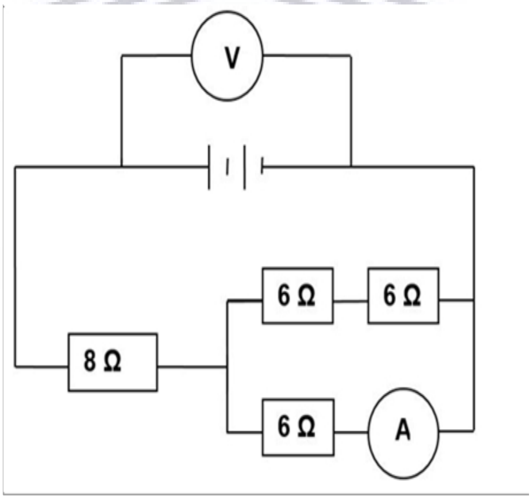
2.2.2 Ammeter (A) (5)

2.2.3 The current passing through the 6Ω resistor with an ammeter. (4)

2.2.4 A television is labelled: 240 V; 750 W.

2.3 Calculate the resistance of the television's resistor. (5)

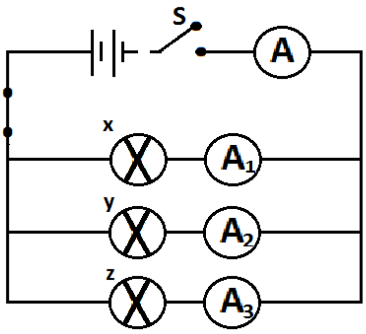
2.4 Calculate the total resistance in the circuit. (6)



[30]

Question 3

3.1 Three bulbs, X, Y and Z with resistances R, 2R and R respectively are connected in a circuit as shown below. The battery has negligible internal resistance. When the switch is closed, the reading on the ammeter, A is 2.5A.

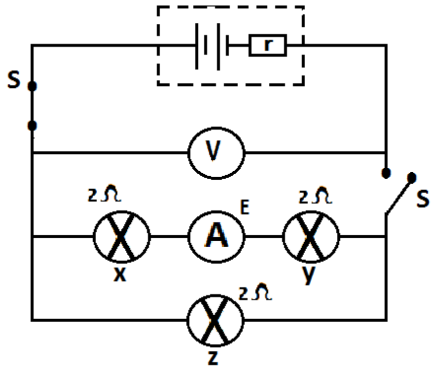


3.1.1 Which ONE of the following correctly describes the readings on the ammeters when bulb Z is burnt out? Explain

(3)

	A_1	A_2	A_3	A
A	1.25	1.25	0	2.5
B	1.6	0.8	0.1	2.5
C	0.75	0.75	0	1.5
D	1	0.5	0	1.5

3.2 In the following circuit diagram, the internal resistance is negligible. The emf of the battery is 6V.



3.2.1 Which terminal of the ammeter is represented by point E? (2)

Switch S is now closed. Calculate:

3.2.2 the total resistance in the circuit. (3)

3.2.3 the reading on the ammeter, A. (3)

3.3 If light bulb Z burns out, how will this affect the value of the following:

3.3.1 the reading of V. (2)

3.3.2 the emf of the battery. (2)

3.4 Calculate the new reading on ammeter A after the light bulb Z has burnt out. (3)

APPENDIX H: POST-TEST

Physical sciences

Grade 11

Control test 2 (Post-test)

Marks: 60

Question 1

1.1 State Ohm's law. (3)

1.2 What is the unit of current? (2)

1.3 Define an emf. (2)

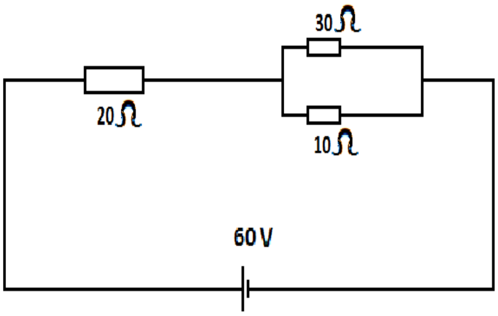
1.4 What is potential difference? (3)

1.5 Which instrument is used for measuring current? (2)

[12]

Question 2

Consider the electric circuit below and answer the questions that follow.



2.1 Calculate:

2.1.1 Effective resistance in the parallel combination. (4)

2.1.2 Total resistance in the circuit. (3)

2.1.3 The magnitude of the current. (4)

2.1.4 The potential difference across the 15Ω resistor. (5)

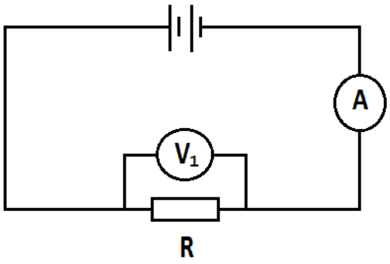
2.2 What will be the current across the 5Ω resistor? (3)

2.3 What will be the voltage across the 20Ω resistor? (3)

[22]

Question 3

3.1 In the accompanying diagram, the battery and the meters have negligible internal resistance. The resistance of R does not change.



How do the readings on the ammeter and voltmeter change, if at all, when an additional resistor is connected in parallel? Explain your answer.

(4)

	Voltmeter	Ammeter
A	Decrease	Increase
B	Remain the same	Decrease
C	Increase	Decrease
D	Remain the same	Increase

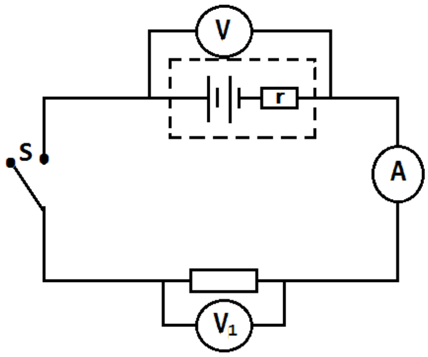
3.2 Tom and Peter conduct an investigation to determine the relationship between resistors. They connect voltmeter and ammeter in the circuit. The battery has an emf of 11.0V.

3.2.1 What is the reading of V and V_1 when switch S is open? Explain your answer. (4)

When switch S was closed, they obtain the following results:

Number of resistors	Voltmeter reading (V)	Ammeter reading (A)
3	10.2	1.5
2	9.6	2.0
1	7.8	3.5

3.2.2 Sketch this circuit in your answer book. Show in your sketch where the learners connected the ammeter. (8)



3.2.3 Identify independent variable in this experiment. (2)

3.2.4 What is the relationship between voltage and current? (2)

3.2.5 What do you observe in current when resistors are increasing? (3)

3.2.6 Calculate the total resistance when resistors are two. (3)

[26]

APPENDIX I: TOP ACHIEVER AT DUTYWA DISTRICT IN 2014

TOP DUTYWA DISTRICT ACHIEVERS WHO OBTAINED PREMIER'S AWARDS

APPENDIX J

LEARNERS WON PROVINCIAL MINQUIZ COMPETITION

APPENDIX K: RESPONSES IN QUESTIONNAIRE

RESPONSES OF 105 LEARNERS IN VIEWS ON PRACTICAL WORK IN ELECTRIC CIRCUITS

The following table shows responses of 105 learners out of 125 learners, 18 respondents were destroyed as they were spoilt and 2 learners were absent from school during that time of collecting questionnaires.

Description	**5**	**%**	**4**	**%**	**3**	**%**	**2**	**%**	**1**	**%**	**No of respondents**
1. Enjoying doing practical work	**101**	**96**	**4**	**4**	**0**	**-**	**0**	**-**	**0**	**-**	**105**
2. Learn from practical work	**98**	**93**	**5**	**5**	**2**	**2**	**0**	**-**	**0**	**-**	**105**
3. Prefer practical work	**82**	**78**	**15**	**14**	**8**	**8**	**0**	**-**	**0**	**-**	**105**
4. Practical work as favorite part	**63**	**60**	**22**	**21**	**18**	**17**	**2**	**2**	**0**	**-**	**105**
5. Practical work helps understanding	**75**	**71**	**30**	**29**	**-**	**-**	**0**	**-**	**0**	**-**	**105**
6. Practical work easy to do	**78**	**74**	**20**	**19**	**5**	**5**	**2**	**2**	**0**	**-**	**105**
7. Useful when leaving school	**8**	**7**	**5**	**5**	**87**	**83**	**5**	**5**	**0**	**-**	**105**
8. A way of seeing how Physicists work	**2**	**2**	**9**	**9**	**80**	**76**	**13**	**12**	**1**	**1**	**105**
9. More practical work in Physical Sciences lessons	**100**	**95**	**5**	**5**	**0**	**-**	**0**	**-**	**0**	**-**	**105**
10. Need practical work to learn Physical Sciences	**90**	**86**	**5**	**5**	**10**	**10**	**0**	**-**	**0**	**-**	**105**

lessons											
11. Have gained confidence in solving electricity related problems	**50**	**48**	**34**	**32**	**16**	**15**	**3**	**3**	**2**	**2**	**105**
12. Can relate what is learnt in class with everyday knowledge	**13**	**12**	**11**	**10**	**53**	**50**	**20**	**19**	**8**	**8**	**105**

APPENDIX L: ANALYSIS OF THE FIRST TEST(PRE-TEST) RESULTS IN GROUP C AND E

GROUP C			GROUP E		
% RANGE	NO. OF LEARNERS	LEVEL	% RANGE	NO. OF LEARNERS	LEVEL
0-29	39	1	0-29	32	1
30-39	18	2	30-39	20	2
40-49	1	3	40-49	2	3
50-59	2	4	50-59	9	4
60-69	0	5	60-69	1	5
70-79	0	6	70-79	1	6
80-100	0	7	80-100	0	7
NO. WROTE: 60			65		
NO. PASSED: 21			33		
NO. FAILED: 39			32		
% PASSED: 35			51		
% FAILED: 65			49		

APPENDIX M: ANALYSIS OF SECOND TEST (POST TEST) RESULTS IN GROUP C

GROUP C					
% RANGE	NO. OF LEARNERS	LEVEL	% RANGE	NO. OF LEARNERS	LEVEL
0-29	39	1	0-29	10	1
30-39	18	2	30-39	15	2
40-49	1	3	40-49	7	3
50-59	2	4	50-59	7	4
60-69	0	5	60-69	17	5
70-79	0	6	70-79	1	6
80-100	0	7	80-100	1	7
NO. WROTE: 60			58		
NO. PASSED: 21			48		
NO. FAILED: 39			10		
% PASSED: 35			83		
% FAILED: 65			17		

APPENDIX N: CONSENT FORM TO LIFE ORIENTATION EDUCATOR

Consent form to Life Orientation educator

I, Busiswa Xongwana, am requesting permission to Life Orientation educator, Miss ………………………………...to conduct interviews in my research study on Effectiveness of the use of Practical Work to Teach Electric Circuits in Grade 11. The research will not interfere with tuition time.

Yours faithfully

Busiswa Xongwana

APPENDIX O: CONSENT FORM TO GRADE 11 LANGUAGE EDUCATOR

Consent form to grade 11 Language educators

I, Busiswa Xongwana, am requesting permission to grade 11 Language educator, Miss…………………………………………...to evaluate level language used in my research instruments. The research will not interfere with tuition time.

Yours faithfully

Busiswa Xongwana

APPENDIX P: CONSENT FORM TO PARENTS AND LEARNERS

Consent form to parents and learners

Parent consent form

I……………………………………, herewith grant permission that my child/ guardian,

(Parent/Guardian’s surname and name)

……………………………………., a learner at Langa S.S.S. may participate in a research study conducted by Miss B. Xongwana in partial completion of her M.Ed degree. I am aware that the participation in this study will not influence my child/ guardian’s studies at school.

Signed: Parent/guardian…………………………………..

Date………………………….

Learner consent form

I………………………………., a learner at Langa S.S.S. in Grade……

(Learner’s surname and name)

Herewith grant permission to be a participant in the research study of Miss B. Xongwana. I am aware that my participation in this study will not influence my studies at school.

Signed: Learner………………………….

Date

APPENDIX Q: CONSENT LETTER TO LANGA S.S.S.

P.O. Box 2055

Dutywa

5000

The Principal

Langa S.S.S.

Dutywa

5000

Sir/ Madam

Request for permission to use physical sciences grade 11 learners in a research study

I, Busiswa Xongwana, M.Ed student in Science Education, am request permission for using grade 11 physical sciences to read and interpret questions in instruments that will be used in a research study on the Effectiveness of the use of Practical Work to Teach Electric Circuits in Grade 11. The research will be conducted in another school.

This will not interfere with your tuition time.

Yours faithfully

Busiswa Xongwana