

Teaching Ohm's law in Grade 11 Physical Sciences using a Multiple Representations Approach

By

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at the University of the Western Cape

SUPERVISOR: PROFESSOR M.S. HARTLEY

DECLARATION

I declare that

**"Teaching Ohm's law in Grade 11 Physical Sciences using a
Multiple Representations Approach."**

is my own work; and that it has not been submitted before for any academic qualification in any other university. All sources I have used or quoted have been indicated and acknowledged by complete references.

NAME: Anadin Zakhele Magadla.

DATE:

SIGNED:



ACKNOWLEDGEMENTS

- Glory be to God the father of Our Lord Jesus Christ who continuously lifts me up from the deep muddy clay to the highest places through His Holy Spirit.
- My sincere gratitude to my lovely wife Phathiswa, “enkosi Bhelekazi”. This research project has denied us our precious time to spend together with our children yet your love for our children substituted my absence. May God richly bless you.
- I express my sincere appreciation to Professor M.S. Hartley for his persistent guidance and fatherly love.
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- Recognitions are extended to my church leadership for releasing me from the church responsibilities during the time of this research study. Your prayers brought success.
- Miss Lineo Ramasike, your inspiration and support motivated me even when I thought of giving up. Ungethi mandla ekwenzeni okuhle.
- My gratitude is also extended to the Eastern Cape Department of Education for granting me an opportunity to do this Master's degree.

DEDICATION

This academic study is dedicated to:

- God the almighty, the ONLY Living and Wise God who graciously gives abundantly.
- My parents Sipho “Magqadaza” Magadla and Nomvume Matshabalala Magadla. You raised “us” your children out of nothing yet you taught us humanity, thank you very much.
- My precious wife Phathiswa and daughters Masimbonge, Yongama and Oasis.



LIST OF ABBREVIATIONS AND ACRONYMES

CAPS	Curriculum and Assessment Policy Statement
CPD	Continuous Professional Development
ECDoE	Eastern Cape Department of Education
FET	Further Education and Training
GET	General Education and Training
HEI	Higher Education Institutions
ICT	Information and Computer Technology
LAIS	Learner Attainment Improvement strategy
LoLT	Language of Learning and Teaching
LTSM	Learning and Teaching Support Material
MEC	Member of the Executive Council
MRA	Multiple Representations Approach
MST	Mathematics, Sciences, and Technology
NDR	National Diagnostic Report
NSC	National Statement Curriculum
PCK	Pedagogical Content Knowledge
SAASTA	South African Association of Science and Technology Educators.
SGB	School Governing Body
SMK	Subject Matter Knowledge
TCM	Talk and Chalk Method
TIMSS	Trends in International Mathematics and Science Study
ZPD	Zone of Proximal Development

ABSTRACT

Background

The purpose of this study was to investigate the value of teaching Ohm's law in Grade 11 using a Multiple Representations Approach (MRA). The need to promote knowledge and skills in problem solving in Physical Sciences together with the use of technology is important. This study explored techniques of improving learner attainment thus ensuring that they achieve the minimum entry requirements for science related fields at university.

Methodology

A case study approach was used. The context is a rural high school in the Eastern Cape. The theoretical framework is constructivism and pedagogical content knowledge. It was a mixed method study with a sample of 48 Grade 11 Physical Sciences learners. Data was collected through a pre-test, an intervention and a post-test. The intervention lessons on Ohm's law were video-taped. A control group was taught using traditional teaching methods and the experimental group was taught using the Multiple Representations Approach. Post-test scores compared the achievement in the two groups. It was followed by focus group interviews with the learners in the two groups.

Findings

The study found that MRA improved learner attainment and assisted in overcoming learning difficulties. It assessed and developed a variety of learners' skills in different forms at different stages of the lesson. The study found that the MRA aroused learners' interest in science and assisted them to visualise the abstract concepts and this led to an understanding of difficult concepts.

Recommendations

The study recommends the use of MRA's by science teachers to increase learners' understanding of Ohm's law. It is recommended that teachers develop fun and interesting science activities to encourage the love of science among learners.

Keywords: *Science Education, Multiple Representations Approach, Ohm's law, Physical Sciences, rural schools.*

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CHAPTER 1

INTRODUCTION TO THE STUDY

1.1. INTRODUCTION

This chapter offers the background and rationale for the study. This is where the context within which the study is conducted is presented and the description of both the research problem and the research question is given. It also highlights significance and the limitations of the study.

1.2. BACKGROUND TO THE STUDY

Both nationally and internationally, the pass rate of Physical Sciences learners is an issue of major concern (Redish, 2006). Globally, learners seem to struggle and find learning Physical Sciences difficult to learn (Redish, 2006). However, MRA is confirmed to improve Physical sciences pass rate (Maseko, 2017). The examination results published over the past few years reflect that there is no improvement in the performance of learners in the Physical Sciences. The Eastern Cape provincial results in Table 1 and column 4 of Table 2 indicates national results from 2013 to 2016. To enable learners to attain the preferred results at a higher level in Physical Sciences, it will be appropriate to explore new teaching strategies.

The study is conducted in the Eastern Cape Province of the Republic of South Africa. Although some top achievers in Physical Sciences in the country are from Eastern Cape, the overall results for Physical Sciences in this province, district and some schools are not good. Table 1 shows the Physical Sciences results for successive four years from provincial level down to the district and the school where the study was conducted.

In the Eastern Cape Province, the 2016 results show evidence of improvement but falling far below 70% as it was targeted by the National Minister of the Basic Education for the 2016 matric class (Motshega A, 2015).

In the district where the study was conducted, the results for Physical Sciences were 41.2%, 44.6%, 52% and 52.1% in the years 2013, 2014, 2015 and 2016, respectively. These results reflect negatively in Physical Sciences performance both provincially and nationally. The improvement of the results depends on the effort by both the learners and the teachers.

Table 26 Physical Sciences results for the past 4 years in percentage.

YEAR	EASTERN CAPE PROVINCE	DISTRICT	SCHOOL
2013	55	41.2	30
2014	51.5	44.6	15
2015	45.9	52	21
2016	49.6	52.1	56

Table 1 shows that from 2013, Physical Science results in the province of the Eastern Cape decreased from 55% in 2013, 51,5% in 2014, 45,9% in 2015 and 49,6% in 2016. This had a negative effect on the overall results of the country. In the district the results indicated an improvement as they increased from 41.2% in 2013, 44.6% in 2014, 52% in 2015 and 52,1% in 2016. In the school where the research was done, the results fluctuated as indicated in Table 1. The results were 30% in 2013, 15% in 2014, 21% in 2015 and 56% in 2016. Although the school results improved by 35% from 2015 to 2016, the fluctuation (yo-yo effect) of these unsatisfactory results prompted the researcher to do the study.

When one looks at the recent history of Physical Sciences grade 12 results especially over the past four years during the National Senior Certificate (NSC) examinations in South Africa, the results are not very encouraging (Department of Education, 2014), refer to table 2. The general performance of candidates reflects a decline from 2014 to 2015 (NSC Diagnostic report,

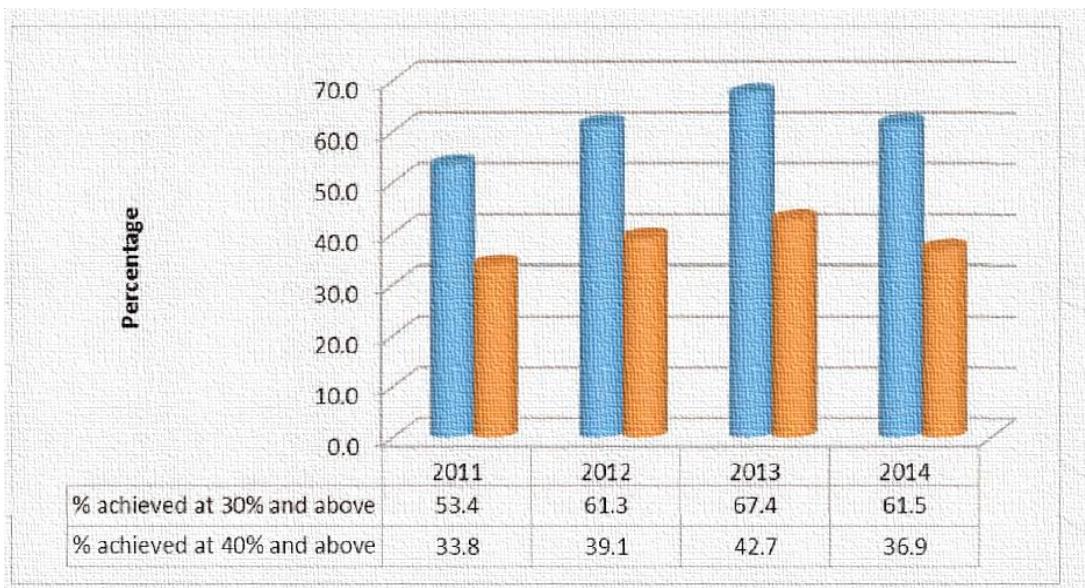
2014). However, there is an improvement in Physical Sciences performance from 2015 to 2016 (NSC Diagnostic report, 2016).

Table 2, adapted from the NSC Diagnostic report of 2016, illustrates the overall achievement in Physical Sciences in the National Senior Certificate for the past four years. This report indicates a slight decrease of 571 candidates writing the subject in 2016 compared to 2015 while there was a noticeable increase of 25 192 from 2014 to 2015 (Department of Education, 2014). The number of candidates who passed at the 30% level increased by 4% while those who passed at the 40% level declined by 5.8% in 2016. In 2013, the national results were 67.4%, 61.5% in 2014, whilst in 2015 they dropped to 58.6%. There was a slight improvement of 3.4% in 2016 results as the pass rate increased from 58.6% to 62%.

Table 2: Overall Achievement in Physical Sciences for the past 4 years nationally.

Year	No. Wrote	No. achieved at 30%and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2013	184383	124206	67.4	61109	33.1
2014	167997	103348	61.5	62032	36.9
2015	193189	113121	58.6	69699	36.1
2016	192618	119427	62	76044	39.5

Figure 1 indicates percentage obtained by learners in Physical Sciences since 2011 to 2014. From the graph of figure 1, most learners obtained between 30% to 40% and the number of learners who achieved from 40% and above is less in every year compared to those who achieved from 30% and above.



Key: Blue represents 30% and above

Orange represents 40% and above

Figure 1. Overall achievement in Physical Sciences (adapted from 2015 NSC Diagnostic Report).

Figure 2 indicates national performance of Physical Sciences from 2011 to 2014. Most learners achieved between 10% and 49.9%. The percentage of candidates performing at the 0 to 29.9% categories increased in 2014 compared to 2013. This signifies a drop in the overall performance. There is also a decrease in the percentage of candidates achieving from 40% to 100% which means fewer candidates passing in flying colours.

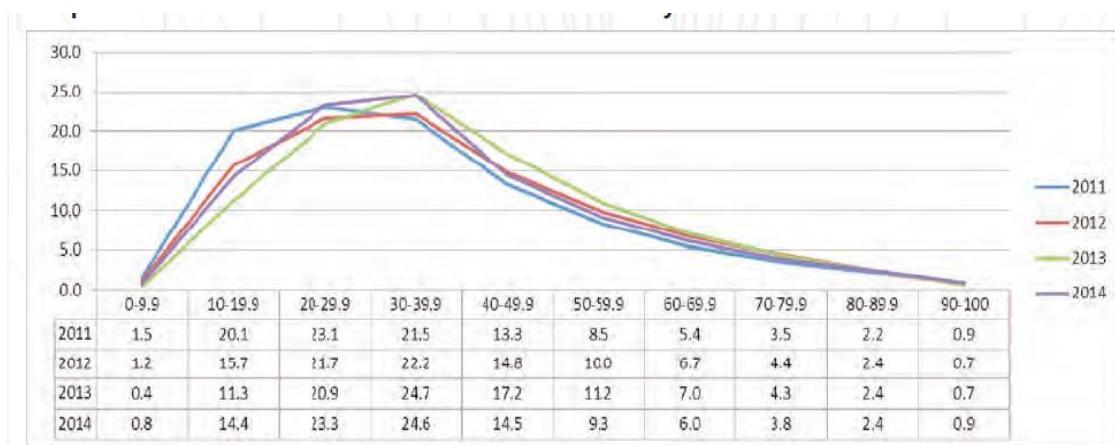


Figure 2: Performance distribution curve (Adapted: 2015 NSC Diagnostic Report)

Due to the fact that many students have great difficulty in successfully developing a scientifically accepted understanding of electricity (Ohms law), the researcher decided to find ways in which to assist learners develop a better conceptual understanding of electricity. The researcher, a Physical Sciences and Mathematics teacher, had put this theory into test to see if it surfaces the critical thinking and accommodation of new concepts to enable learners to perform better and obtain good outcomes which meet the national standards as set by the Department of Education (DoE). This research was done in order to use the Multiple Representations Approach when teaching other topics in Physical Sciences syllabi should the study yield positive outcomes.

In line with the recommendations of the Curriculum and Assessment Policy Statement (CAPS) and in view of the challenges described above, the researcher decided to discover techniques in which learners' performance in Physical Sciences can be enhanced. The aim of the study is to explore how Multiple Representations Approach could be used to improve learners' understanding of Ohms law in a rural school in the Eastern Cape and to improve performance of learners in Physical Sciences.

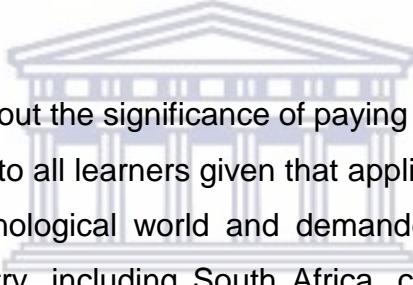
1.3. STATE OF SCIENCE EDUCATION IN SOUTH AFRICA

The education system in South Africa has experienced remarkable alterations in the previous years with the aim of transforming it into a competent education system that can match and be equivalent to the international standards. Amongst the changes, the introduction of the National Curriculum Statement (NCS) which was revised and is now called the Curriculum and Assessment Policy Statement (CAPS) can be regarded as the most noticeable and important change that affected all stakeholders in education.

CAPS was introduced in 2005 by the national Department of Education with the aim of equipping learners with knowledge, skills and values necessary for

fulfilment and meaningful participation in society as a citizen of a free country (Department of Education, 2002). It is also designed to meet the challenges posed by the scale of change in the world, the growth and development of knowledge and technology as well as the demands of the 21st century that obliges learners to be exposed to different and higher levels of skills and knowledge (Department of Education, 2002).

In spite of all these changes, the underperformance of learners in the National Senior Certificate (NSC) examination, especially in Physical Sciences and Mathematics, is a serious challenge to all stakeholders of education. It has a direct impact on the training and supply of skilled people to the human resource of the country. The shortage of skilled people in the country affects the economic growth and the technological advancement of the nation (Redish, 2006).



Redish (2006) points out the significance of paying more consideration to the facilitation of physics to all learners given that applicable skills are needed in an increasingly technological world and demanded in the labour market. Therefore, any country, including South Africa, cannot afford not to have enough learners entering into a Physical Sciences study field. It thus becomes imperative to pay more attention to the teaching of Physical Sciences due to technological advancement and to supply in the labour market needs.

Research in science education plays an essential role in analysing the actual state of scientific literacy and the practice in schools in addition to the improvement of instructional practice and teacher education (Duit, 2007). Another problem facing science education in South Africa is the scarcity of qualified teachers such that South Africa depends on other countries for the supply of Physical Sciences teachers (Magadla, 2014). He further argued that about 50 % of the Physical Sciences in one of the Eastern Cape education districts are not South Africans. Magadla (2014) also stated that in most schools of that district, learners are taught Physical Sciences by teachers who are not qualified to teach it. For instance, it is common to find a Life Sciences, History or any other teacher with no background in science to be

assigned a science class. More than 30% of learners who were interviewed indicated that MRA encouraged them to follow science careers of which about 17% of those specified that they will become science teachers (Maseko 2017). Such reports give hope that using MRA when teaching Physical Sciences might assist to solve the science teacher shortage.

Students taught by such unqualified teachers perform poorly especially in the grade 12 examinations. This could be one of the reasons why South African learners were placed last against 38 and 58 countries which participated in an international study of Mathematics and Science achievement called Trends in International Mathematics and Science Study (TIMSS) in the years 2001 and 2003 respectively (Makgato & Mji and 2006 TIMSS 2011). This underperformance by learners has led to a decrease in the number of learners who entered into science based programmes at universities due to the decrease in the number of learners who passed science on higher grade between the years 2005 and 2007 (Kriek & Grayson 2009).

The figures in Table 3 shows the results of a research that was conducted ten years ago by Kriek & Grayson (2009) which indicated poor performance in South African learners in Physical Sciences. South Africa is still faced with challenges of underperformance in Physical Sciences as it was the case ten years ago.

Table 3: 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

Out of 61.5% of learners that passed Physical Sciences in 2013, only 36.9% obtained 40% and above. There was a little decrease of 2.9% in learners who obtained 30% and above from 2014 to 2015 while those who scored 40% and above made an unnoticeable decrease of 0.8%. In the year 2016, Physical Sciences results indicated some improvement of 3.4% in both categories of learners who scored 30% and above and those who scored 40% and above, respectively. This little improvement gives hope that there is a room for improvement in the performance of Physical Sciences should the DoE, teachers and learners strive for new techniques of dealing with the subject, hence the researcher conducted this study.

Table 4: Overall achievement of grade 12 learners in CAPS Physical Sciences 2013-2016.

Year	% achieved at 30% and above	% achieved at 40% and above
2014	61.5	36.9
2015	58.6	36.1
2016	62	39.5

1.4. CHALLENGES IN SCIENCE EDUCATION PROVINCIALY AND AT THE DISTRICT LEVELS

Grade 12 Physical Sciences' poor results in the Eastern Cape remain a challenge. A number of possible aspects which were identified eleven years ago by Reddy (2004) are presently still contributing to underperformance of learners in Physical Sciences. Based on the researcher's experience as Physical Sciences educator over the past fifteen years of teaching, learners underperform due to most of the following factors:

1.4.1. LACK OF RESOURCES

Lack of science laboratories is a national and international problem and this means reliance on textbooks for science teaching. Recent studies indicated in South Africa 86% of public schools are in need of science laboratories (Uitenhage science centre, 2017). The problem of inaccessibility of resources in schools contributes undesirably to the teaching and learning of Physical Sciences as learners learn and comprehend better when they are hands-on (Makgato 2007). The DoE (2001) noted that majority of schools that offer Physical Sciences do not have facilities and equipment to support effective teaching and learning. The teaching of Physical Sciences remains at a theoretical level without any experiments to enhance understanding and application of knowledge. Though the DoE has highlighted that there is a lack of resources in schools, this situation remains a problem that leads to poor performance of learners. A recent study has noticed this problem and recommended that the Eastern Cape department of education should expose learners in rural areas to science world by providing science centres or laboratories as that will improve learner attitude to science and attainment in Physical Sciences (Xongwana 2014).

1.4.2. UNDER-QUALIFIED AND UNQUALIFIED EDUCATORS

Globally, there is a challenge of both under-qualified and unqualified science educators. According to the report that was published by the Edu Source (DoE, 2001), most Physical Sciences and Mathematics educators are not qualified to teach these subjects. Many educators who are teaching Physical Sciences are under qualified to teach this subject. The results in the Science Audit in 1999 indicated that more than 68% of science educators had no formal subject training in these subjects (Mangena, 2001). The department of education has discovered that even some of the qualified educators, have insufficient training in teaching Physical Sciences. This has been found to be a problem mostly at the junior secondary school level (DoE, 2001).

About 8200 Science educators were targeted by the DoE for in-service training to address the lack of subject knowledge due to such problems (DoE, 2001).

The Department of Education was reported to be facing difficulties in Physical Sciences as there was a decline in the number of those achieving matriculation exemption in the Senior Certificate Examination (Howie, 1997, 2001). Self-regulating verification of the serious flaws in Science and Mathematics education found in the Presidential Education Initiative Research Report (Department of Education, 1999) also provoked the then President of South Africa to emphasise the crucial need for the upgrading in school Science and Mathematics:

“Special attention will need to be given to the compelling evidence that the country has a critical shortage of mathematics, science, and language teachers, and to the demands of the new information and communication technologies”. (Excerpt from President Thabo Mbeki’s parliamentary address in 1999, quoted in Department of Education, 2000).

A number of interventions in Mathematics, Science and Technology were implemented in response to the above demand. MRA is believed to encourage learners to follow science careers.

Findlay & Bryce (2012) discovered that understanding the behaviour of electricity and particularly elementary direct current circuits (also known as simple circuits which includes Ohm's law) has been a persistent challenge to learners, novice and experienced teachers. They also argued that even qualified teachers across all the different school phases can have difficulty in understanding and teaching electricity to learners.

1.4.3. CLOSING DOWN OF SCHOOLS DUE TO POLITICAL PROTESTS

There are persistent political protests in South Africa since the second decade of democracy. These protests prevent schooling as learners are also involved in these protests. This contributes negatively to the general academic results. For a period of more than eight weeks, schools were closed down in Vhuwani, Limpopo province due to demarcation protests where more than eight schools were burnt down (Nomnganga, 2017). In another case, people protesting for service delivery closed down Maluti and Matatiele for about two weeks. Some closed the R56 road between Matatiele and Mount Fletcher for about two days for the same reason. These two incidents interrupted the grade 12 preparatory examinations as schools could not access the education district offices to collect question papers. (Maqhubu, 2017). In most cases these protestors involve learners in their actions and prevent anyone to attend school. This in turn contributes negatively in matric results including Physical Sciences performance.

1.4.4. NEGATIVE ATTITUDE OF LEARNERS TOWARDS PHYSICAL SCIENCES

Some learners have negative attitude towards Physical Sciences because it is considered to be the most difficult subject. Science seems to be abstract for learners; at times as they find it difficult to understand scientific concepts (Baser, 2006). For this reason, it is important for educators to do demonstrations when teaching and also 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 early stages of

development. Hartley (2014) believes that exposing learners to science activities such as reading of science related journals, science festivals, science clubs and career exhibitions in the field of science can change learners' attitudes for better. 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.

1.4.5. LACK OF PARTICIPATION IN SCIENCE ACTIVITIES

Hartley (2014) conveyed that rural high school learners who won a science competition either in a district or provincial level, who were also members of a science club, were motivated in such a manner that four out of nine members enrolled for engineering studies and others following science degrees. 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 exhibitions 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. They also prompt them to appreciate science and the positive attitude produces good results. Unfortunately, educators are reluctant to expose learners to science activities. They find them to be time consuming.

1.4.6. MISCONCEPTIONS OF SCIENTIFIC TERMS

National Diagnostic Report (2014) repeatedly noted that learners are answering questions incorrectly as a result of them having misconceptions in using scientific terminology. From the results of many thousands of studies reported in Duit (2007), research has shown that individuals are not simply passive learners but make sense of new information in terms of their previous ideas and experiences. One outcome of such learning is that learners' knowledge is not consistent with the scientists' science. In other words, the

pre-knowledge which learners bring to the classroom that make sense to them based on their daily life experiences may not match the science context and hence may be wrong.

These views are often firmly held, are resistant to change and present difficult challenges for teachers of science and researchers of science education. Alternative conceptions may arise as a result of a variety of contacts students make with the physical and social world (Griffiths & Preston, 1992). It is well known that such student beliefs influence how students learn new scientific knowledge and play an essential role in subsequent learning.

A review of the research relating to students' misconceptions of science concepts reveals that misconceptions have many common features. They are often strongly resistant to traditional teaching methods and students are generally reluctant to transform these misconceptions (Driver & Easley, 1978).

Gilbert, Osborne & Fensham (1982) reported that learners' pre-knowledge about some science concepts have an important role in realizing and interpretation of the knowledge. Researchers emphasised that teachers should be aware of the learners' misconceptions and in order to eliminate them effective teaching methods should be used by the teachers. Even if a student that holds a misconception is willing to struggle through the cognitive dissonance, they must first be able to correct their misconception prior to forming a correct mental model. Learning is the result of the interactions between what the learner is taught and his/her current ideas, therefore misconceptions interfere with further learning.

1.4.7. LIMITED TIME ALLOCATION IN THE CAPS

The Curriculum and Assessment Policy Statement (2011) indicates that practical work must not be separated from theory in order to strengthen the concept being taught. The CAPS (2011) document indicated that the practical

work can be in the form of a practical demonstration, an experiment or an investigation. This is a more meaningful way of teaching science so that learners could construct meaning in learning. But some educators claim that practical work is time consuming and makes it difficult to finish the syllabus considering the time that is allocated for CAPS in Physical Sciences (Sibam, 2014).

1.4.8. SOCIO-ECONOMIC FACTORS

The learners' background plays a role in poor performance in Physical Sciences (DoE, 2001). The impact of violence and HIV/AIDS can also have confrontational effects. Some learners are heading their families as some of their parents have died due to HIV/AIDS related issues. Shortfalls and inequalities in the education system are most evident in areas which have sustained poverty and high levels of joblessness. It is difficult for learners to have basic learning materials such as calculators and instrument boxes and this contributes destructively to learning. Others come to school with empty stomachs and have to endure the gruelling experience of being learning while they are hungry (DoE, 2001).

1.4.9. URBAN-RURAL DIFFERENCES

The Eastern Cape has about 6,239 schools mostly in rural areas compared to Western Cape and Gauteng provinces which are mostly urban and have about 1500 rural schools each (Isaacs, 2007). This enormous difference contributes to poor service delivery in the Eastern Cape Province. Urban schools have an advantage of technology learning teaching support materials whilst rural school lack such. ICT projects such as Khanya in the Western Cape Province and Gauteng Online Project in Gauteng significantly contribute to improved learning outcomes in those urban schools.

Freire (1971) ascertained that usually learners from the rural schools do not enjoy the benefits of well-resourced schools and qualified teachers. He is

supported by (Molele, 2017) who disclosed that compared to other provinces, Eastern Cape as the most rural province is declared to have high number of mud schools. The ECDoE targeted to build 24 proper schools in the 2015/2016 financial year. A huge blow is that only three of those schools (12.5%) were built by this province during that specified time frame (Molele, 2017).

A huge percentage of learners in the rural communities are poor compared to those in urban areas. Another challenge facing Physical Sciences in South Africa is language. The language problem is worse in rural areas compared to urban areas. Learners from rural areas speak with their own syntax, semantics and accent (Ndzala 2014). This disadvantages them as they usually misunderstand the Physical Sciences language.

The Khanya Project provided almost 24 000 computers in 613 schools and also 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 and every 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 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 84.7% in 2014. ICT has a potential to improve the quality of education and training in general education and training (GET) and further education and training (FET) bands when applied effectively as indicated in the outcomes in these intervention programmes.

The above highlighted programmes are also needed in remote rural and previously disadvantaged schools to improve the pass rate in Physical Sciences.

1.4.10. ABSENTEEISM BY BOTH EDUCATORS AND LEARNERS

Several media platforms have reported that some educators and learners especially in remote rural schools were sometimes reluctant to attend school. In a few legitimate cases the reasons for absenteeism are that of bad weather conditions. It has been reported that roads were closed and these prohibited school attendance during final examinations because of snowfall (Bavuma & Nomnganga, 2017). These includes heavy rain storms and snowfall. These prohibited school attendances by both teachers and learners as 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. Improper access roads and bridges are mostly found in rural areas compared to urban areas.

1.5. INTERVENTIONS IN SCIENCE EDUCATION IN SOUTH AFRICA AND THE EASTERN CAPE PROVINCE

WESTERN CAPE

Great emphasis on the promotion of Mathematics, Science and Technology (MST) began with the introductory era of the democratic government in South Africa. These fields are seen as the critical basis for socio-economic development of the country. This statement is supported by other researchers who confirm that Mathematics, Science and Technology have been national priority in South Africa (Suping, 2003).

In 2001 the Department of Education established the Dinaledi Schools Project. The aim of the project was to increase the number of matriculants with university-entrance Mathematics and Science passes. The venture began in 2006 with 400 schools and is still ongoing, with the performance of these schools being continuously supported and monitored. The Department of Education's (2010) main goal related to the project is dedicated on

upgrading the performance of learners in the Mathematics and Physical Sciences. In 2008 a 100-hour teacher training process was undertaken with 2 400 teachers in Dinaledi schools across all nine provinces to strengthen their content knowledge, improve their teaching of Mathematics and Science and improve learner performance. Yet, despite all the support from the Dinaledi project, the results are still very poor (DoE, 2010).

The partnership of Department of Education (DoE) with the Shuttleworth Foundation in 2012, worked to develop and distribute the Siyavula Mathematics and Physical Science textbooks for grades 10 to 12 to all schools offering these subjects. This project focused on increasing the number of grade 12 learners who pass Mathematics and Physical Sciences. In total 1277 550 Mathematics textbooks and 934700 Physical Science textbooks have reached their target groups. In 2014, the DoE provided the subject advisors with CD's and DVD's with question paper exemplars in all NSC subjects, uploaded onto the DoE's website with self-study guides in the ten key subjects to enhance teaching and learning. Common examinations were introduced and administered in grade 11 for Mathematics and Physical Science to prepare learners for the final grade 12 examinations.

The Eastern Cape department of education in conjunction with the University of the Western Cape initiated a project whereby teachers from the various districts were selected and trained in Advanced Certificate in Education, specialising in Physical Sciences. In this project, teachers were exposed to content and various methodologies as to how to teach Physical Sciences in order to upgrade learner attainment, and also to motivate learners to take Physical Sciences as a specialisation subject in secondary school as well as at tertiary institutions. The project continued and trained these teachers up to a Masters level. The teachers are utilised by the Eastern Cape Education Department to train other teachers in fields like Natural Sciences in the General Education and Training (GET) phase.

Learner Attainment Improvement strategy (LAIS) programs that are in place as a form of alleviating challenges in Physical Sciences include:

1. Bright sparks

In these programs grade 12 learners from about three to five neighbouring schools are grouped together in one school. These should be learners who are best Physical Sciences performers from each of those school. Guru Physical Sciences teachers are chosen and assigned to teach those learners.

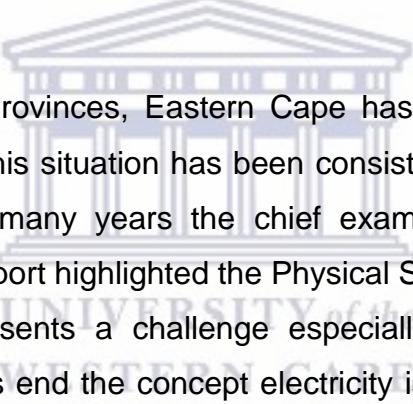
2. Winter and spring schools which are marked by overcrowded classes and do not cater for individual attention for learners.
3. Mini quizzes and Astro quizzes competitions that take place in March and accommodate only two learners per school.
4. Science festival which is held in Grahamstown in the Eastern Cape Province, and not all learners are able to attend the festival as it is far from many schools in the province.
5. Nelson Mandela Metropolitan University (NMMU) program for FET physical science educators which aims at developing educators in Physical Sciences.
6. Science Olympiads, SAASTA science school's debates and science week target only a few learners and other schools do not bother participating.
7. 1 + 4 program which is aimed at developing foundation and intermediate phase educators in numeracy which is a base for Physical Sciences.
8. Maths, Science and Technology grant which is aimed at supporting schools that are struggling with Physical Sciences.

One of the aims of science education is to enable students to develop a proper understanding of science including problem solving, inquiry, information gathering, analysis, interpretation and other essential process skills needed to tackle practical problems on a daily basis (Department of education, 2011). The NCS Grade R-12 serves the purpose of providing learners an access to Higher Institutions of Education (HIE) (CAPS 2011).

1.6. RATIONALE FOR THE STUDY

Eastern Cape Province is one of the worst performing provinces in South African matric results. One of the subjects that learners are performing poorly in is Physical Sciences. Physical Sciences is achieving within the lowest pass rate since 2013 compared to other content subjects which the MEC for Basic Education referred to as the most popular subjects (Motshega 2015).

Table 5 indicates that in the Eastern Cape Province, Physical Science is the subject with the second lowest learner achievement since 2014 to 2016. The Eastern Cape Physical Sciences' pass rate was 51.5%, 45.9% and 49.6% in 2014, 2015 and 2016 respectively. Mathematics was the lowest with a 42.0%, 37.3% and 37.5% in those years. Accounting has been performing better than these two subjects as its pass rate was 68.0%, 52.7% and 61.8% in the past three years.



Compared to other provinces, Eastern Cape has the lowest pass rate in Physical Sciences. This situation has been consistently happening over the previous years. For many years the chief examiner, through the DoE's national diagnostic report highlighted the Physical Science Paper 1 as one of the areas which presents a challenge especially when it comes to its application, yet to this end the concept electricity is a challenge to learners (DoE 2011, 2012 and 2013).

Table 5. Summary of the last three performing subject nationally since 2013 and Physical Sciences since 2013 in Eastern Cape Province only.

Subject	YEAR			
	2013	2014	2015	2016
Accounting	65.6%	68.0%	52.7%	61.8%
Physical Sciences	67.4%	51.5%	45.9%	49.6%
Mathematics	59.1%	42%	37.3%	37.5%
Nationally (Physical Science)	64.9%	61.5%	58.6%	62.0%

The overall percentage obtained by learners in electricity in 2013 was only 21.1 %. This performance fairly improved to 51% in 2014 and decreased again to 15.5% in 2015. In 2016 it increased from 15.5% to 47% only. This is represented in table 6. The learner performance, as depicted in Figure 3, 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 and 2016 (Motshega, A. 2016).

The chapter of electricity in high school Physical Sciences is one of the most important chapters as it carries a large percentage of marks in the examination in physics. At tertiary level it is also important that learners get good understanding of this chapter especially for those learners that will follow electricity related careers. The majority of questions in electricity are middle and high order questions. TIMMS (2016) indicated that the underperformance of learners in practical design questions is not a challenge experienced by South African learners only, but is the same challenges for other countries.

The knowledge and skills regarding laboratory apparatus are tested in grade 12 examinations and are valued by universities in the engineering or science related fields (DoE, 2000). Learners could be developed to be critical thinkers as highlighted by Swain, Monk & Johnson (1999) through the use practical work that aims at seeing problems, seeking ways to solve them and arriving at new conclusions. For example, the challenge of load shedding that once faced South Africa could be improved.

Table 6. Table indicating the overall percentage performance of learners in electricity in 2013 to 2016 nationally.

YEAR	Overall percentage performance of learners in electricity in 2013 to 2016
2013	21.1
2014	51

2015	15.5
2016	47

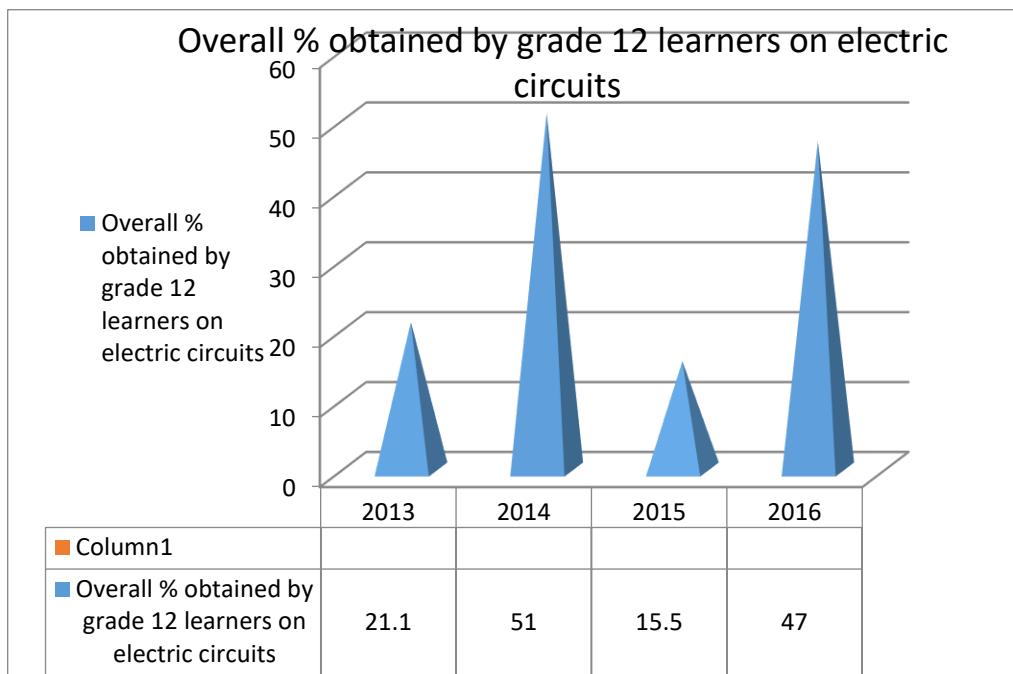


Figure 3: Graph showing grade 12 past results on electricity nationally.

The researcher's interest in this study was provoked by poor performance in Physical Sciences grade 12 learners in the school and district where this research was conducted as indicated in Figure 1 and Tables 2 and 3. It is the researcher's argument that, from his 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 problematic 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, the learner performance could improve. Although this study focused on grade 11 in electric circuits, a closer look at grade 12 performance will give a clear picture of the problem. Grade 12 is externally examined, moderated and marked while grade 11 is externally examined and moderated but internally marked. Therefore, Grade 12 results are more fair and good at illustrating problems compared to grade 11.

The study intended to explore the effectiveness of teaching Ohms law by employing a Multiple Representation Approach. The National Diagnostic Report (2014) showed that learners have misconceptions concerning electric circuits. Students mostly struggle with working on calculations (Ohms law) and find difficulty in answering questions that are practically based. This might be caused by the fact that learners lack 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 attainment. The CAPS document for Physical Sciences grade 10-12 exposes a teaching pedagogy that promotes development of critical thinking, scientific reasoning and strategic abilities among learners. This can only happen in the sciences when learners are exposed to practical work.

Hartley, (2014) asserted that teachers should improvise where there is a shortage or absence of resources while ensuring a vibrant learning environment. This study could equip teachers with knowledge that it is not an absolute necessity to only make use of sophisticated equipment, but that even self-developed equipment may produce the desired results.

As a concerned Physical Science teacher, the researcher has intentions of improving these results through the implementation of Multiple Representation method of teaching Ohms law as means of remedying the situation.

1.7. RESEARCH PROBLEM

Reports indicate that the topic electricity remains a challenge due to its abstract nature of concepts and that science literacy level is gradually dropping (Baser, 2006; TIMSS, 2011). Learners who are unable to understand basic electricity concepts usually label the subject as difficult. This does not only affect their performance, it also discourages them from choosing Physical Sciences as a subject at high school, thus limiting their future possibilities in a career in sciences.

According to the Examiners' reports in national curriculum statement's diagnostic report, conventional practical activity and revision are recommended to improve learners' performance, especially in electricity, and the majority of learners loose many marks on questions that are inquiry based than the recall question types Department of education (2010; 2011; 2013). Most of the inquiry based questions are categorised under the higher order questions according to Bloom's taxonomy of the cognitive domain of classifying questions. Department of Education [DoE], (2014) provided examination guideline for Grade 10-12 South Africa. The learning objectives for grades 11 and 12 topics are outlined in guidelines and they indicated that approximately 33% of 150 marks is from the topics electricity and magnetism, which is quite a big portion relative to the other physics topics.

Most teachers employ a talk and chalk or lecture method when teaching Physical Sciences shying away from other teaching methods or approaches. Many teachers claim that the lecture method is not time consuming compared to practical work so it helps them cover or finish syllabus in time (Sibam, 2014). Ndokwana (2014) concurs with this report and provided the following reasons as to why practical work is not done by Physical Sciences teachers?

- There is a lack of laboratory equipment and this annoys some Science teachers.
- Some teachers feel that they are lacking skills to conduct practical work in Physical Sciences due to the lack of developmental workshops.
- Classes are overcrowded yet practical work requires plenty of space.

Those teachers who do teach practical work only engage with that which is prescribed by the department so as to comply with the curriculum requirements (Sibam, 2014). There are many teaching methods or approaches that can be used in different situations to produce better understanding by learners. Such approaches include demonstrations, conducting practical, animations, and discovery methods etcetera. Such methods or approaches need thorough preparation by the teacher and are time consuming.

These approaches could also be expensive as they need material like teaching aids when one uses them in his or her teaching. Another reason that makes it difficult to employ these teaching method is that they need plenty of space. Vakalisa & Gawe (2011) proclaim that at all levels of schooling, classrooms are often overcrowded in most South African schools, and hence it is difficult to do so.

Some teachers fail to employ these teaching methods or strategies as they claim that they are not comfortable with the handling of materials, however, the majority of teachers have no problem. Dillon (2008) generalized that teachers who have been properly trained in Physical Sciences are comfortable and positive about practical work. With the majority of teachers continuing teaching using talk and chalk method only it is likely that there will be no improvement in the Physical Science matric results; instead they will deteriorate. Staver (2007) argued that, educators should integrate the core body of scientific knowledge and scientific enquiring as to clarify science and its applications.

Staver (2007) furthermore claims that teaching is aimed at the facilitation of learning and if learners fail to learn, the educator should carry part of the responsibility. This implies that when educators plan their lessons, they have to be sensitive to their learners' needs and adjust their teaching strategies and techniques to assist learners. Once learners understand scientific principles and are able to apply their scientific knowledge to the world they live in, they gain a lifetime thirst for knowledge and the acquisition of skills that can be learned and developed on their own (Staver, 2007).

It is against this backdrop that the researcher became interested in undertaking research on this topic electricity but with a focus on teaching Ohms law in grade 11 Physical Sciences using Multiple Representations.

1.8. RESEARCH QUESTION

There is only one major research question to this study with four sub-questions, which are believed to support the main research problem. These research questions seek to find answers as to how learners could be taught and learn in a way which will increase their chances of scoring more marks on high order questions.

The main research question is formulated as follows: How can a Multiple Representations Approach be used to teach Ohm's law in Grade 11 Physical Sciences?

The sub-questions being the following:

- (i) What was learners' initial understanding of electricity?
- (ii) How was Ohms law lessons taught using (a) the Multiple Representations Approach and (b) the traditional method?
- (iii) What was learners' understanding of Ohms law after the Multiple Representation approach?
- (iv) What were learners' perceptions of the Multiple Representation lessons?

1.9. CONTEXT OF THE STUDY

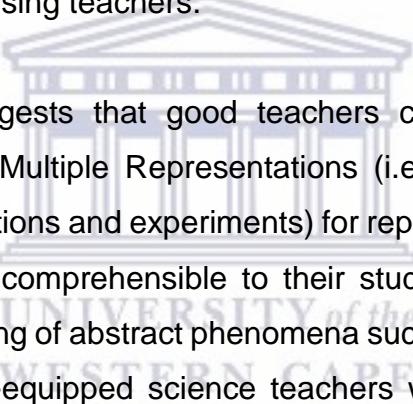
The researcher is teaching in a primary school and has conducted this study in a high school, since the topic Ohms law is for grade 11 in high school level. This is a previously disadvantaged high school in an education district in the Eastern Cape, South Africa. The school is situated in a rural village of a small rural town with one headmaster, one deputy principal, 15 teachers (educators) and about 600 learners starting from grades 8-12 at the time when this research was conducted.

It has an average 1:35 teacher-learner ratio with only one Physical Science teacher teaching grade 10 to 12. The researcher decided to use this school to minimise travelling costs and to maintain the study's naturalistic nature. As a teacher from another school, the researcher had to conduct his study on

Saturdays as promised on the ethics that the study will not interfere with the school teaching hours.

1.10. SIGNIFICANCE

The research results may be beneficial to science teachers in terms of improving strategies for the design of teaching Ohms law and at the same time to improve learner mark attainment in electricity. This could in turn enhance learners' chances of doing well in answering high order questions hence having a positive impact on the Physical Sciences results in the Eastern Cape. As Kruger, Summers, & Palacio, (1990) in their study indicated that teachers were often ill-equipped to teach science, and that the conceptual area of electricity is one which presents considerable challenge to both prospective and practising teachers.



Shulman (1986) suggests that good teachers characteristically possess powerful armoury of Multiple Representations (i.e. analogies, illustrations, examples, demonstrations and experiments) for representing and formulating a subject to make it comprehensible to their students. This is particularly apparent in the teaching of abstract phenomena such as electricity. The study might assist those ill-equipped science teachers with powerful armoury of Multiple Representations resulting in good or acceptable Physical Sciences learner attainment specifically in the electricity topic.

As highlighted by 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 through the MRA, and in particular 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 MRA to teaching Physical Sciences.

This study could provide insight into using Multiple Representations Approach (MRA) to teach other challenging topics in Physical Sciences. It could also add value to teachers in rural schools as a teaching approach to increase the chances of learners to pass in electricity where resources are limited.

MRA approach can facilitate developing positive attitudes towards science. This study also provides instruments and procedures for conducting related research in the future. The awareness of misconceptions allows teachers to see their views in totally different ways which may lead to reconstruction of their science knowledge so as the instructional strategies used in the classroom. Science teachers, after knowing the misconceptions, can select science content and design lessons that will cover the interests, knowledge, understanding, abilities, and experiences of their learners in order to increase learners' understanding.

1.11. LIMITATIONS OF THE STUDY

Best and Kahn (1989) define limitations as the conditions beyond the control of the researcher that will place restriction on the conclusion of the study and its application. Being a case study design, this study draws conclusions from only one school hence the results cannot be generalised for the district, province, country and internationally. The participants' responses and reaction to the study might have been negatively affected by the big gap between the research sessions compared to everyday science teaching instruction of the Physical Sciences provided in CAPS's subject statement policy as this study was only conducted on Saturdays and public holidays.

1.12. STRUCTURE OF THE THESIS

This study is outlined in the following chapters:

Chapter 1: Introduction to the study

This chapter serves as the introduction to the research by highlighting the background of the study, the state of Science Education in South Africa, Interventions made by the National Department of Education in the country as well as the Province of the Eastern Cape in order to improve performance of learners in Physical Sciences. The research problem, the research question, the significance of the study, as well as the limitations to the study are also highlighted. It is in this chapter where the context of the study is explained. Importantly, chapter 1 also provides an introduction to the successive chapters.

Chapter 2: Literature Review

In this chapter theoretical framework and the current literature related to the study are reviewed. International, national and local studies addressing this study are discussed in this chapter. Chapter 2 attempts to show the relationship between this study and what has been revealed from previous researches.

Chapter 3: Research Methodology

In this chapter, the research design and methodology, including the quantitative and qualitative research methods are discussed. The procedures, design, population, sample and instrumentation that were used to measure the effectiveness of the conceptual development teaching strategies are discussed. Validity and reliability of the study is explained. Also the ethical aspects of the research are explained. As discussed by Hornberger and Corson (1997), a good scientific study does not only provide details about a phenomenon and its context, but will also discuss all technical procedures which are undertaken to come up with the study's conclusions.

Chapter 4: Research Results

Research results are mentioned and interpreted in this chapter. This is where the synthesis of quantitative and qualitative data takes place.

Chapter 5: Discussion

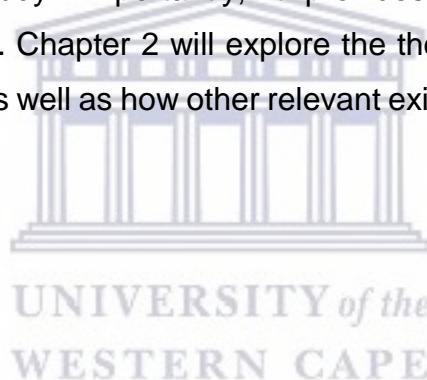
Based on the results of the study, the discussions and analysis of the data are detailed in this chapter.

Chapter 6: Conclusion and recommendations

In this chapter, a summary is provided. Conclusions and recommendations are drawn regarding the effectiveness of the applied Multiple Representations Approach and teaching strategies on Ohm's law are also given.

1.13. SUMMARY

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 provides an introduction to 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 focused on the introduction to the study. This chapter outlines the theoretical framework that underpins this study and the relevant literature that supports and clarifies the study. It also highlights South African and international studies in the teaching of Ohms law in grade 11 Physical Sciences using Multiple Representations Approach.

2.2. LITERATURE REVIEW

A Literature review refers to the selection of the available documents (both published and unpublished) on the topic which contains information, ideas, data and evidence written from a particular standpoint. This evidence fulfils certain aims or expresses certain views on the nature of the topic and how it is to be investigated. The effectiveness evaluation of these documents in relation to the research being researched is also considered (Geertz, 1973). This literature review starts by looking at the theoretical framework that underpins the study

2.3. THEORETICAL FRAMEWORK

This study is underpinned by the theories of constructivism and pedagogical content knowledge (PCK).

2.3.1. CONSTRUCTIVISM

2.3.1.1. THE CONSTRUCTIVIST VIEW OF HUMAN LEARNING

Constructivism is an epistemological view of knowledge attainment emphasising knowledge construction rather than knowledge diffusion and the

recording of information transferred by others (Ausubel, 1968). Constructivism is defined in four principles

1. Knowledge can be founded on past constructions. Each person's network of knowledge is constructed as s/he creates while relating with the environment and trying to make sense of experiences.
2. Constructions effects from assimilation and accommodation. Assimilation refers to the use of the already existing information in our personal networks of facts to deduce new information established. If the new information is contradicted during assimilation, it is accommodated by adapting our existing concepts (Mwamwenda 2004). It is further argued that learners will learn more easily if the new knowledge is presented in terms of the known or existing knowledge (Fourie, Griessel & Vester, 1991).
3. Learning is a process of intervention. Learning in constructivism is not seen as an accumulation of facts: the learner needs to experience, hypothesise, manipulate objects, pose questions, ask questions, negotiate and investigate (Piaget, 1950).
4. Meaningful learning takes place through reflections. Knowledge is created through processes of reflection, inquiry and action on the part of the learner. According to Lichtenberg & Troutman (2003), constructivism is a theory that grew primarily out of the pioneering work of Jean Piaget (1896 – 1980), a Swiss psychologist, and Lev Vygotsky (1896 – 1934), a Russian psychologist. Both were interested in how the growth of knowledge takes place. They worked separately and came with same conclusions although their approaches were somewhat different.

People gain knowledge through learning. Learning takes place when a person is mentally stimulated or taught, while knowledge is the creation of meaning and understanding within a social context (Chetty, 2014). The role of the learner is regarded as one of building and transforming knowledge. Robottom (2004) defines knowledge as concepts that are created in the mind of the learner. According to the constructivist learning theory the learner constructs his/her own knowledge in such a way that new knowledge is connected with

existing knowledge (Ausubel, 1968). For this reason, prior knowledge is of importance in the learning and teaching of physics. Unfortunately, learners' prior knowledge is not always acceptable from a scientific point of view.

Learners come to class with their own personal ideas about physical phenomena and attach their own meanings to concepts. Their intuitive (or alternative) conceptions have been identified as an important source of learner difficulties in understanding physics (Driver & Easley, 1978). The construction of knowledge by a learner mostly depends on the methods that a teacher uses. Learners construct knowledge in different ways as all people are unique.

Within constructivism there are different notions of the nature of knowledge and the knowledge construction process. Three types of constructivism: exogenous constructivism, endogenous constructivism and dialectical constructivism have been identified (Piaget 1950). Piaget (1950) further clarified that endogenous constructivism or cognitive constructivism focuses on internal individual constructions of knowledge. This perspective emphasises individual knowledge construction which is stimulated by internal cognitive conflict as learners strive to resolve mental disequilibrium. Students may be said to author their own knowledge, advancing their cognitive structures by revising and creating new understandings out of existing ones. This is accomplished through individual or socially mediated discovery-oriented learning activities.

Dialectical constructivism or social constructivism (Brown, Collins, & Duguid, 1989) views the origin of knowledge construction as being the social intersection of people, interactions that involve sharing, comparing and debating among learners and mentors. Through a highly interactive process, the social milieu of learning is accorded centre stage and learners both refine their own meanings and help others find meaning. In this way knowledge is mutually built (Vygotsky's, 1978). It emphasises the supportive guidance of mentors as they enable the learner to achieve successively more complex skills, understanding, and ultimately independent competence.

The fundamental nature of social constructivism is collaborative social interaction in contrast to individual investigation of cognitive constructivism. Through the cognitive give and take of social interactions, one constructs personal knowledge. In addition, the context in which learning occurs is inseparable from emergent thought. This latter view known as contextualism in psychology becomes a central principle of constructivism when expressed as situated cognition (Mwamwenda, 2004).

The modern interpretations of constructivism pedagogy have been developed through two interpretations of constructivists developed by Piaget and Vygotsky (Piaget, 1952 and Vygotsky, 1978). Those interpretations are radical and social constructivism. Piaget developed the reductionist approach into the constructivist approach, that learning is a dynamic process within the construction of knowledge (Piaget, 1952). Radical constructivism then concludes that knowledge can only be developed if the knowledge about world is true, the person believes the knowledge and there is a reasonable belief that the knowledge is true (Vygotsky, 1978).

There is much that is laudable, insightful, and progressive about constructivist theory and practice. It is far superior to the behaviourist theory of mind and learning against which Piaget (1952) and early cognitive psychologists, such as Brunner (1961) struggled. Constructivism stress on learners' engagement in learning, and the importance of understanding student's current conceptual schemes in order to teach fruitfully, are progressive, as is its stress on dialogue, conversation, argument, and the justification of student and teacher opinion in social setting.

Piaget (1952) identifies three stages that are important in the construction of knowledge. Those stages include: pre operational stage, concrete operational stage and formal operational stage. For this context learners are on concrete and formal operational stages. Constructivism stresses on understanding as the goal of science instruction. This clearly shows the importance of how the information should be presented to the learners.

Learners can understand a phenomenon differently based on how it was presented. Methods and representations that will allow different learners a chance to interpret information in ways that make meaning to them are important. Either learner construct knowledge from within the learner her/himself or through the interaction with other learners, hence the concepts of radical constructivism and social constructivism.

The epistemology of radical constructivism finds its fundamental assumptions in a specific epistemology and philosophy of science (von Glaserfeld, 1996). According to this epistemology, all human knowledge from everyday observations to scientific knowledge formation as apprehension and representation of some kind of reality that lies outside of the knowing subject and existing as such by itself, is in principle impossible. It is through a creation of the observer that everything can be known of this external reality (Swedberg, 2003). Everything that human beings can know of this external reality is a construction. We can comprehend our reality only in the form in which it has been assembled by ourselves. The sum of all constructions is the ‘experienced reality’ in which we live.

Constructions also take place as co-constructions in social contexts, and, thus, must be tested there. The formation of scientific knowledge is not in principle, but only in gradual steps, different from everyday knowledge. Scientific knowledge is constructed knowledge, which has to prove itself useful in regard to certain contexts, interests and problems as ‘or ‘operationally. In its ultimate metaphysical implication, this in principle always-constructed and always-provisional status of knowledge is considered to be a cogent call for tolerance between different systems of knowledge and convictions and their followers.

Social constructivism means that learners developed knowledge through social interactions and discourse (Drivers, Squires, Rushworth, & Wood-Obinson, 1994). This social interaction means learners learn from their tutors and their peers. Social constructivism pedagogy has been linked to science

education as it can be for epistemology of science as well as the science content.

Vygotsky emphasised on how the culture and social contexts in which we develop influence our learning. He argued that intellectual growth happens twice for a child, at social level and at personal level but emphasising on the social aspect more (Vygotsky, 1978). This means learners should be much involved in their learning. Bruner (1961) expands constructivism to include the role of the teacher as it is neglected in social constructivism. Learning should be directed through some teaching methods like discussions, questioning, and experimenting (Weber, 2017). These methods enable teachers to play a very active role in social constructivism. Teachers need to be confident and competent to implement the social constructivist approach and they must understand the epistemology of science. Teacher education needs to include social constructivist approach. In the case of this study, Multiple Representations social constructivism is the key.

This is so because some representations need social interpretations from peers to make them more effective whilst the individual also need to give his/her own interpretation of the representation. The learners in the process need to be guided by the teacher to achieve the desired outcomes hence scaffolding is used in this study.

The theory of constructivism which is firmly rooted in the cognitive school of psychology and the theories of Piaget dating back at least as far as 1960 underpinned this research. Constructivism discards the perception that learners are blank slates. Learners do not absorb thoughts as teachers present them, instead they create their own knowledge (Van de Walle & Lovin, 2006). The learner learns by constructing what has been learnt into a mental network, in a unique and personal technique (Mc Dermott & Rakgokong, 1996). This is especially seen as early as in the first year of teaching Grade R. Learners come to school with a prior knowledge from their own social environment. This differs from learner to learner because of the wide range of

social environments in South Africa, especially between the rural areas and the urban areas (Le Grange, 2014).

The basic principle of constructivism simply means that learners construct their own knowledge in the physical world and that construction requires tools, materials and effort. The technique learners construct thoughts can be observed in a similar manner as the tools used to build understanding of our own existing thoughts, the knowledge that we already possess. The materials we act on to build understanding may be things we see, hear or touch (using our senses), that is elements of our physical surroundings.

Occasionally the materials are our own thoughts. The effort that must be supplied is active and reflective thought. If minds are not actively thinking, nothing happens (Van de Walle & Lovin, 2006). As suggested by Smith (2001) thoughts form the foundation for constructivism that views learners as creating knowledge by acting on experience acquired from the world and their discovery of meaning in it.

Le Grange (2014) argues that in a Grade R classroom the teacher constructs active thinking through play in context-based settings. The teacher places scientific concepts in a contextual setting so that learners can create scientific knowledge in their everyday world and engage it in many situations. This does not end here but grows with the child, so teachers need to use this technique (play in context-based setting) in their teaching for effective teaching to take place. It is for this reason that the researcher also used this technique termed it as role-play in this study.

Different learners employ diverse thoughts to give meanings to the same new idea they come across. What is important is that the construction of an idea is almost indeed different for every learner, even in the same situation or classroom (Van de Walle & Lovin, 2006). Mc Dermott and Rakgokong (1996) refer to this phenomenon by arguing that learners do not recall content exactly as it is presented, but that they understand instructional situations in various techniques. The Grade 11 class used for this study was diverse: they adapt

the content knowledge provided to their own separate forms of social knowledge. This individual adaptation of content is consistent with constructivist priorities and perspectives.

To construct and understand a new idea requires active consideration of it. Scientific thoughts cannot be transferred into a passive learner. Instead learners need to be mentally active for learning to take place. Constructing knowledge calls for reflection, deliberation and concentration in an uninterrupted technique (Van de Walle & Lovin, 2006). This is approved by Piaget who concludes that learners are not empty vessels into which knowledge must be transferred. Knowledge is created actively and not received passively. This prompted the researcher to actively involve the experimental group of learners in this research.

The general principles of constructivism are based largely on Piaget (1952) processes of assimilation and accommodation. Through direct experiences of the world learners take an active part in “constructing” learning. These experiences may possibly challenge their current perception of the concept, called a schema which involves learning to accommodate new experiences by modifying schema to assimilate newly acquired data.

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A state of equilibrium is reached once this process of assimilation and accommodation has taken place. Vygotsky and Bruner's (1961) work evolved from these thoughts and led to a consideration of the impact of social experience upon learning (Turner 2013). Constructivism is the theoretical consideration of how knowledge construction takes place and it recommends that teaching is not a matter of transferring data to students nor is learning a matter of passively absorbing information from a book to a teacher.

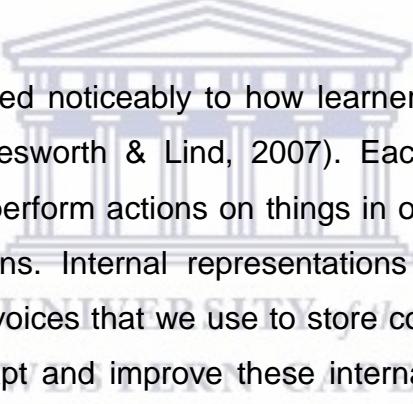
Competent teachers help learners to construct their own thoughts by drawing from their individual imagination and information from their specific cultural and socio-economic backgrounds. The manner in which a class is conducted, the social climate established within the classroom and the materials available for students to work all have a substantial impact on what is learnt and how

well it is understood (Van de Walle & Lovin, 2006). Due to context-based learning in Grade 11, the teacher's resources and effective planning for each day plays a vital role in constructing scientific knowledge.

Constructivism suggests that there should be communication between the teacher and the learners and among the learners themselves for classroom practice. A language-centred classroom is required. Language, through which meaning is communicated, negotiated and shared, is essential in the construction of scientific knowledge (Mc Dermott & Rakgokong 1996). This is why the researcher sometimes code-switch and communicates by asking leading and guiding questions for the greater part of the study.

2.3.1.2. COGNITIVE ESTABLISHMENT

(i) PIAGET



Jean Piaget contributed noticeably to how learners understand and induct their thoughts (Charlesworth & Lind, 2007). Each of us interacts in our environment. As we perform actions on things in our environment, we build internal representations. Internal representations are perceptual images, networks, paths and voices that we use to store concepts and relationships we discover. We adapt and improve these internal representations as we have new experiences in our environment, so that we accommodate new information received through new interactions. Each new representation that we construct is a modification of the one that came before it. To study how these perceptual representations establish, Piaget designed tasks to interview learners of different ages, and many of these tasks involved scientific concepts (Lichtenberg & Troutman, 2003).

Piaget acknowledged four stages of cognitive or mental growth and establishment. Early childhood teachers are concerned with the first two periods and the first half of the third (Charlesworth & Lind, 2007). Piaget acknowledged the first period starting from birth to about age two (called the sensorimotor period), and is labelled as the first part of the unit. By these time learners begin to learn about the world. They establish all their sensory

abilities: touch, taste, sight, hearing, smell and muscular. They increase their growing motor abilities so as to grasp, crawl, stand, and eventually, walk. In this first period, learners are explorers and need chances to employ their sensory and motor abilities to acquire fundamental skills and concepts.

Through these activities the learners assimilate, take into mind and understand a great deal of information. They learn to identify objects using the information they have acquired about features such as colour, shape, and size. As learners near the end of the sensorimotor period, they reach a stage where they can engage in realistic thought; that is, as a replacement of acting spontaneously, they learn to reason through a solution before arguing a problem. They enter into a time of rapid language establishment (Charlesworth & Lind, 2007).

The second period, called the preoperational period, extends from about age two to seven. During this period, learners begin to establish concepts that are more like those of adults but these are still developing relative to what they will be like in maturity. These concepts are often referred to as pre-concepts. During the early part of the preoperational period, language continues to grow quickly, and speech is used increasingly to express concept knowledge (Le Grange, 2014).

Learners begin to use concept terms such as big and small (size), light and heavy (weight), square and round (shape), late and early (time), long and short (length), and so on (i.e. comparing). For learners to understand Ohms law they need to compare variables used in Ohms law and those are electric current (I), resistance (R) and potential difference (V). This ability to use language is one of the symbolic behaviours that emerge during this period. Learners learn to use symbolic behaviour in their representational play, where they may use sand to represent food, a stick to represent a spoon, or another child to represent father, mother, or baby.

Play is a major arena in which learners establish an understanding of symbolic functions that underlie the later understanding of abstract symbols such as

numerals, letters and written word (Charlesworth & Lind, 2007). Practical work also challenges teachers in most cases. The execution of practical work in the classroom is a major challenge. One study conducted by Motlhabane & Dichaba (2013) explored how in-service teachers (adults) acting as learners modeling practical work in school laboratories. Empirical evidence from this, play where teacher played as children showed that teachers learn best from one another's lessons.

The results of the study show that teachers can acquire valuable skills through role-play (Motlhabane & Dichaba, 2013). These results concur with Charlesworth & Lind's (2007) results discussed in the paragraph above. Because role-play benefits both the learners between two and seven years of age according to Charlesworth & Lind (2007) and adults according to Motlhabane & Dichaba (2013), the researcher believes that it is still appropriate for people of all ages, and Grade 11 learners included, to enhance learning, hence used it. Structured play is used as the greatest vibrant device to construct information in science. Scientific vocabulary is imparted within the limits of the daily plan, through structured play concepts, as seen in this specific study.

According to Piaget's view, learners acquire knowledge by constructing it through their interactions with the environment. Learners do not wait to be instructed to do this; they continually try to make sense out of everything they encounter (Piaget, 1978). Piaget (1978) divides knowledge into three areas. Physical knowledge is the type that includes learning about objects in the environment and their characteristics: colour, weight, size, texture, and other features can be determined through observation and are physically within the object (Charlesworth & Lind, 2007). In this study, Grade 11 learners use exploration to discover new knowledge in learning Ohms law especially using computer simulations.

Logico-scientific knowledge is the type that includes relations each individual constructs: such as same and different, more and less, number, classification, and so on, to make sense out of the world and organize information

(Charlesworth & Lind, 2007). In this study, these concepts are integrated within the Grade 11 daily programme and formal teaching takes place to initiate learning these concepts. Social or conventional knowledge is the type that is created by people: such as rules for behaviour in various social situations.

Logico-scientific categories are constructed to organize information. For example, in this study the three physical quantities (electric current, potential difference/voltage and resistance) are interdependent and have varying sizes (same and different, more and less, number which is quantity/size and classification). Intellectual autonomy establishment is an atmosphere where learners feel safe in their relationship with grown-ups, where they have the chance to share their thoughts with other learners, and where they are stimulated to be vigilant and inquisitive, come up with interesting thoughts, problems and questions, use creativity in solving problems, have self-confidence in their aptitudes to figure out things for themselves, and speak their minds with confidence.

Learners need to be presented with problems to be solved through games and other activities (MRA) that challenge their minds. They must work with tangible materials and real problems (Charlesworth & Lind, 2007). In this study the researcher provided learners with concrete objects and used classroom situations to solve problems to ensure that what they learn is sustainable and that it is not learned by rote. Most of the scientific concepts for Grade 11 physics can be established through this active participation and this is rational and effective for scientific learning of all learners.

The general conception of learning by Piaget is still appropriate for today's classroom. The strength of his approach is centred on the child's thinking, or the progression, not just the answer, self-initiated, active involvement in a rich environment, and viewing the role of the teacher as a guide or resource person (Smith, 2001).

(ii) VYGOTSKY

Lev Vygotsky, a cognitive establishment theorist like Piaget, founded an opinion that recognizes both establishmental and environmental forces. Vygotsky (1979) thought that just as societies established devices like scalpels and tractors, they establish mental tools. People established techniques of cooperating and communicating new capacities to design and think in advance. These mental tools helped societies to master their own behaviour. Vygotsky referred to these mental tools as signs. He believed that speech was the most important sign system because it freed us from distractions and allowed us to work on problems in our minds.

Speech enables the child to interact socially and facilitates thinking. This is why in this study the researcher gives learners a chance to voice out their opinions. In Vygotsky's opinion, writing (communication) and numbering are important sign systems (Charlesworth & Lind, 2007). This is referred to as Natural and Cultural establishment. Natural establishment influences learning as the result of maturation. Cultural establishment results from the child's interaction with other members of a specific cultural environment and is improved by the use of language (Smith, 2001). Communication is the basis for learning in any classroom. People make use of questioning as a forum to transfer facts and establish thinking strategies.

Piaget looked at establishment as if it originated mostly from the child without help, from the child's inner maturation and spontaneous discoveries, while Vygotsky (1978) thought it was correct only up to the age of two. At that point, culture and the cultural signs were required to develop thought. He thought that the internal and external forces work together to create new information. Vygotsky placed greater emphasis than Piaget on the role of the adult or more mature peer as an influence on learners' mental establishment (Charlesworth & Lind, 2007).

In any classroom situation, learners come from different cultural backgrounds, therefore, it is important for a teacher to find common ground for learning to

take place. Learning to solve problems by operating from the known to the unknown enables learners the opportunity to share their experiences and so learn from one another, particularly if their experiences are not the same. The researcher in this study was actively involved in the learning environment by interacting with their thinking processes by asking continuous questions.

Vygotsky (1978) argued that people must be active to establish intellectually, but more than that, the culture or environment must also be active. He understood and assumed that the “tools” in the environment, which aid learners in conceptualizing, change the very nature and potential of their learning compared to what would have taken place without the tool. Vygotsky claimed that learners have a tendency to label everything at the age of 6. This is in accord with the child’s attainment of language, the tool that links them to the outside world. The child links the properties or functions of an object to a label. The label provides a means for storing and retrieving internal representations.

Once a label is attached to something, the child tends to resist to modifying its meaning (Lichtenberg & Troutman, 2003). This implication turns out to be a reality when learners start using scientific language; concepts are built by giving them labels within their active environment. Piaget stresses on learners as intellectual explorers constructing their own discoveries and constructing knowledge individually. Vygotsky established the concept of the zone of proximal development (ZPD). This suggests that the concept’s or relationship’s internal representation lies anywhere in the middle of being ready for establishment and being established to its fullest potential (Lichtenberg & Troutman, 2003). The area between where the child is operating independently in mental establishment to where s/he might go with support from an adult (a teacher in this case) or more mature child is called the ZPD.

Vakalisa & Gawe (2011) concurring with Bruner (1961) referred to scaffolding as the initial support given to learners to learn a skill or identify parts or categorise things. Slowly the teacher switches to a learner-centred approach

(usually questioning or discussion or debate) until learners can totally perform on their own without any support. Cultural knowledge is acquired with the assistance or scaffolding provided by an adult or more mature learners (Charlesworth & Lind, 2007).

A collaborative attainment of knowledge can be an effective method for learning to take place. In this study it is often seen that learners help each other in finding solutions to classroom activities. In this study, the researcher also provides with assistance (scaffolding) towards finding the relationships between resistance, current and potential difference. As learners learn, they guide their thinking by talking to themselves (private speech).

Adults use private speech when they mentally compose a list of what they want to accomplish during the day and talk themselves through it. In a cooperative learning group, learners hear other people's thoughts and assimilate their thoughts into their own private speech (Smith, 2001). As learners debate and discuss in most cases of this study, private speech also occurs.

A vital aspect in the learning process according to Vygotsky (1978) is a mediator (teacher, parent, knowledgeable peer). This mediator supports the child who is in the proximal zone, by working through problem situations with him or her to focus on relevant properties of a concept or relation and consequently makes it possible for the child to internalize concepts and relationships not only more quickly and more accurately, but beyond his or her self-sufficient competencies. With the mediator's help the child is facilitated to reach their potential beyond what they could achieve independently. The nature of the dialogue that takes place between the mediator and the child is a vital part of this mediation process.

Appropriate and effectively nuanced dialogue helps the child construct an inner voice that assists the child in considering, sorting and analysing problem situations, even when the mediator is not present (Lichtenberg & Troutman, 2003). An important question asked in this study is "How is A affected when

you change the quantity (increase or decrease) of B". The teacher uses this question to stimulate or prompt the thinking process and for learners to later construct their own inner voice of asking "what is the relationship". This can be a valuable tool for establishing number concepts (quantity/size).

Vygotsky (1978) believes that presenting material that is a little ahead of establishment is what good teaching encompasses. He agrees that learners might not fully understand it at first, but they understand it in time, with appropriate scaffolding (Charlesworth & Lind, 2007). A great deal of support or scaffolding is needed by learners in the early stages of learning in order to grasp a task is Vygotsky's argument. This assistance or set of prompts should be gradually reduced so the child can master the skill autonomously as time goes.

Teachers can encourage "talking aloud" about how a student finds the answer and can encourage listening skills while other learners explain their solutions (Smith, 2001). As mentioned before, the use of questions is a well-proven method in sciences and human nature because that is the technique learning takes place. For that reason, for learners to expand on their knowledge and exchange cultural background signifiers, listening skills must be improved. Instruction should not impose pressure on establishment. Instruction supports it as it moves ahead.

Concepts constructed independently and spontaneously by learners lay the foundation for the more scientific concepts that form part of the culture (Charlesworth & Lind, 2007). Teachers need to identify each student's ZPD and provide appropriate instruction. When learners react with zeal, inquisitiveness and vigorous involvement, teachers will know they have hit upon the right zone (Charlesworth & Lind, 2007). The programme is just as good as the teacher presenting it. The teacher needs to build the eagerness by offering a day-to-day programme that is exciting, organised, and most of all, well-planned. The researcher believes that he made a worthy effort to ease the process for learners to reach the zone because he was so actively involved in the learners learning environment.

2.3.1.3. THEORETICAL BACKGROUND OF THE CONSTRUCTIVIST ARGUMENT IN DIDACTICS.

Essentially, there are four very different theoretical contexts which represent the background for constructivist didactics. They are also being used by the heroes of this movement. These theoretical contexts are: radical constructivism, the neurobiology of cognition, systems theories, and current conceptions of learning developed in the field of cognitive psychology (Terhart, 2003).

On the other hand, it is possible and responsible to understand teaching, and the practice of teaching as something that makes stimulating environments available, which make things easier. Through these environments, independent learning can be facilitated, both in the form of acts of constructing and reconstructing knowledge and acts of gaining insight and understanding. Learning, in the real sense of the word, is never controlled in its course and result but always involves an individual in social contexts constructing and reconstructing inner-worlds.

This means the responsibility for learning lies with the learner. For this learning to be possible teacher must teach in a relaxed environment. Teaching must not be a transmission of a prepared package of knowledge divorced from concrete situations. To the extent that constructivist didactics limits itself to the claim that all learning starts from already existing knowledge (Terhart, 2003).

The teacher, therefore, has to recognise learners' pre-existing knowledge in order to facilitate construction processes in the direction of the acknowledged instructional goal of transmitting book and scientific knowledge. It is dismissed by more radical exponents of constructivism with some justifications 'trivial constructivism' (von Glaserfeld 1996). Nevertheless, constructivist didactics is clearly dominated by moderate positions whose influence grows in

proportion to the extent to which they pursue concrete research and practical projects, not just programmatic arguments.

2.3.2. PEDAGOGICAL CONTENT KNOWLEDGE (PCK)

Shulman (1987) first introduced the notion of PCK as a fundamental component of the knowledge base for teaching. The definition of pedagogical content knowledge (PCK) has evolved over the years as educational scholars reframed the original concept in various ways (Depaepe, Verschaffel & Kelchtermans, 2013). Depaepe et al., (2013) argue for an integrated approach to PCK where curriculum knowledge as well as subject matter knowledge is regarded as forming part of PCK.

2.3.2.1. CONCEPTIONS OF PCK

PCK, according to Shulman (1987), is what makes possible the transformation of disciplinary content into forms that are accessible and attainable by students. This includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction. It distinguishes the teacher from the content specialist. Shulman's model has been elaborated upon and extended by other scholars (Grossman, 1990; Magnusson, Krajcik, & Borko, 1999).

Although there is no universally accepted conceptualization of PCK, there is agreement with two key elements of Shulman's model-knowledge of representations of subject matter and understanding of specific learning difficulties and student conceptions (Shulman, 1987). Firstly, PCK refers to particular topics, therefore is distinct from general knowledge of pedagogy, educational purposes, or learner characteristics; secondly, it differs from subject matter knowledge (SMK); and thirdly, PCK is developed through an integrative process rooted in teachers' classroom practice, implying that beginning or novice teachers will have relatively undeveloped PCK.

Shulman (1986) described the concept of pedagogical content knowledge (PCK) as a distinct body of knowledge that distinguishes teachers from content specialists. The emphasis was on combining the content knowledge and how the content knowledge is presented to learners. Although there may be various definitions of PCK, at the centre of those is the idea that the transformation of subject matter knowledge for the purposes of teaching is emphasised. This combines what teachers know about subject matter and how they transform that knowledge into curricular events. Marks (1990) broadened Shulman's (1987) concept by including knowledge of subject matter per se and as well as knowledge of media for instruction. Grossman (1990) also expanded the concept by defining four central components of PCK

The four central components of PCK:

- (a) knowledge and beliefs about the purposes for teaching a subject,
- (b) knowledge of learners' understanding, conceptions, and misconceptions of particular topics in a subject matter,
- (c) knowledge of curriculum and curriculum materials, and
- (d) knowledge of instructional strategies and representations for teaching particular topics.

Park and Oliver (2008) pointed out the "knowledge of assessment of student understanding as one of the most important component of PCK." As different as ideas from the scholars are, the central themes of PCK are (a) knowledge of instructional strategies incorporating representations of subject matter and understanding of specific learning difficulties and (b) student conceptions with respect to that subject matter.

Other lines of research on teaching have emphasized a critical role of PCK in teachers' planning and actions when dealing with subject matter in classrooms (Loughran, Berry, & Mulhall, 2012), shapes teachers' learning of new instructional approaches and strategies (Putnam & Borko, 1996), and

influences student learning. This means PCK should be central to science education and science teachers should possess PCK to facilitate learners' learning.

2.3.2.2. PEDAGOGICAL CONTENT KNOWLEDGE AND EFFECTIVE SCIENCE TEACHING

Appleton (2003) claims that mastering the content or theory of Physical Sciences while lacking skills to convey that theory to learners is a problem. He stressed that Physical Sciences teachers are expected to apply their pedagogical content knowledge gained through their qualification and CPD as means of narrowing the gap between theory and practise,

The National Education Policy act 27 of 1996 requires the South African teachers not to be subject specialist only but to be aware of different teaching and learning approaches (South Africa, 2000).

Teachers of various subjects should change learners' engagement in their respective subjects from rote learning and memorisation of facts to meaningful analysis, application, synthesis and evaluation through constructivist teaching practises in order to achieve best result (Yilmaz, 2008). He further states that in constructivism, the classroom becomes a micro-society where learners become jointly engaged in activities, discourses and reflection. In addition to mastering the subject knowledge teachers are expected to be skilled on how to help learners gain that subject matter. Brook and Brook (1997) differentiate constructivist classroom from traditional classroom using a table where this micro-societal character of constructivist is shown.

Table 7. The difference between the constructivist classroom and traditional classroom.

CONSTRUCTIVIST CLASSROOM	TRADITIONAL CLASSROOM
1. Learners primarily work in groups.	Learners primarily work individually.
1. Assessment of learning is interwoven with teaching and occurs through observations of learners at work and through learner portfolio.	Assessment of learning is viewed as separate from teaching and occurs mostly through testing.
2. Teachers seek the learners' ideas in order to understand learners' present conceptions for use in subsequent lessons.	Teachers seek correct answer to validate learning.
3. Teachers behave in an interactive manner mediating the environment for learners.	Teachers behave didactically, disseminating information to learners.
4. Learners are viewed as thinkers with emerging theories about the world.	Learners are viewed as blank slates onto which the teacher stamps the information.
5. Heavy reliance on primary sources of data and manipulative materials,	Heavy reliance on textbooks and workbooks.
6. Pursuit of questioning by students is highly valued.	Strict adherence to fixed curriculum is highly valued.
7. Curriculum is presented whole to part, emphasising big concepts.	Curriculum is presented part to whole, emphasising basic skills.

From Brook and Brook (1997).

2.3.2.3. DEVELOPING TEACHERS' PCK

Teachers' craft knowledge is the key in the teaching of sciences. The essence of craft knowledge pertains to a "teaching sensibility" rather than to "a knowledge of propositions." Van Driel, Veal, and Janssen (2001) perceive craft knowledge as integrated knowledge which represents teachers' accumulated wisdom with respect to their teaching practice. Shulman

introduced PCK as a specific category of knowledge “which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching” (Shulman, 1986). The key elements in Shulman’s conception of PCK are knowledge of representations of subject matter on the one hand and understanding of specific learning difficulties and student conceptions on the other. These two elements are intertwined therefore the more representations teachers have at their disposal and the better they recognize learning difficulties, the more effectively they can deploy their PCK.

Later on Shulman included PCK in what he called “the knowledge base for teaching.” This knowledge base consists of seven categories, three of which are content related (i.e. content knowledge, PCK, and curriculum knowledge). The other four categories refer to general pedagogy, learners and their characteristics, educational contexts, and educational purposes (Shulman, 1987). Shulman’s knowledge base encompasses every category of knowledge which may be relevant for teaching while van Driel, Jong, and Verloop, (2002) define craft knowledge as restricted to types of knowledge which actually guide the teachers’ behaviour during classroom practice.

Within the definition of craft knowledge, he considers PCK to be a specific form of this craft knowledge. He asserted that PCK implies a transformation of subject matter knowledge, so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice. Thus, teachers may derive PCK from their own teaching practice (e.g. analysing specific learning difficulties) as well as from schooling activities (e.g. an in-service course on student conceptions).

Teachers should promote conceptual change by discussing the unusual results of certain phenomenon with learners. They should challenge students’ conceptions about a concept by urging learners to explain a phenomenon and give reasons why a phenomenon does not behave as expected in (for example) an experiment. This helps teachers to understand conceptions and misconceptions that learners have about a concept.

Because pedagogical content knowledge (PCK) includes teachers' understanding of how students learn, or fail to learn specific subject matter, the development of PCK is an important goal to focus on in professional development programs. The research literature clearly indicates the complex nature of PCK as a form of teachers' professional knowledge that is highly topic, person, and situation specific.

This implies that professional development programs aimed at the development of teachers' PCK cannot be limited to supplying teachers with input, such as examples of expert teaching of subject matter. Instead, such programs should be closely aligned to teachers' professional practice and, in addition to providing teachers with specific input, should include opportunities to endorse certain instructional strategies and to reflect individually and collectively, on their experiences.

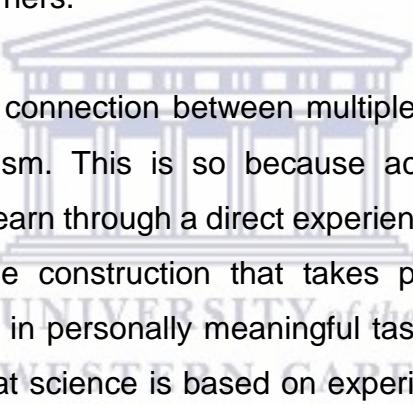
2.4. RESEARCH ON MULTIPLE REPRESENTATION

Constructivists claim that individuals learn through a direct experience of the world, through a process of knowledge construction that takes place when learners are intellectually engaged in personally meaningful tasks (Conceicao-Runlee & Daley, 1998). Chittaro and Serra (2004) claimed that constructivism is the fundamental theory that motivates educational uses of Virtual environments (a form of Multiple Representations Approach) as follows: "our type of experience is a first person one, that is a direct, non-reflective and possibly, even unconscious type of experience".

On the contrary, third-person experiences, that result from the interaction through an intermediate interface. In many cases, interaction in Virtual Environments (VEs) computer generated environment in this case can be a valuable substitute for a real experience, providing a first-person experience and allowing for a spontaneous knowledge acquisition that requires less cognitive effort than traditional educational practices. Winn (1993) also claimed virtual environments can provide three kinds of knowledge-building

experience that are not available in the real world; they are concepts of size, transduction and reification, which have invaluable potential for education.

Teachers use different approaches when teaching. They always think that those methods or approaches are best for learners but the reality is that learners are different and they perceive information differently. When teachers use multiple representations they expose their learners to different representations. Some learners are more comfortable with visual representations than words and equations. 3D graphs, simulations, equations, words and pictures form part of multiple representations. This enables learners to associate well with multiple representations. From Ohms law representations to deeper understanding multiple representations are able to cover all. This is because multiple representations cover different cognitive levels of learners.



There is a very clear connection between multiple representations and the theory of constructivism. This is so because according to constructivist theorists, individuals learn through a direct experience of the world, through a process of knowledge construction that takes place when learners are intellectually engaged in personally meaningful tasks. Recently the national television exposed that science is based on experiment hence it should not be taught through TCM rather through MRA (Maseko, 2017).

2.4.1. WHAT IS MEANT BY MULTIPLE REPRESENTATIONS?

Multiple Representations which includes videos, concrete objects and virtual manipulatives among others are ways to symbolise, describe and to refer to the same science entity. Representations can be categorised into two classes, namely internal and external representations. Internal representations are defined as “individual cognitive configurations inferred from human behaviour describing some aspects for the process of physics and problem solving”.

On the other hand, external representations can be described as structured physical situation that can be seen as embodying physical ideas (Van Heuvelen & Zou, 2001). According to a constructivist view, internal representations are inside the students' minds, and external representations are situated in the students' environments (Nguyen & Meltzer, 2003). Examples of external representations in physics include words, diagrams, equations, graphs, electrical circuit diagrams, ray diagrams and sketches. Hence, the positive role of multiple representations in student learning has been suggested by many educators.

External representations help learners understand complex concepts. Typical interactive environments as shown below offer learners many different ways to visualize scientific phenomena including video, animations, simulations and dynamic graphs. Simulation provides a graphical representation of simulated molecules as well as dynamic graphs describing their behaviour and simple numerical displays of system variables (Van Labeke & Ainsworth, 2006).

Each of these can be designed for different, equally important educational reasons. They can help learners come to understand the complex forms of visualisations required for professional and expert practice. They can be designed to give learners indirect experience of phenomena that is difficult to experience directly in educational settings (such as the video of experiments moving electrons). They can provide visualisations of phenomena that are impossible to see in the real world yet whose experience will provide understanding that is difficult to achieve without such representation (e.g. molecular simulations in chemistry). However, all have one thing in common – they don't just provide a single visualisation: instead they provide multiple representations simultaneously.

2.4.2. ADVANTAGES OF MULTIPLE REPRESENTATIONS AND WAYS OF LEARNING SCIENTIFIC CONCEPTS WITH MULTIPLE REPRESENTATIONS

Multiple representations of scientific concepts are provided for good educational reasons. The functions of multiple representations fall into three broad classes. Firstly, multiple representations can support learning by allowing for complementary information or complementary processes. The simplest illustration of complementary information in our Force and Motion example would be displaying values for mass, force, friction and velocity.

Each representation, be it a graph, an equation, a numerical display, is representing different aspects of a simulated body. The choice of which representations to use is therefore likely to depend on the properties of the represented information. For example, mass might be represented as a simple numerical display as it does not change as the simulation runs, whereas velocity might be represented in a dynamic graph or a table because these representations are time-persistent (Ainsworth & Van Labeke, 2004) and so show how velocity has changed over time.

If all this information had to be included in a single representation, then this would either mean that it was represented in ways that were inappropriate to its form (e.g. mass on a time-series graph), at the wrong scale or in the simplest possible way (for example, numerical displays or tables of all the values). So, multiple representations in this case allow different information to be represented in ways that are most appropriate to the learners' needs.

Cognitive flexibility theory highlights the ability to construct and switch between multiple perspectives of a domain as fundamental to successful learning (Spiro & Jehng, 1990). Dienes (1973) argues that perceptual variability (the same concepts represented in varying ways) provides learners with the opportunity to build abstractions about mathematical concepts. It also

can be the case that insight achieved in this way increases the likelihood that it will be transferred to new situations (Branford & Schwartz, 1998).

2.4.3. LEARNING COMPLEX SCIENTIFIC CONCEPTS

One learner from Uitenhage in the Eastern Cape claimed that MRA shows how nature works (Maseko, 2017).

The learning of complex scientific topics is generally, even habitually, supported by the use of multiple representations. It has been argued that there are many roles that different combinations of representations can play in supporting learning. However, it has been suggested that the benefits of multiple representations do not come for free. Learners are faced with a number of complex tasks and as the number of representations increases, so do these costs. Learners learn by doing, reading, reflecting and sharing ideas and this kind of learning links theory and practise (Ndokwana, 2014). 100% of learners who were interviewed by Ndokwana in his study indicated that practical work plays an important role in their learning process.

A number of possible frameworks exist and some researchers suggest design principles (Mayer, 2001). However, that for many of the complex representational systems used to support science learning we may not yet be at the point of producing definitive principles, instead there are a number of heuristics that could be used to guide a design. The first heuristic is to use only the minimum number of representations that you can use (Ainsworth & van Labeke, 2004). This minimises complexity in using the representations to learn scientific concepts.

Secondly, carefully assess the skills and experience of the intended learners. For example, do they need support of constraining representations to stop misinterpretation of unfamiliar representations or would this extra representation not provide any new insight without a great deal of work by the learner. Thirdly, consider how to sequence representations in such a way to maximise their benefits. Allow learners to gain knowledge and confidence with fewer representations before introducing more.

A fourth heuristics is to consider what extra support you need to help learners overcome all the cognitive tasks associated with learning with multiple representations. That is to identify if learners need additional help in relating the representation to the domain and whether the system has been designed to help learner see the relation between representations. For example, are consistent labels, colours and symbols used and representations that are related placed close to one another?

Finally, consider what pedagogical functions the multi-representational system is designed to support. If the primary goal is to support complementary functions, then it may be sufficient that learners understand each representation without understanding the relation between them.

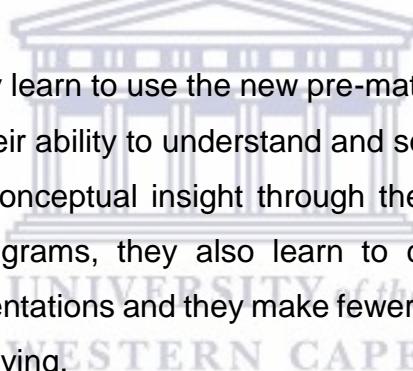
The task for the learner is to identify when to select particular representations for particular tasks. Learning may be hindered if they spend considerable time and effort in relating representations unnecessarily and so designers may consider ways to either discourage learners from doing this. If the goal is to constrain interpretation, it is imperative that the learner understands the constraining representation. Consequently, designers must find ways of signalling the mapping between representations without over-burdening learners by making this task too complex.

If the goal is for learners to construct a deeper understanding of a domain, if they fail to relate representations, then processes like abstraction cannot occur (Ainsworth & van Labeke 2004). Although learners find it difficult to relate different forms of representations, if the representations are too similar, then abstraction is also unlikely to occur. Consequently, it is difficult to recommend a solution to this dilemma. But if you need learners to abstract over multiple representations then you should provide considerable support for them to do so, by providing focussed help and support on how to relate representations and giving learners sufficient time to master this process.

Metoui and Trudel (2012) claim that Multiple Representations Approach are powerful tools to help learners develop complex scientific knowledge. But as

all powerful tools require carefully handling and often considerable experience before people can use them to their maximum benefit. Beginners using powerful tools may not achieve the same results as experts and so we should consider how these tools can be designed to allow learners to develop their expertise. We acknowledge that mostly, beginners do not learn without support from others, either peers or teachers.

Only a carefully planned, properly structured, research-based teaching intervention specifically designed to address these particular shortcomings and attitudes has proved capable of effecting significant change in such unpromising conditions. Equipping students with multi-representational skills appears to allow them to step back from the required mathematics long enough to see “the bigger picture”, that is, the true nature of the problem, the underlying principles and concepts, and possible ways of solving it.



As students gradually learn to use the new pre-mathematical strategies, they gain confidence in their ability to understand and solve physics problems. As they develop more conceptual insight through the use of alternative tools, such as physics diagrams, they also learn to choose more appropriate mathematical representations and they make fewer mistakes in the numerical stages of problem solving.

2.4.4. COMPUTER 3D GRAPHICS AND SIMULATIONS AS REPRESENTATIONS

The use of computer-based simulations has been recognized as a powerful tool to stimulate students to engage in the learning activities and to construct meaningful knowledge. Dynamic computer based models or animations can help students visualise the science concept (Chang, Quintana & Krajcik 2010). Some of the Science teacher concurred with this statement when they were interviewed but emphasising that they emphasised that animations allow the kids at least to visualise some of the conceptual things that they talk about (Waight & Gillmeister 2013).

Whiteside (1986) stated that computer simulation-based instruction is useful to reach the analysis, synthesis, and evaluation in hierarchical levels in Bloom's taxonomy. Meyer & van Niekerk (2008) define simulation as the fake of a real-life situation which is usually in simplified form. Learners are placed in a spot where they can understand aspects of real life by participating in activities that are closely related to it. While not substituting direct involvement with the situation, simulations organizes learners for practice by providing them with the opportunities to develop while testing their cognitive and psychomotor skills in a reasonably risk-free setting, in which the consequences of any mistake are less costly than in the real setting. The simulation used in this study therefore provided an opportunity to learners to work in a reasonably risk-free setting as there could be no explosion of light bulbs. It is also less costly than the real setting as there are no costs of buying electric equipment for these practical instead learners construct electric circuits using computer simulations.

Vakalisa & Gawe (2011) argue that teachers and learners increasingly use information and communication technology (ICT) in teaching and learning. They further claim that ICT can supplement teaching and learning. It is for this reason that the researcher decided to use computer simulations as it really simplify abstract knowledge about electricity and shows how electrons move through the conductor thereby faking abstract and invisible information into concrete and visible one to enrich learning.

In a study conducted by Metiouii & Trudel (2012) students work with circuits drawn on the screen of the computer and with simulated instruments that act like actual laboratory instruments. Their findings indicated that simulations assisted learners to learn and understand circuit analysis concepts as electronic workbench software acted like actual laboratory experiments on a computer. Circuits can be modified easily with on-screen editing, as a result of analysis provides fast and accurate feedback. This 'hands-on' approach experiment is more cost effective and safer. It is also more detailed and

efficient than experiments from real equipment as its errors are far less than human errors.

They also asserted that 3D computer graphics and simulations are vital for robust understanding of science. More importantly these researchers documented that exposure to macroscopic, sub microscopic and symbolic representations which are computer based studies that contained visualised models like animations resulted in the experimental group outperforming the comparison group.

2.4.5. USING MULTIPLE REPRESENTATIONS TO SUPPORT THE CONSTRUCTION OF DEEPER UNDERSTANDING

To learn science language, and to solve science problems successfully, students must become competent in multiple representations. This means that when solving a problem, students must be able to interpret and construct different representations, identify their similarities and distinctions, and move between these representations. Some of the recent studies indicated that MRA supports learners to construct deeper understanding of science concepts be it concrete or abstract. Majority (70%) of learners attained 50% and above after being taught through MRA compared to 70% of them who attained less than 30% before taught through MRA (Tabane, 2014).

In his study, he recommended that all topics be taught in MRA making use of all available resources. Quality of grade 12 pass means getting a pass level that would allow one to be admitted to a bachelor's degree in a university. Universities need a minimum of 50% pass for someone to do a bachelor's degree. Teaching strategies that improve the quality of Physical Sciences results include the following:

- a) Involving learners through practical work and
- b) group discussions (Ntlanganiso, 2014).

Learners who were taught using MRA claim that it assisted them to easily adjust in science careers in HEI (Uitenhage Science Centre, 2017). Findings

indicated that learners' interest is aroused by hands-on activities where interact (Ntaka 2014). Maseko (2017) reported that MRA makes learners enjoy science as they become fascinated by how things work.

2.4.6. MULTIPLE REPRESENTATIONS IN GEOMETRY AS A WAY OF REPRESENTING ELECTRIC CIRCUITS (OHMS LAW)

Geometry is one of fundamental methods which people use to understand and to explain the physical environment by measuring length, surface area and volume. Geometric skill is the key in the representation and understanding of electric circuits. Enhancing geometric thinking is very important for high level mathematical thinking, and it should be developed with spatial interaction and manipulation in daily life (Clements & Battista, 1992; Tan, 1994). However, in traditional classrooms, geometry learning is usually conducted only through the description of text, 2D graphs and mathematical formulas on whiteboards or paper.

In some important topics, such as measuring the area and volume of 2D or 3D objects, traditional teaching methods often focus too heavily on the application of mathematical formulas, and lack opportunities for students to manipulate the objects under study. Consequently, many students can memorize the formulas and even appear to succeed in their course work without fully understanding the physical meaning of the math formulas or geometry concepts (Tan, 1994).

2.4.7. IMPLICATIONS OF MULTIPLE REPRESENTATIONS FOR PHYSICAL SCIENCES TEACHING

Swain et al. (1999), noted that the aim should be to teach learners to use Multiple Representations in a particular scientific context using variety of representations at the same time, rather than to use only one representation for all situations. In science classrooms, teachers are responsible for

designing constructivist situations and concrete connections for learners so that scaffolding of knowledge can be achieved. Multiple representations-based instructions meet this need in the science classroom.

Effective science instruction needs more than lecturing or any single representation method of instruction. Effective teaching therefore does not simply teach students what is correct, it also ensures that students do not believe what is incorrect (Staver, 1996). It requires active involvement of the students in the learning process. Laughbaum (2003) claims that teachers should spend some time of the physics lesson on the relationships between manipulative and abstract symbols and emphasize applications of multiple representations. Teachers should also encourage students to think about connections between multiple representations.

In traditional science classroom, there is a need to encourage students to think more deeply on science concepts to intrinsically motivate them for learning, to make students appreciate the nature of science by getting rid of rote memorization, and to avoid overemphasizing rules and algorithms. In fact, new instructional methodologies like multiple representations-based instructions might address this need.

2.5. SUMMARY

Based on implications in the literature, the methodology of teaching is an important factor that influences understanding of science. In the present study, the concern is learners' ways of discovering and formulating science including how teachers can facilitate the process as to improve learners' understanding of electricity in grade 11 curriculum.

There are various instructional strategies such as demonstration, computer assisted instruction, cooperative teaching, concept mapping etc. used to teach Physical Sciences effectively to learners. The most challenging aspect

of the Physical Sciences classroom is to help teachers and developing teachers to see science as an evolving framework of concepts (spider's web of concepts) and to understand that there is a relationship between concepts (Novak, 2010). The next chapter is dealing with the study's methodology.



CHAPTER 3

METHODOLOGY

3.1. INTRODUCTION

The previous chapter looked at the theoretical framework that guides this research. In this chapter, the research methodology is described and justification for the research design from literature together with the theoretical orientation framed it. To locate the methodology for my research question, Ritchie and Lewis (2003) retains that the use of methodology is heavily swayed by the intentions of the research and the exact questions that need to be answered and therefore these were kept at the forefront.

This study was focused on the main research question, namely,
How can a Multiple Representations Approach be used to teach Ohm's law
in Grade 11 Physical Sciences?

The sub-questions being the following:

- (i) What was learners' initial understanding of electricity?
- (ii) How were the lessons on Ohms law taught using (a) the Multiple Representations Approach and (b) the Traditional Method?
- (iii) What were learners' understanding of Ohms law after the multiple representation approach?
- (iv) What were learners' perceptions of the multiple representation lessons?

3.2. RESEARCH SETTING

Research setting can be defined as the environment within which a study is conducted (Angaama 2012). Creswell (2009) and Denzin & Lincoln (2005) argued that convenient selection of the schools within the framework of the criteria set out that the study should be in line with the naturalistic nature of the study. Naturalistic nature of the study reveals a deeper understanding of individuals and small groups which are studied in their own naturalistic settings of a particular situation in its naturalistic setting including the

language and every day way of life of individuals in that situation (Basit, 2010). The researcher is teaching in a primary school and has conducted this study in another school as his topic Ohms law is for grade 11. This is a previously disadvantaged in an education district in the Eastern Cape, South Africa. It is a medium size school high school starting from grade 8 to grade 12 with an enrolment of about 600 learners. Classrooms are overcrowded although this school is medium in size. Appendix S (i) indicates that more than two learners usually share one desk in this school. It was not the case during this study as two groups were formed and were taught separately and (ii) this school has 17 teachers including the principal and the deputy principal. The researcher decided to use this school to minimise travelling costs.

As a teacher from another school, the researcher had to conduct his study on Saturdays as promised on the ethics that, the study will not interfere with the school teaching hours. On the first Saturday learners complained that they are hungry hence the researcher had an obligation of bringing some nutrition every Saturday. This, again, was to maintain the natural setting because these learners are fed by the school every school day through government's school nutrition programme.

The researcher's intention was to use school's laboratories for two activities which are practical experiment and Phet which is a computer programme for science animations as some of the multiple representation strategies in his study. Unfortunately, the school had no computer laboratory at all, but only few computers which were used for administration purposes. The school had no science laboratory either. The little science equipment of the school was kept on lockable cupboards in a safe lockable classroom.

The school does have the electricity equipment but is not in good condition as the bulbs are no longer working and both the available ammeters and voltmeters are in bad condition to such an extent that they were not working too. Knowing the advantages of computer animations, the researcher decided to cancel the practical activity as he could not afford to buy electricity equipment. He successfully managed to do the activity of Phet programme

on computer animations using five laptops. Although there was no school computer laboratory, learners could switch on and use computers. The researcher then introduced learners to electricity on the Phet animations. He continued to show them how to construct an electric circuit on this programme and manipulate it as they were instructed.

Having the knowledge that constructivism greatly emphasise the role played by prior knowledge (which includes language) for abstract concepts to be well understood (Duchy, Schweingruber & Shouse, 2007; Lincoln & Guba, 1985), the researcher therefore started by investigating the language of learning and teaching (LoLT) used in that school. English was used as a language of teaching and IsiXhosa was used to explain here and there as the lesson proceeds in this study as that was discovered to be the norm of that school. IsiXhosa was used as it is the home language for the majority of the learners in this class and the few whose home language is Sesotho also understand and speak IsiXhosa fluently. The researcher was quite aware of the disadvantages of using code switching as Diwu (2010) discovered that learners who are taught using code switching and allowed to code switch during the lesson tends to use code switching even when they answer questions, but what is interesting in his results is that such learners get higher marks than those who have not used code switching especially when they are required to show an understanding of the relationship between terms.

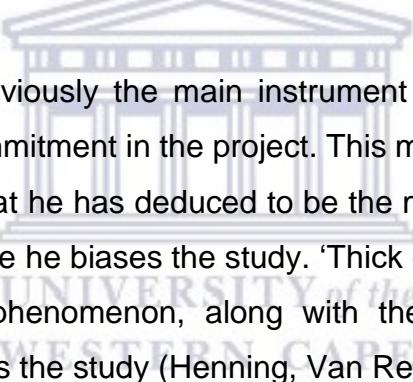
The research instruments of this study were piloted before the actual study was implemented. The piloting of this study is explained in section 3.5.

3.3. RESEARCH DESIGN, TECHNIQUES AND APPROACHES USED IN THIS STUDY

Research design refers to the outline, plan, or strategy that will be used to seek an answer(s) to the research question(s). Planning a research design means that the researcher must specify how the participants are to be assigned to their comparison groups, how the researcher is going to control for possible variables, and how data will be collected and analysed (Johnson

& Christensen, 2012). The research design is the researcher's overall design strategy of how one would generate valid data to answer the research questions.

The focus of my research understanding the teaching of Ohm's law in grade 11 using multiple representations approach. This study requires data sources such as focus group interviews, observations, testing and analysis of test scores. Although these result in a wealth of rich information, extensive time and resources may be mandatory to satisfactorily signify the area being studied (Hancock & Algozzine, 2006). The aim is to realize the situation under investigation predominantly from the participants' and not the researchers' viewpoint. Since the researcher is the principal tool for data collection and analysis in this research, significant amounts of time were spent in the setting of those being studied (Hancock & Algozzine, 2006).



The researcher is obviously the main instrument of research and makes meaning from his commitment in the project. This means that he will present the discoveries or what he has deduced to be the meaning of the data. This does not mean that he biases the study. 'Thick description' is what gives a validation of the phenomenon, along with the basis of a theoretical framework that locates the study (Henning, Van Rensburg, & Smit (2004). The researcher has decided to use a case study. It is unlike other types of studies in that it has thorough descriptions of a particular unit or system restricted by space and time. Among other things which are often studied in case studies are individuals, actions and groups.

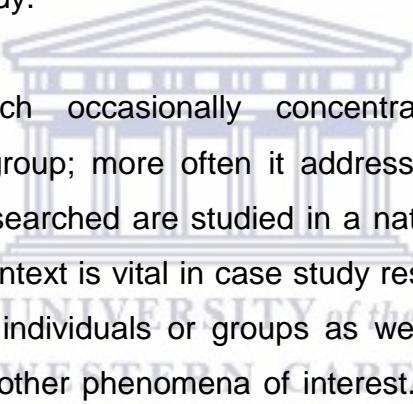
Researchers hope to gain in-depth understanding of situations and meaning of those involved through case studies. Freebody (2003) recommends that insights gathered from case studies can directly influence processes policy, and future research. Although case studies are broadly deliberated in the literature and engaged regularly in practice, little has been written regarding the precise steps one may use to magnificently design, conduct, and

disseminate the findings of a case study project (Hancock & Algozzine, 2006).

The case study approach

(i) The nature of case studies

A case study is a particular instance of a confined structure, for example, a group, a public, a class or a school. It offers a special example of real people in real situations, allowing person who reads to understand concepts more clearly than merely by presenting them with philosophies or ideologies. Definitely, a case study can allow readers to understand how ideas and intangible principles can fit together. It can gain access to situations in ways that are not always predisposed to numerical analysis. (Cohen et al, 2000). Hancock & Algozzine (2006) mentions numerous significant characteristics that define a case study.



Case study research occasionally concentrates on an individual representative of a group; more often it addresses a phenomenon: The phenomena being researched are studied in a natural setting, confined by space and period. Context is vital in case study research and its profits are in-depth research of individuals or groups as well as events, conditions, plans, activities, and other phenomena of interest. Case study research is also abundantly descriptive, since it is grounded in deep and various bases of evidence. Doing case study research means pinpointing an area that can be analysed deeply in its natural context using numerous sources of data (Henning et al, 2004). The process is more important than the results in a case study (Henning et al., 2004). The meaning is that when conducting a case study one needs to stick to the correct procedures of the case study because it is procedural in nature.

(ii) Strengths and weaknesses of the case study approach

Bassey (2004) offer a compilation of ten articles written in the last half of the twentieth century on different aspects of case study. The editors recognise that the term "case study" is ill defined. A case study is a deep investigation of one or a few cases in naturally occurring social situations rather than an

experiment or a survey (Bassey, 2004). It has a problem of generalizability, narrative analysis and issues of authenticity and authority. The characteristics of good educational research in terms of a case study according to Bassey (2004) are trustworthiness, validity and reliability. The method of investigation and its report must be ethical, mainly in terms of respect for persons. The outcomes of the research must be significant to someone (policy maker, parent, learner, teacher, manager, etc.), in that way advising that person's work and facilitating to improve it.

(iii) Application of the case study approach in this research.

The case study approach was employed in this research to explore the teaching of Ohm's law in grade 11 using multiple representations approach. The research question is concerned about the technique of teaching Ohm's law in grade 11. The researcher identified the topic due to the needs of the students in his school and nationally to improve mark attainment in Physical Sciences especially in Ohm's law. The focus of the researcher is in one grade, one school of the Eastern Cape district. Two lessons were taught in MRA and the other in TCM recorded for analysis purposes.

This case study took a form of a quasi-experimental research design. Trundle & Bell (2010) define quasi-experimental design as a research design that looks like the true experimental design because one group is used as the experimental group and the other as a control. The difference is that stratified random sampling is used to assign them to their groups instead of random sampling as it happened in this study. Johnson and Christensen (2012) define stratified random sampling as a procedure of dividing a population into mutually exclusive groups called strata and then a simple random sample or a systematic sample is selected from each stratum.

3.4. THE RESEARCH SAMPLE

Cohen, Manion and Morrison (2007) have suggested that in purposive sampling, researchers handpick the participants to be included in the sample

based on their judgment that the participants possess the necessary characteristics applicable to the study. The study was conducted in a high school which is close to the researcher's home hence convenient and purposive sampling was used in choosing the school.

Researchers often choose to undertake studies in smaller settings or representative samples because certain factors such as cost, time, accessibility, for example, make it impossible for the research to involve the whole of the target population. According to Polit and Beck (2008) sampling is the process used by the researchers to select a portion of the population that will represent the entire population. The sample size required is determined by the purpose of the study, the nature and size of the population and the type of research.

The total number of Physical Science grade 11 learners in this school is 63. Out of the 63 learners, only 48 of them volunteered to participate in the research. As the researcher wanted each group to have high performing, mediocre and the lowest achievers, the class was divided into two groups to form the experimental group and the control group. To form these two groups, learners were categorised according to their achievement in a pre-test. Categories were: best achievers with higher marks of more than 50%, mediocre composed by those who scored 50% exactly and the lowest achievers formed by learners who scored below 50%.

Each of these three categories (best achievers, mediocre and lowest achievers) was then divided into two halves where about 50% of each category randomly formed experimental group and the other portion randomly form control group. Both the experimental and the control groups had 24 learners respectively. (refer to table 8). They were divided into mutually exclusive groups called strata and then a systematic sample was selected from each group to form a stratified random sampling as described by (Johnson & Christensen 2012). This also gave each learner equal chances to be in any group, either a control or experimental group. Secondly this ensured that both groups have all categories of learners.

Table 8. Table of sampling technique.

PARTICIPANTS	SAMPLE SIZE	TECHNIQUE
Physical Sciences grade 11 learners	48	Whole sample
Participants per group	24 per group	Stratified random sampling

3.5. PILOT STUDY

This is a small-scale study which is conducted prior to the actual study using a limited number of participants who will not take part in the study but meet the inclusion criteria or have the same characteristics as the sample that will be used in the study (Brink, van de Walt & van Rensburg, 2012). Because of this, the researcher has piloted the research instruments using a school that has the same characteristics as the school on which the research was conducted.

These two schools are:

- Within the same geographic area,
- Both previously disadvantaged schools hence same economic background,
- Of equivalent pass rates in official examinations and lastly the researcher
- Have used the same grade 11 as in the study.

Piloting is advantageous in that it provides valuable information to the researcher as to what to expect in the real study. It also assists to uncover certain mistakes and errors in instruments or methods so that necessary steps could be engaged to correct them before conducting the main study.

More importantly piloting also tests the practical aspects of the research study (Brink et. al., 2012). From piloting the researcher learnt that allocated teaching time for multiple representations was not enough hence he extended it to

three sessions each taking about two to three hours. He also learnt that more explanation on most items in the interview schedule was needed as they seem to be vague to the majority of learners, hence he was forced to restructure those items to make them more clear and unambiguous. In some cases, the researcher decided to change the vocabulary as it was noticed to be beyond the participants' level of education.

3.6. RESEARCH INSTRUMENTS

3.6.1 PRE AND POST TESTS

It is vital to detect students' conceptions in advance and after instruction as to improve instruction and students' scientific understanding. To develop a long term plan of instruction, it is essential for teachers to know what conceptual areas students find most challenging (Plummer & Krajcik 2010). For those reasons and also to discover what learners know about electricity, and specifically Ohms law before and after they were taught through multiple representations (MRA) and talk and chalk method (TCM), the researcher formulated a pre and post-test. Another aim of the pre-test was to merit grouping of learners for the purpose of forming the experimental and control group through a stratified random sampling.

The pre-test was set such that it revived what learners learnt in grade 10 electricity topic hence preparing learners for what should be learnt in grade 11. This was in line with Witzig, Rebello, Siegel, Freyermuth, Izci, and Mc Clure, (2014) who indicated that assessment should support learning while at the same time offering support to facilitate students to respond to a question that might be initially beyond their reach. By incorporating scaffolds into assessment, this enables them to think about the concepts promptly.

Both of these tests were composed of the following types of questions: recall type, questions which require: conceptual understanding, application, both

understanding and application. The pre-test was composed of ten multiple choice questions and they were all based on grade 10 work as this topic electricity is also covered in grade 10 curriculum.

Post-test questions were based on what was taught to both groups and the language used was equivalent to their standard. Researchers stress that an assessment should match the instructional style and language used within that specific course for an assessment to be on an accepted standard (Witzig, et al., 2014). The test had four questions containing sub-questions that sum up to the total of 30 marks. Question one had four multiple choice questions each carrying two marks where learners were tested mostly on the correct procedure of connecting circuit, comparing current of parallel and series identical light bulbs through calculations and calculating parallel and series resistance. In question two learners were expected to reproduce what they have learnt by stating Ohms law.

They also applied Ohms law to calculate resistance of a resistor given the current passing through it and the amount of voltage supplied. The last sub-question of question two required the learners' comprehension where they were asked to explain the effect of connecting resistors both in series and in parallel to the resistance and current. Question 3 required them to conclude or decide whether the bulbs were connected in parallel or series based on their observation of the bulbs' brightness at home.

To ensure that assessment meets the standard, the post-test was moderated by three Physical Sciences experts, one holding masters in science education who is also a senior marker of Physical Sciences in the Eastern Cape department of education, the other two were still doing masters in Physical Sciences. One of them is a Physical Sciences examiner and the last one is a physical science subject specialist or adviser in one district of the same province. Reliability and validity were tested and guaranteed through this moderation which also checked if the tests were well organised, relevant, objective, suitable and precise. Leedy and Ormrond (2010) emphasise that

the researcher has to bear in mind these points when developing a data collection instrument.

3.6.2. LESSON PLANS

Different lesson plans, one for talk and chalk method (TCM) and three for multiple representations approach (MRA) were developed by the researcher to teach Ohm's law.

THE TCM LESSON PLAN

The TCM lesson was developed based on the traditional teaching practices. This lesson heavily relies on the text book and the teacher (the researcher in this case) as the sources of information. The researcher teaches what is in the textbook and enriches it by writing important point such as definitions, equations and tables on the chalkboard. Learners use calculators and instruments in addition to textbooks throughout this lesson. Some exercises are done to test learners understanding of lesson. This TCM lesson is characterised by all aspects of the traditional classroom in table 7 of this study. This lesson plan is presented as appendix M of this study.

THE MRA LESSON PLANS.

The MRA had three different activities which are water analogue, role play and Phet simulation. Although these three activities of MRA were identical in nature, each had its own lesson plan. These MRA lesson plans were developed based on constructivist classroom. Refer to table 7 for constructivist classroom.

CONDUCTING THE STUDY

MRA 1: WATER ANALOGUE

RESEARCHER'S ACTIVITY

The researcher provides learners with the following:

funnels X 1 per group,

1500ml bottles X 2 per group,

A Knife/scissor

A long flexible plastic pipe on which each group should cut the followings:

1-metre-long plastic pipe,

2-metre-long plastic pipes,

4-metre-long plastic pipes.

A tape measure.

Other materials used in this activity are notebooks and textbooks, pens, instrument boxes, calculators, chalkboard and chalk, three stop watches per group.

INSTRUCTIONS / PROCEDURE.

Work in groups of at least 6 members per group. Assign these duties to group members. Time keeper X 3, a recorder, a commander and a water pourer.

One learner who holds an empty bottle to be filled with water from the full bottle (this member is called the commander). The commander must put one end (about 3cm) of the pipe into the empty bottle.

The water pourer must fill one of the 1500ml bottles with clean water. Place the mouth (opening) of the water filled bottle into the funnel with the funnel facing down. This learner must then lift up the water filled bottle such that the pipe makes an angle of 45° to 60° with the horizontal surface.

The researcher blows the whistle. As the whistle is blown, each time-keeper starts or switches the clock on. Water is poured from the full 1500 ml bottle into the funnel such that this water goes through the pipe into the empty 1500ml bottle. The commander commands his/her group member's time keepers to stop the stopwatch immediately when the bottle is full. Each time-keeper announces his/her recorded time to be recorded down by the group's scribe in the presence of the researcher. This procedure is done using a 2-meter-long pipe, 4-meter pipe and a 1-meter pipe. Only one group performs a 1-meter-long pipe activity. (appendix S.(v) is a photo of a group performing a long-metre pipe activity. Not shown in this appendix is the recorder and a 3rd time-keeper). Refer to appendix R for class exercises.

MRA 2: ROLE PLAY.

RESEARCHER'S ACTIVITY

STEP 1. The researcher chooses a smooth level place outside for this activity. The researcher gives learners equipment and instructions to follow.

INSTRUCTIONS / PROCEDURE.

- a) As a group prepare a running path by measuring a 12 metre distance.
- b) Place 4 chairs 4 metres apart in this running path. Each group's running path must be at least 5 metres parallel to each other.
- c) Place your chairs firmly placed on the flat surface such that they did not fall or cause injuries to runners when they run on these paths as they will be expected to step on top of the two middle chairs and turn around the other two chairs on the end sides of the path.
- d) Removed all foreign objects from the paths such as stones and tins which might cause injuries to runners.
- e) Collect approximately 100 stones per group. Place these stones at one end of the running path (called the home) such that all homes are on the same side.
- f) As group members, assign these duties among the group members: one runner (energy carrier), one supplier, three collectors and a recorder.

STEP 2. The researcher will blow the whistle for the suppliers to supply the runners with stones.

- a) Runners will then start running from the starting point also called home through the running path stepping over the two chairs and turn around the last chair back to the starting point where they will drop those stone in the home place. They will be given another stones by their suppliers and run back again.

(NB. Group 1 runner is supplied with 1 stone at a time while group 2 is supplied with 2 stones. group 3 runner is supplied with 3 stones and group 4 runner is supplied with 4 stones).

- b) After 20 seconds researcher will blow the whistle for collectors to collect all the stones dropped in that first 20 seconds. Runners will continue running for another 2nd 20 seconds collecting and dropping the stones as in the first 20 seconds and the researcher will blow the whistle at the end of the 2nd 20 seconds for collectors to collect the stones dropped in the

- second 20 seconds. The process will continue for the 3rd 20 seconds which is the last.
- c) The collectors per group will collect and count the stones dropped by runners per interval (i.e. 1st, 2nd and 3rd 20 seconds) and recorded by the recorders in the presence of all groups and the researcher.

For better understanding of this activity, refer to appendix S (vi). Displayed in this photo are the following:

- i) Group A, B and C's running paths indicated as rows A, B and C respectively.
- ii) Line 4 represents home for each group. Learner P of group A is seen dropping a stone in his home while the group's supplier is stretching her hand as she is supplying another stone. Learner R of group C is seen approaching his home.
- iii) Line 2 and 3 are the two middle chairs where runners need to step over. Learner Q of group B is seen stepping over chair 2. They turn around the chairs indicated as line 1.

STEP 3.

Remove the two chairs that are in the middle of the running path and repeat steps a to c in step 2 above. This is referred to as the smooth surface.

STEP 4.

In the classroom, the researcher gives learners worksheets to fill and some problems to solve in their respective groups. Refer to appendix O for this worksheet and exercises.

MRA 3. THE Phet SIMULATIONS.

RESEARCHER'S ACTIVITY

The researcher gives learners equipment and instructions to follow as they do the experiment.

INSTRUCTIONS / PROCEDURE.

PART 1

The researcher assists learners to switch on lap-tops and open the Ohm's law Phet programme. Learners work together as groups according to these instructions.

1. Make an electric circuit by dragging and connecting the following:
 - i) 3 X 2 Ohm resistors in series,
 - ii) 1,5 volt cells in series,
 - iii) Ammeter and a switch.
 - iv) close the switch and record the ammeter readings.
2. Add a second 1,5 v cell in series, voltmeter across the cells, and record the ammeter readings.
3. Add the third 1,5 v cell in series, voltmeter across the cells, and record the ammeter readings.

PART 2

Make an electric circuit by dragging and connecting the following:

- i) 3 X 1,5 volt cells in series, voltmeter across the cells,
 - ii) ammeter, switch, 2 Ohm light bulb,
 - iii) close the switch and record the ammeter reading.
1. Add a second 2 Ohm light bulb in series to the first light bulb and record the ammeter reading.
 2. Add the third 2 Ohm light bulb series to the 2 light bulb and record the ammeter reading.

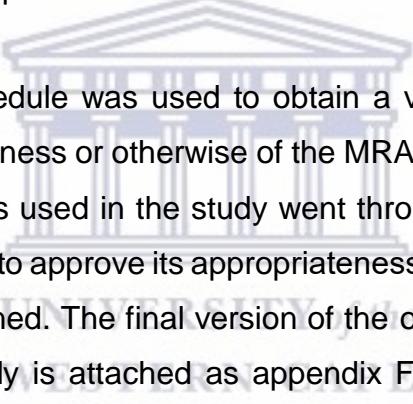
PART 3

1. Make an electric circuit by dragging and connecting the following:
 - i) 3 X 1,5 volt cells in series, voltmeter across the cells.
 - ii) ammeter, switch, 2 Ohm light bulb,
 - iii) Record the ammeter reading.
2. Add a second 2 Ohm light bulb parallel to the first light bulb and record the ammeter reading.
3. Add the third 2 Ohm light bulb parallel to the 2 light bulbs and record the ammeter reading.
4. Complete the activity by doing exercise in groups. (refer to appendix P for this activity).

Figures 5, 6 and 7 reveal group's part 3 of this activity. (N.B. there are no ammeters and voltmeters yet in these figures). A photo was also taken to reveal one of the group doing Phet simulation on appendix S (iii). Beneath each lesson plans are learners' exercises including worksheets.

3.6.2. OBSERVATION SCHEDULE

The lessons were video-recorded to allow thick description of the implementation. To analyse the video-tapes, an observation schedule was developed. In this observation schedule, the frequency of both the learners and researcher participation based on the following was observed from the videos: asking questions, giving explanations, discussing, debating, hand-on (active involvement). An observation schedule that was used to collect this data is attached as appendix F.



This observation schedule was used to obtain a valid and comprehensive picture of the effectiveness or otherwise of the MRA. The development of the observation schedules used in the study went through a series of checking by science experts as to approve its appropriateness to the learners' standard and the study concerned. The final version of the observation schedule that was used in this study is attached as appendix F in the appendices. The recorded lessons were transcribed and codes were used for each subject to keep anonymity.

3.6.4. INTERVIEW SCHEDULE

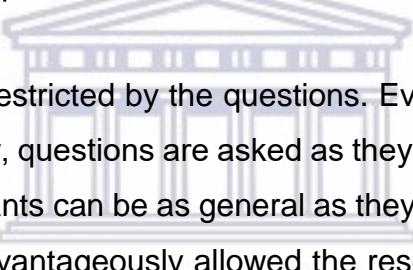
The interview schedule was designed to be flexible enough to allow learners to express themselves in relative freedom and to enable the interviewer to ask thought-provoking questions. Respondents were asked the same basic questions in the same order, which provided consistency. The only difference was in items 3 and 4 where the control group was expected to estimate their post-test scores if they were taught through MRA before writing the post-test. An interview schedule is attached as appendix H

After interview transcription, the data was sub-divided and assigned categories in the form of labels. This process, known as coding, was done to assign units of meaning for the descriptive data (Kvale & Brinkmann, 2009). Once coding was done, data was categorised into themes.

Before number check, interviews were audio-taped. After transcriptions, learners were given specific quotes to ensure that they were quoted correctly.

3.7. FOCUS GROUP INTERVIEWS

An interview is a suitable and effective technique to collected data. Access to data that is inside a person's mind can be gathered by the researcher through the help of an interview (Cohen & Manion, 1989). Interviews that exist in the research may be structured, unstructured or standardized (Patton, 1990). In structured interviews questions are set in advance and strictly followed.



The participants are restricted by the questions. Even if there is a plan in an unstructured interview, questions are asked as they come to the interviewer's mind and the participants can be as general as they feel like in answering the questions and this advantageously allowed the researcher to include follow-up questions during the interviews. Patton (1990) regarded an unstructured interview as more like an informal dialogue while Smith (1975) states that unstructured interviews is "depth interviewing".

Schuman and Presser (1981) define a structured interview as comprising of pre-specified questions and the response of the participant is greatly restricted. They further describe an unstructured interview as permitting the participant to liberally express their opinions on a certain issue. Questions asked in an interview can either be open-ended or closed (also known as fixed response questions). In an open-ended interview (unlike a close ended one), the participants are not limited by choice, but they express themselves in their own words. This is good because the interviewee gets to open up and to express themselves liberally on an issue concerned.

Semi structured interviews, which Patton (1990) refers to as an "interview guided approach" seem to strike a balance between the two extremes. Questions or issues to be covered are specified in advance in an outline form but the interviewer will decide on the sequence or wording of the questions in the course of the interview. The guide will be kept as a checklist of issues to be covered but there will still be room for the interview to become fairly conversational and situational and logical gaps can be closed (Patton 1990). It is worth noting as outlined in Appendix H that the type of interviews that were conducted with students were semi-structured.

The reason for opting to use this type of interview was established with the expectation to stimulate more data from learners, as Kvale (1996) recommended to researchers that if they need to know how people understand their world and their life, it is a must that you talk with them. He further emphasises that qualitative research interview tries to understand the world from the subject's point of view.

Brink et. al., (2012) define focus group interviews as those with five to fifteen people whose opinions and experiences are requested simultaneously. Focus group interviews were conducted with twelve learners. There were six learners, from experimental group and another six from group B. These learners were not randomly chosen nor purposefully selected rather first grouped according to their merit from their post-test performances. There were two learners volunteered or chosen by their merit group members. The merit groups were higher marks, mediocre and the lowest achievers to form this focus group. These learners were interviewed in the presence of their classmates. Interviews were conducted by the researcher himself and was videotaped and transcribed with the knowledge and approval of the learners.

Semi-structured interviews are advantageous as they can help to ensure coverage of the researcher's agenda, while also providing opportunities for interviewees to talk about what is significant to them, in their own words (Hobson & Townsend, 2010). The researcher's agenda in this case was to find both the effect of multiple representations in improving grade 11 learners'

pass rate and their perception or and attitude of multiple representations in the teaching of Ohms law.

- In the school setting, the learners might feel bolder in a focus group than when interviewed on a one-to-one basis.
- Participants may be stimulated to think more deeply and critically as other group members can question their stances, in a way that the interviewer might feel reluctant to do;
- Focus group interviews are more economical in terms of money and time; There is more group dynamic discussion, and less influence of the researcher on the outcomes

The purpose of the focus group interview was to explore:

- learners' performance with respect to multiple representations and talk and chalk method
- learners' attitude towards Physical Sciences before and after multiple representations
- learners' attitude towards Ohms law (electricity) before and after multiple representations.
- learners' career interest before and after multiple representations.

The verbatim transcripts were later discussed with each subject to confirm the accuracy of the documented data. The data were then studied both qualitatively and quantitatively, open coding and the generation of categories (Patton, 1987). First, the concepts associated to the topic being investigated were identified and then clustered into similar categories under the headings of opportunities and challenges. Although several learners were interviewed, space limitation would not permit for a detailed description of the outcomes for all interviewed learners.

3.8. DATA COLLECTION PROCEDURES

The researcher decided that a mixed methods approach would be the most suitable method for this study. Johnson and Christensen (2012) define a

mixed methods research approach as one in which the researcher uses a mixture or combination of quantitative and qualitative methods, approaches, or concepts in a single research study or in a set of related studies.

The quantitative methods alone could not completely capture the data needed to answer the research questions. Hence, the researcher felt that the qualitative elements would add more flesh or give a broader meaning to the quantitative data. This substantiates the views of many researchers who are of the belief that mixed methods have more advantages over the erstwhile dichotomous quantitative versus qualitative positions (Johnson, 2009).

Some advantages of mixed methods as outlined by Johnson and Onwuegbuzie (2004) include the following:

- narrative descriptions of qualitative methods can be used to supplement meaning to numbers acquired through the quantitative;
- the researcher can respond to a broader range of research questions when using mixed methods;
- the strong point of one method can overcome the flaws of the other method.

The two methods can add perceptions and understanding that might be missed when only a single method is used. However, this does not mean that mixed methods approaches to research do not have any disadvantages.

Although mixed methods approaches provide richer data than either quantitative or qualitative methods alone, they also have some flaws (Johnson & Onwuegbuzie, 2004). Some of these flaws include the following:

- Majority of researchers are likely to master either the quantitative or qualitative method, but not both hence it is difficult for a single researcher to carry out both qualitative and quantitative research;
- Mixed methods are more expensive and time-consuming than a single method.

Despite these difficulties of the mixed methods designs, the feeling was that richer, more meaningful data was worth the sacrifice. Hence, as an alternative, a mixed methods procedure was engaged in favour of the quantitative or qualitative alone. Tests were used in such a way that their responses could provide data for quantitative analyses however focus group interviews and audiotape-recorded material also constituted useful sources of qualitative data in this study. Video-tapes were transcribed as they enable the researcher to comment on all of the non-verbal communication that took place. The point is that it is often insufficient to transcribe spoken words only as other unspoken data is also useful (Cohen, Manion, & Morrison, 2000). Complete audio-visual footage usually overcome the bias of the trend towards recording repeated events and the biasness of the observer's view of a single event. Audio-visual data collection has the ability of allowing for full analysis diminishing both the reliance on prior interpretations by the researcher (Morrison 1994). Refer to table 9 for data collection used in this research.

The following steps were followed in the data collection plan: (see table 8 for these steps).

Step 1: The pre-test was conducted with the whole grade 11 learners who were willing to participate as the first step of the study. The pre-test scores were used to categorise learners on merits. the categories were high performers, mediocre, and low achievers. The experimental and the control groups were formed based on the pre-test scores, with each group containing approximately equal number of learners from each category.

Step 2: Multiple Representations Approach (MRA) lessons of (Ohms law) were presented to the experimental group and a talk and chalk method (TCM) lessons of Ohms law were presented to the control group. MRA had three different activities which were role play, water analogue and Phet simulations.

Step 3: These two groups wrote a same post-test (A2) simultaneously. This was done to prevent or avoid chances that one group may copy from the other.

Step 4: Sometime later, the control group was given opportunity to be taught Ohms law using MRA. This was done to comply with the ethics values as Brink, et al (2012) states that right to fair treatment is one of the human rights that must be protected in research.

Step 5: A focus group interview (FI) was conducted thereafter with its members chosen from both the experimental group and the control group through a stratified random sampling as mentioned earlier in section 3.7.

To ensure validity the researcher opted to interview learners after testing them. This was in line with Cohen, Manion and Morrison (2008) who explained concurrent validity as the form of validity where data gathered from using one instrument correlates highly with data gathered from using another instrument. For this reason, both a test and an interview were employed to investigate the effectiveness of MRA over TCM to improve learner attainment.

Table 9. Table showing the data collection procedure.

	GROUP (control)	GROUP (experimental)
Step 1	A1	A1
Step 2	TCM	MRA
Step 3	A2	A2
Step 4	MRA	-----
Step 5	FI	FI

Where A1 means pre-test.

A2 means post-test.

TCM means talk and chalk method (traditional teaching method).

MRA means Multiple Representations Approach and

FI means focus group interviews.

Table 10. Summary of the data collection method.

RESEARCH QUESTION:	METHOD	INSTRUMENT	RESPONDENT	ANALYSIS
(i) What was learners' initial understanding of electricity?	Pre-test	Test	Learners	Marking memorandum
(ii) How were the Ohms law lessons taught using (a) the Multiple Representations Approach and (b) the traditional method?	Intervention , video-taping and observation of video-taping of lessons	Lesson plan design	Learners	Questions and answers. Thick description.
(iii) What was learners' understanding of Ohms law after the multiple representation approach?	Post-test	Test	Learners	Marking memorandum
(iv) What were learners' perceptions of the multiple representation lessons?	Interviews	Interview schedule	Learners	Coding

3.9. DATA ANALYSIS

The first level of data analysis, which was presented in this chapter, was done in separate stages. The pre-test, classroom observation schedule, post-test and focus group interviews correspondingly addressed chiefly the following critical questions: namely,

- (i) What was learners' initial understanding of electricity?
- (ii) How were Ohm's law lessons taught using (a) the Multiple Representations Approach and (b) the traditional method?
- (iii) What were learners' understanding of Ohm's law after the multiple representation approach?
- (iv) What were learners' perceptions of the multiple representation lessons?

This is how the data was analysed as it gives answers to the aforesaid questions.

- a) Learners' scores in the pre-test determined what knowledge of electricity or Ohm's law they hold from grade 10 to grade 11.
- b) The data obtained from the analysis of classroom activities through classroom observation schedule gave a picture of how Ohm's law lessons were taught using both the (a) Multiple Representations Approach and (b) the traditional method (TCM)?
- c) The post-test scores disclosed what learners hold of Ohm's law after they were taught using the TCM and MRA.
- d) The information sucked from learners through focus interviews unveiled how learners perceived MRA.

As mentioned earlier that this is a mixed approach research study, the data was analysed both qualitatively and quantitatively.

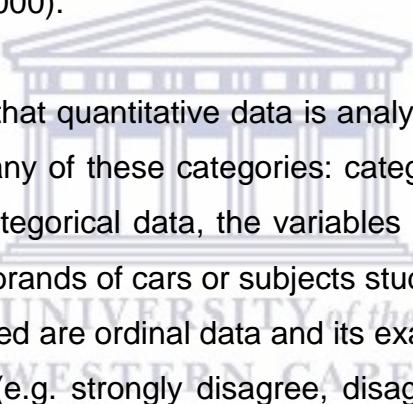
3.9.1. QUALITATIVE DATA ANALYSIS

The test scores of the post-test were categorised into highest scores, mediocre and lowest scores for both control group and experimental group separately. One learner from each category was randomly chosen to represent the category in the focus group interviews. Both experimental group

and B were interviewed through focus group interviews after writing the post-test as means of collecting qualitative data. Those interviews were videotaped and were transcribed thereafter. The data that was collected from those focus group interviews was coded then classified into noticeable themes or categories.

3.9.2. QUANTITATIVE DATA ANALYSIS

A quantitative research method pursues to launch fundamental connections between the independent and the dependent variable (Simayi, 2014). This led the researcher to employ this method as it is believed to be appropriate for this study because effective teaching and learning depend on various factors such as: the physical and social context in which an activity takes place Putnam and Borko (2000).



Field (2009) claimed that quantitative data is analysed in terms of numbers. This data can fall in any of these categories: categorical data, ordinal data, interval or ratio. In categorical data, the variables are distinct categories or groups, for example, brands of cars or subjects studied at school; and so on. Data that can be ranked are ordinal data and its examples are choices made in an aptitude scale (e.g. strongly disagree, disagree, agree, and strongly agree).

The case where equal intervals represent equal differences in the property being measured is referred to as interval variables (Field, 2009). Examples of interval variables include test scores. Interval variables with the additional condition of having a true zero are referred to as ratio variables. Interval variables was used in this study as learners' test scores were categorised based on intervals of less than 50% scores, 50% scores and 50% and above test scores.

The researcher decided to use 50% because this percentage is used nearly by all South African universities as the minimum score admission requirement

for students to specialise in each field. Recently, the ECDoE in a national radio station announced that they offer bursaries to people who are interested in teaching. They stressed that they only award teaching bursaries to learners who managed to score at least 50% in the subject one is to teach as this score is the minimum entrance requirement in the HEIs of South Africa (Jikijela, 2017). The director general of the ECDoE concurred with this statement in a provincial principals meeting where he said to meet the minimum admission requirements to a Bachelor's Degree study at a higher education institution, a candidate must obtain, in addition to the NSC, an achievement rating of 4 (i.e. adequate achievement, 50% to 59%) ECDoE. Patent /. ISBN 978-1-4315-2691-8.

The pre-test scores were analysed using spread sheet and were categorised according to high achievers, mediocre and low achievers. Each of these categories was randomly divided into two equivalent halves to form control and experimental group to ensure balance of learners' conceptual understanding in these two groups. Furthermore, pre-test scores were used to determine learners' prior-knowledge (conceptions and misconceptions) of the topic electricity as they dealt with this chapter in grade 10.

The post-test scores for both experimental group and control group were analysed using spread sheet and compared to see which group performed better than the other. This comparison was done based on three stages which were:

- comparing the post-test scores per group.
- comparing groups' pre-test scores with the post-test scores.
- comparing groups' post-test scores per question category.

This was then analysed both qualitatively and quantitatively. The group with better marks/achievement was considered as the one which has received better method of teaching between MRA and TCM. To meet the condition of independence of data, both groups wrote the pre and the post-test simultaneously.

3.10. VALIDITY AND RELIABILITY

Face, content and construct validity are the three types of validity that a good research instrument should address. Creswell (2005) asserts that content validity is the extent to which the items in an instrument and the scores obtained from administering it are representative of the research objectives. Cohen et al. (2007) further recommend that content validity is guaranteed if an instrument fairly and comprehensively covers the domain it is requires to cover.

Face validity is a judgment on how appropriate the items are to the instrument. This is usually determined by specialists in the field of the study. Determining if the scores from an instrument have a purpose, are useful, significant, and meaningful establishes construct validity (Creswell, 2005). This is also determined by expert opinion. A number of measures were taken in order to ensure construct, face and content validity in this study as explained

The first versions pre-test, post-test, lesson plans interview schedule and all lesson plans were sent to science experts for peer review. Recommendations by those experts were considered and changes were made on those instruments as recommended by the experts. The study was piloted and adjustments were made again were there was a need as highlighted in section 3.5.

To ensure that assessment meets the standard, the post-test was moderated by three Physical Sciences experts, one holding masters in science education who is also a senior marker of Physical Sciences in the Eastern Cape department of education, the other two were still doing masters in Physical Sciences. One of them is a Physical Sciences examiner and the last one is a physical science subject specialist or adviser in one district of the same province. Reliability and validity was tested and guaranteed through this moderation which also checked if the tests were well organised, relevant, objective, suitable and precise. Leedy & Ormrond (2010) emphasise that the

researcher has to bear in mind these points when developing a data collection instrument.

The researcher ensured the validity by interviewing learners after testing them. This was in line with Cohen, Manion & Morrison (2008) who explained concurrent validity as the form of validity where data gathered from using one instrument correlates highly with data gathered from using another instrument. For this reason, both a test and an interview were employed to investigate the effectiveness of MRA over TCM to improve learner attainment.

3.11. TRIANGULATION

Trustworthiness, reliability and transferability of naturalistic research design are essential since they expose the quality of the study (Guba & Lincoln, 1994). This section argued efforts of making data for the case studies as rich and trustworthy as possible. Creswell and Miller (2000) described triangulation as a validity technique where teachers pursuit for convergence among numerous and dissimilar sources of information to form themes or categories in a study. The four types of triangulation include different techniques of collecting data, various sources of data, different investigators and different perspectives to the same data (Denzin, 1989).

In keeping with Denzin 's (1989) list of triangulation, this study involved collecting data in different methods and from various sources so that the multiplicity of views, present in the social situations, could be detected. This study employed diverse sources of evidence, namely test, (quantitative) interviews, and classroom observations, (qualitative) to corroborate one set of findings with another in the hope that two or more sets of findings would converge on a single proposition (Massey, 2004).

3.12. TRUSTWORTHINESS AND AUTHENTICITY OF RESEARCH FINDINGS

Reliability is one of the notions that contributes to trustworthiness in a qualitative approach (Pine, 2009). Researchers believe that reliability is the ability to act consistently, honestly, openly and carry on with accurate collection and analysis of data neutrally (Babbie & Mouton, 2001; Sagor, 2005; Pine, 2009). To guarantee trustworthiness and authenticity in this study, the following processes were put in place:

- *Member checking.*

The transcriptions of the interviews were crosscheck by the two more teachers other than the researcher (Babbie & Mouton, 2001; Sagor, 2005; Pine, 2009).

- *Authentic research findings.*

Validity is the establishment of authentic research findings to guarantee that the researcher can make a reasonable claim based on them (Denzin & Lincoln 2005). To ensure justice of this study, the researcher strived for a balanced interpretation of findings by ensuring that the opinions of all respondents (including outliers) have not been omitted. Hence, opinions that were against the researcher's objectives were also included and interpreted in the study (Denzin & Lincoln, 2005).

- *Establishment of credibility.*

Referential adequacy, peer debriefing, prolonged engagement, audit trail and member checking are recommended procedures for credibility establishment (Lincoln & Guba, 1985). Referential adequacy was implemented by keeping evidence (data collection and data analysis) in the form of audio-tapes of interviews from the learners, transcripts of validation of the analogue by the physics expert, learners' work including pre-test and post-test, the researchers' record book with the learners" assessment tasks. and the researcher's workbook with lesson plans. As means of improving credibility of the study, translations from isiXhosa to English were done by two head of departments, (Head of Department African languages and Head of Department for English) to ensure that the correct translation were correct reflections of the learners' original ideas. As this was a case study, no generalisations will be made (Denzin & Lincoln, 2005).

3.13. ETHICAL ISSUES

Van de Walt and van Rensburg (2012) state that the researcher is responsible for conducting research in an ethical manner from conceptualisation and planning phase, through the implementation phase to the dissemination phase. Burkhardt and Nathaniel (2008) concur with them by affirming that ethical treatment of data implies integrity of research protocols and honesty in reporting results. Such reason guided the researcher to follow the ethical standards throughout this research study. Dowling & Brown (2010) cited the Council in the United Kingdom (U.K.) as it has a framework of ethical principles for educational research which institutions of higher learning seem to be applying to a fair degree.

These principles require that:

- Every research has to be planned, revised and carried out to ensure integrity and excellence.
- The researcher informs staff and subjects about the purpose, methods and aimed possible use of the research, what their participation in the research entails, and what risks, if any, are involved.
- The researcher must respect confidentiality of information supplied by research participants and respects the participants' anonymity.
- Research participants must participate on their own will, without any pressure and free from any intimidation.
- Researcher must avoid any harm to research participants.
- The independence of research must be clear, and any conflicts of interest or partiality must be explicit and the researcher undeniably followed these principles.

The researcher committed himself to the ethics code of the university Ethics Committee before the university granted him the right to conduct the research. The Eastern Cape Education Department Research Ethics Committee Standards were met and permission was obtained by the researcher (see appendix A) before commencing with the research in school as well as the

University of Western Cape's Senate Ethics Research Committee (see appendix B).

Prior to commencement of data collection, ethical clearances were obtained from the University of the Western Cape. Letters asking permission to conduct a research at school were sent to the Department of Education, the school principal, and the chairperson of the School Governing Body (SGB). Parents of the learners who participated in the study and the learners were asked to fill consent forms.

The researcher fully informed the research participants about the purpose, methods and intended possible use of the research, what their contribution in the study requires, and what dangers and threats are, if any.

- Parents of the learners who participated in the study and the learners were asked to fill consent forms. (see appendix E).
- The purpose of the research was explained to the learners and the ethical commitments were clarified before starting the study.

The researcher ensured anonymity by not mentioning the names of the schools used in the study and also used pseudonyms for the names of learners. The results of the study were shared with and the Eastern Cape Department of Education the school involved. All lessons including the interviews, were videotaped with the permission of the participants.

3.14. SUMMARY

This chapter examined 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 ethical issues. The actual test can be accessed in the appendix section namely. Chapter four and five respectively discuss the research analysis, results and the summary of results, recommendations as well as conclusions reached in the study.

CHAPTER 4

RESULTS

4.1. INTRODUCTION

The previous chapter dealt with the methodology used in this research study. Chapter Four describes the results of this research study. In addressing the research problem, the following research question was investigated:

How can a Multiple Representations Approach be used to teach Ohm's law in Grade 11 Physical Sciences?

The sub-questions being the following:

- (i) What was learners' initial understanding of electricity?
- (ii) How were the Ohm's law lessons taught using (a) the Multiple Representations Approach and (b) the traditional method?
- (iii) What were learners' understanding of Ohm's law after the multiple representation approach?
- (iv) What were learners' perceptions of the multiple representation lessons?

4.2. WHAT WAS THE LEARNERS' INITIAL UNDERSTANDING OF ELECTRICITY?

To determine what the learners understand of Ohms law, the researcher gave them a pre-test on electricity. As a baseline assessment, this test aimed at finding out what the learners already know about electricity as it is covered in the grade 10 curriculum. The second reason for conducting a pre-test was for grouping learners into experimental and control groups as informed by the marks they obtained.

Forty-eight grade 11 learners who were willing to participate in the study wrote the test. This test comprised of ten multiple choice questions. Learners were provided with a number of options to choose as answers and they were

expected to choose only one out of the given options as there was only one correct answer.

Learners' pre-test scores indicated the following:

The total of 48 learners wrote the pre-test. 15 learners which is 31% of the class scored 50% and 9 of them which constituted 19% of the class achieved above 50%. The remaining 24 learners which is the half of the class scored below 50%. These pre-test scores are tabulated in table 11.

Table 11. Learners' scores for the pre-test per categories.

Categories of scores	Number of learners who scored in this category	Percentage of learners who scored in this category
Scores < 50%	24	50
Scores = 50%	15	31
Scores > 50%	9	19

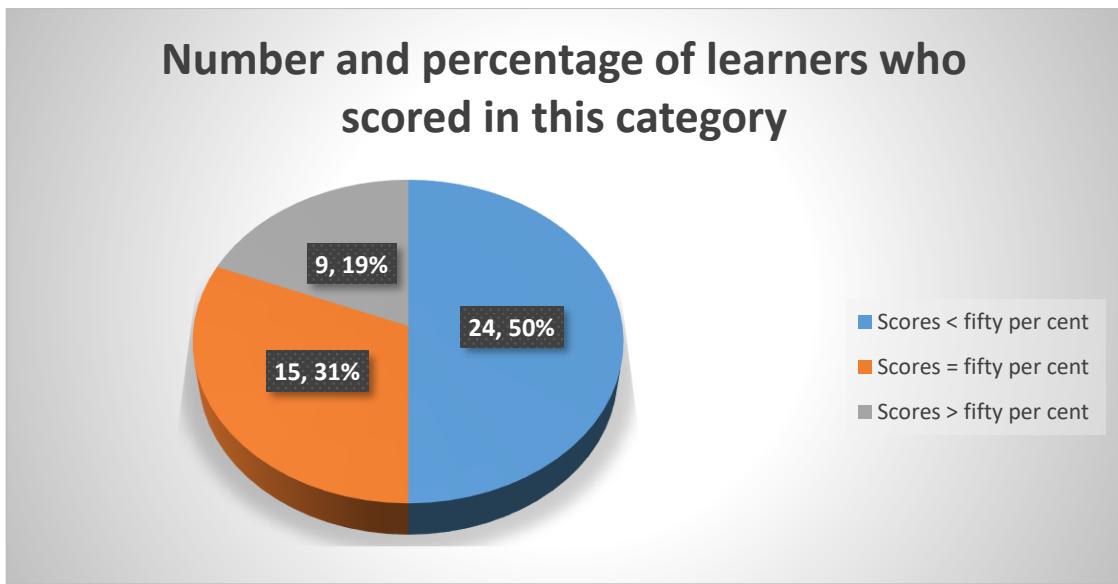


Figure 4. Figure representing numbers and percentage of learners' scores in the pre-test.

4.3. HOW WERE THE OHM'S LAW LESSONS TAUGHT USING THE MULTIPLE REPRESENTATIONS APPROACH?

The experimental group consisting of 24 learners was taught Ohm's law through Multiple Representations Approach before writing a post-test while the control group (24 learners) were taught using the traditional teaching method (talk-and-chalk method). For ethical reasons the control group were later also taught using the Multiple Representations Approach after writing the post-test. Although these groups were taught separately, their results have some similarities hence will be presented simultaneously.

4.3.1. WATER ANALOGUE

Learners from the experimental were asked to voluntarily form four groups of at least six members per group. These groups were labelled as group A, B, C and D respectively. They were provided with a long plastic pipe. Each group used a knife and a tape measure to cut the pipe into two and four meter lengths from the provided pipe. Each group was provided with two similar bottles each with a capacity of one thousand five hundred millilitres, one of those bottles was filled with water while the other one was empty.

The researcher explained the role to be played by each member in the group before they were asked to choose members to play those roles in their groups. Each group had three members working as time keepers using their cell phones. The other member poured water into the empty bottle through the pipe using the provided funnel so that there is no water that would spill down. The fifth member held the empty bottle as water was poured into it. Appendix S (v) indicates how water analogue was done.

The three time keepers pressed on their stop watches simultaneously as the researcher blew the whistle for water to be poured from the full bottle to the empty bottle. The one who held the empty bottle commanded the time keepers to stop their stop watches immediately when that empty bottle was full. The sixth member recorded the times from the time keepers' stop watches. Appendix S(iv) displays three cell phones that were used as stop watches, 1500ml bottle, a funnel and a recording book. A whistle held by the researcher as he was examining whether those times were correctly recorded is also seen. Four groups were formed and each group was given the procedure for the activity (see appendix N for water analogue procedures) and the researcher also explained the procedure.

This water analogue was divided into four activities; the first activity used the four-metre-long pipe followed by the two-metre-long pipe (second activity). The third activity was a one-metre-long pipe activity which was performed by one group and all the other learners observed. The fourth activity included the calculations, estimations, discussion and reporting on water analogue. The control group did the water analogue like the experimental group and they displayed approximately the same feeling and behaviour as the experimental group in every respect as far as interest, excitement and participation.

4.3.1.1. A TWO METRE - LONG PIPE WATER ANALOGUE.

All four groups started with a two metre - long pipe activity. The researcher felt that the times for the first activity should not be recorded as it should be

taken as a practice to familiarise learners with the skill of doing the activity. He moved around the groups helping them to set the apparatus accordingly as they were not used to them. The pipe had to make an angle of approximately sixty degrees with the horizontal until the empty bottle was full. Appendix S (v) is a photo displaying how water analogue was conducted. Two time-keepers holding their stop watches are standing next to the other two group mates. Learners were free and talking loudly during this activity to an extent that the researcher had to exercise more class control for the activity to proceed without wasting a lot of time.

He moved around the groups and got their attention to take instructions. For instance, at some stage he loudly drew their attention by asking: 'Ready?... ready?' and even code switched to the learners' home language "sesi ready sonke"? meaning "are we all ready?". Learners were still talking due to excitement. The researcher ended up referring to specific groups instead of generalising. He asked group A if they were ready. Most of the group A members replied:"yes". He then moved on to the next group and enquired if they were ready: Most of the group B members replied:" yes".

There was less noise now in the class as these two groups were quiet, even some of group C and group four members were ready for the activity to start. The researcher continued to draw their attention by enquiring if the two last groups were ready to start, thus making sure that everyone was ready. He then cautioned the commanders to talk loudly and boldly with strong voices. At some moments some learners were cracking jokes.

The researcher: (drawing their attention) "Hey, keep quiet, ready".

He blew the whistle. Water was poured through from the full bottle to the empty bottle immediately as the whistle blew and the time keepers turned on their stop watches. All learners concentrated on their work, each doing his or her job and observed what happening during that time. To prove that they were observant one learner said to group A-time keeper:

" Oh no! You delayed to press on your stop watch Eunice" (a pseudonym).

Few were still talking, but focused to the activity. As the bottles were about to be filled the researcher alerted both the commanders and time keepers. This action helped a lot because all the commanders attentively and timeously instructed their time keepers to stop their stop watches immediately as their bottles were filled. The commanders instructed the time keepers in each group to stop. Learners were excited to finish first or before others or even to just successfully finish. A small number of the participants were even dancing for their success.

Time keepers with the control of the researcher independently publicized their times per groups for recorders to transcribe. Although all the recorded times were different, each group's times were close to each other compared to other groups' time. Group A's times confirmed that Eunice indeed started later than others as her time was noticeably shorter than other time keepers' time especially in her group. Nevertheless, these recorded times were kept as indicated in Table 12.

Table 12. Recorded times for 2-metre-long pipes.

GROUPS	Time taken to fill the 1500 ml bottle		
	T 1	T 2	T 3
Group A	24.20	24.21	20.40
Group B	21.05	21.01	21.19
Group C	26.18	27.09	27.50
Group D	21.06	21.57	21.65

4.3.1.2. A FOUR METRE - LONG PIPE.

The two metre - long pipe activity was then followed by the four-metres-long pipe using the same procedure and same groups as in the two-metre-long pipe. Learners displayed the same interest, excitement and noise but were still co-operative as in the previous activity. The researcher had to control them throughout the activity. They were at least more accurate this time and consumed less time compared to the two-metre-long pipe activity. Table 13 shows the recorded times for the four-metre-long pipe.

Table 13. The recorded times for the four-metre-long pipe.

GROUPS	Time taken to fill the 1500 ml bottle		
	T 1	T 2	T 3
Group A	31.22	31.46	31.61
Group B	25.31	26.19	26.30
Group C	41.30	41.33	42.39
Group D	35.52	35.37	35.23

4.3.1.3. A ONE METRE - LONG PIPE ACTIVITY.

A new group of five members was formed for the experiment with the one metre - long pipe. The researcher randomly selected one recorder from group A, one commander from group B and one member to pour water was chosen from group C. Three time keepers were selected from groups 2, 3 and 4, respectively. The same procedure used in the two and the four metre - long pipes was employed. All the other learners became observers. This one-metre-long pipe activity is shown in appendix S (v) with time keepers waiting for the commanders' voice so that they can stop their stop watches.

Even in this activity learners were still excited and noisy to an extent that the researcher instructed them to stop the noise claiming that they will not be able to hear the commander. Some of the time keepers were disturbed by some of the observers who commanded them to stop their stop watches before the actual commander commanded them such that the researcher reprimanded those observers. He then asked for time keepers' records which were proclaimed as 12.32 seconds followed by 17.71s and 17.91s, respectively. This activity was repeated because of the big differences in the time records caused by the aforesaid disturbance. The second reason to repeat it being that the pipe was nearly hundred per cent vertical instead of being at least sixty degrees with the horizontal. He politely asked the group to repeat;

mentioning those factors. He held the pipe and demonstrated the angle he expected the pipe to be held.

Learners controlled their excitement this time to an extent that only the commander's voice was heard commanding time keepers to stop their stop watches as expected. The only problem this time was that the researcher noticed that one time - keeper delayed to press on her stop watch and that was confirmed by other learners who did not hesitate to point her out immediately when the researcher said 'someone got it wrong this time again'.

There was a big difference of her time taken compared to the other two time keepers' recorded time. The recorded times were 18.62s, 21.30s and 21.50s. The same time keeper repeated the delay to press on her stop watch at a wrong time. At this stage the researcher disqualified her as a time keeper and she was replaced by another learner from the observers and the activity became a success this time. The final recorded times to fill the 1500 ml bottle through a 1-metre-long pipe were indicated in table 14.

Table 14. Times to fill the 1500 ml bottle through a 1-metre-long pipe.

	Time taken to fill the 1500 ml bottle		
	T 1	T 2	T 3
Group A	20.13	20.41	20.40

The one-metre-long pipe activity took a longer time to be completed compared to the two-metre-long pipe and four-metre-long pipe respectively as it was the only one repeated more than two times. One of the reasons for this time delay is that a greater number of the learners were observers and not directly involved or engaged in the activity. They made more noise compared to when they were all involved in the activity. Even those who were engaged were disturbed by the observers causing them to concentrate less on the activity, but the researcher intervened by controlling the class.

4.3.1.4. CALCULATIONS, ESTIMATIONS, DISCUSSION AND REPORTING ON WATER ANALOGUE.

Each group worked on the exercises which were provided to them by the researcher (see appendix O). Learners arranged themselves around the desks with their sheets of papers, calculators and pens on the desks. Most of the unoccupied desks were pushed to the back in the classroom while there were few that were left in the front.

The researcher distributed the sheets of papers with activities to all the groups. He then explained all the questions to the learners. Learners were attentively listening to the researcher as he explained to them the questions after which they did calculations and estimations in their groups. The first question required them to relate or associate electricity terms to what they have done in the water analogue. Each group started by discussing and reported its conclusion to the whole class through a reporter either chosen by the group members or volunteering. They asked questions for clarity and continued with their work after the researcher clarified for them.

Among the few questions that were unclear to the learners was the average time that would be taken to fill the 1500 ml bottle when using the 3m and the 5m pipes respectively. Some of the learners in different groups wanted to start with estimations before calculations, hence the researcher advised them to start with calculations of the 1, 2 and the 4-metre-long pipes explaining to them that estimations depend on answers they will get from those calculations.

Table 15. Group A's recorded times to fill the 1500 ml bottle using different lengths of pipes.

Length of the pipe	Volume of water in the filled bottle	Time taken to fill the bottle			Average time	Rate at which the bottle is filled
		T 1	T 2	T 3		
1 metre	1500ml	20.13	20.41	20.40	22.31	67.23
2 metre	1500ml	24.20	24.21	24.40	24.27	61.80
3 metre	1500ml				26.08	57.60
4 metre	1500ml	31.33	31.46	31.61	31.43	47.73
5 metre	1500ml				36.82	40.74

Table 16. Group B's recorded times to fill the 1500 ml bottle using different lengths of pipes.

Length of the pipe	Volume of water in the filled bottle	Time taken to fill the bottle			Average time	Rate at which the bottle is filled
		T 1	T 2	T 3		
1 metre	1500ml	20.13	20.41	20.40	22.31	67.23
2 metre	1500ml	21.05	21.01	21.19	21.11	71.05
3 metre	1500ml				24.15	62.11
4 metre	1500ml	25.31	26.19	26.30	25.93	57.84
5 metre	1500ml				38.08	39.39

The researcher clarified that and learners continued working on their own in their groups. They calculated the average time taken by water to fill the bottle using the 1 m, 2 m and 4 m pipes, respectively after which they estimated the time that would be taken to fill the 1500 ml bottle if the 3 m and the 5 m long pipes were used. The researcher also wrote on the chalk board as he was

explaining questions to the learners. Whilst explaining questions, he explained the content into deeper details like when drawing a graph one has to make sure that it has a heading, and both x and y axis labelled accordingly in scale.

Table 17. Group C's recorded times to fill the 1500 ml bottle using different lengths of pipes.

Length of the pipe	Volume of water in the filled bottle	Time taken to fill the bottle			Average time	Rate at which the bottle is filled
		T 1	T 2	T 3		
1 metre	1500ml	20.13	20.41	20.40	22.31	67.23
2 metre	1500ml	26.18	27.09	27.50	26.95	55.70
3 metre	1500ml	35.50	36.41	36.50	36.14	41.50
4 metre	1500ml	41.30	41.33	42.39	41.46	35.90
5 metre	1500ml					

Table 18. Group D's recorded times to fill the 1500 ml bottle using different lengths of pipes.

Length of the pipe	Volume of water in the filled bottle	Time taken to fill the bottle			Average time	Rate at which the bottle is filled
		T 1	T 2	T 3		
1 metre	1500ml	20.13	20.41	20.40	22.31	67.23
2 metre	1500ml	21.06	21.57	21.65	21.43	0.09
3 metre	1500ml				27.05	0.11
4 metre	1500ml	35.52	35.37	35.23	35.31	0.11
5 metre	1500ml				39.21	0.13

As learners were drawing and comparing graphs which they drew from the data collected in the MRA activities, he further explained how to recognise the

dependent and the independent variables and which one is placed on the x axis and y axis when drawing the graph. Tables 15, 16, 17 and 18 show the final recorded times to fill the 1500 ml bottle using different lengths of pipes for group A, B, C and D respectively. These tables also indicate the calculated average times to fill the bottle together with the rate at which the bottles were filled by these different groups.

After calculations, learners debated and discussed the questions until they came to conclusions in their groups about the answers. As they were discussing, few learners in some groups complained that they were not fluent in English and asked from their group members to explain, debate or discuss in isiXhosa. To quote, one learner who was begged by her group members to come up with her views. She said “*ku-graph A ikhawulezile ukugcwala kuba igradient yakhona i-steep*”, meaning that in graph A, the bottle was filled faster than in other graphs because graph A’s gradient is steeper than the other graphs. Her answer was correct. One more interesting thing that was noticed in that discussion is that group members in one group did not accept uninformed answers and asked for justifications for answers then allowed the discussions to continue harmoniously. The whole class listened attentively after that. Learners enjoyed the lesson as they continued chatting and laughing and not disturbing this session. The researcher moved around group by group monitoring the progress and giving some assistance where it was needed.

There was an excellent cooperation among group members as they worked through this activity, communicating, joking and laughing in audible accepted voices. At some stage the researcher noticed that some were occasionally looking and pressing their cell phones as others were continuing with the work and few of them were making noise. Among themselves some were bold enough to reprimand others for making noise and disturbing them.

The researcher continuously reminded and alerted learners about the time limit and provoked them to move on to other questions. He constantly explained each question as he asked them to move on to it. Towards the end

of the session one member from each group reported to the whole class his or her group's answers concerning linking or associating Ohms law with the water analogue. Each group decided on its own how to choose the reporter, either through volunteering or they chose him or her. In one group of the four groups no one volunteered and the researcher opted at randomly pointing one member to report.

The first reporter started to report in isiXhosa but the researcher asked her to use English and indeed she reported in fluent English. Nonetheless, those who were uncomfortable to report in English were allowed to code-switch to their home language. The reporting stage stimulated learners' curiosity and they were very excited. All the four groups reported very well and their answers were correct. They all reported that the resistance is represented by the pipe, two groups correctly said that the voltage is represented by the bottle filled with water while the remaining groups only believed that it is represented by the bottle and did not mention the water. Three groups thought that the electric current is represented by water without specifying whether water in the filled bottle, water running through the pipe or water filling the empty bottle and one group precisely understood that it was the water that was running through the pipe. The groups' responses regarding this are tabulated in table 24.

Table 19. Learners' responses to link parts of water analogue with the electricity concepts.

Electricity or Ohm's concepts	Parts of water analogue that were linked to the electricity concepts			
	Group A's responses	Group B's responses	Group C's responses	Group D's responses
Electric current	Water	Water running in pipe	Water	Water
Voltage	Bottle	bottle with water	water with water	Bottle
Resistance	pipe	pipe	pipe	pipe

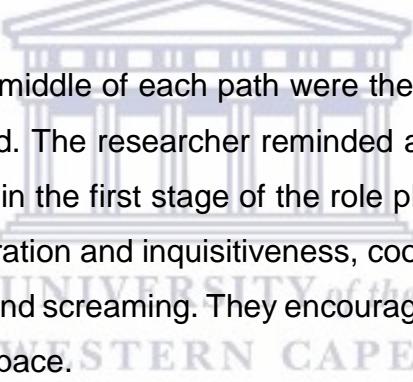
Two groups managed to come with new things as they related the pouring of water into the pipe from the already filled bottle as opening the switch. One group went further to integrate Physical Sciences with another subject (technology) by explaining that pouring water into the pipe is an effort something learnt from grade 9 technology. Some learners spontaneously lead discussion giving directions on what and how they should argue concerning science concepts learning as one said in Xhosa "hayi sithetha into engabalulekanga nous. apha si khompera l" meaning "no, we are now discussing unimportant issues of which here we are only asked to compare this".

The researcher requested the other group members to supplement what has been reported by the reporters but all the four groups rarely responded for those additions. He also probed each group with questions every time the reporter finished reporting and those probing questions led learners to demonstrate the relationship between the electric current and resistance. (i.e. what happens to current when the resistance changes?). Models, formulae, equations and symbols were used to discover these relationships with the help of the researcher. After the reporting session the researcher summarised the lesson by re-emphasising the three basic terms or concepts used in Ohms law which were electric current, voltage and resistance and their relationships through explanations. The effect of videotaping during discussion was that few learners became shy and were reluctant to speak once they discovered that the camera was directed on them whereas some enjoyed it and became more active. The majority of the learners ignored it.

4.3.2. ROLE PLAY

During the role play learners enjoyed the game, cheering, screaming and laughing, but at the same time followed the instructions well. Occasionally some chairs fell down as runners stepped over them but the group mates would voluntarily reset them immediately showing responsibility by so doing.

The runner of group rp C was slightly slow compared to the other two runners such that some learners giggled at him but he persevered not displaying any disappointment - instead he generated a joke out of it while enduring the running. The number of stones collected in each twenty seconds during the sixty seconds time interval was recorded per group by the recorders. Group rp A collected five stones in the first twenty seconds, four stones in the second twenty seconds and four stones in the third twenty seconds of that sixty seconds. For group rp B it was eight, eight, and six stones while group rp C recorded twelve, twelve and nine stones for the first, second and third twenty seconds, respectively. The total number of stones collected by each group in sixty seconds was found to be thirteen, twenty-two and thirty-three for group rp A, rp B and rp C, correspondingly. This is not astonishing as group rp A runner was given one stone at a time, group rp B was given two stones and group rp C runner was provided with three stones.



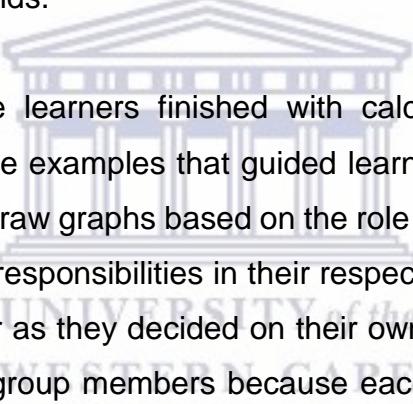
The two chairs in the middle of each path were then removed and the same exercise was repeated. The researcher reminded all the groups of the rules and instructions. Like in the first stage of the role play, learners continued to show a great concentration and inquisitiveness, cooperating with controllable enjoyment, cheering and screaming. They encouraged the runners not to give up, but to pick up the pace.

All learners proved to have gained the skill of the game as only one chair fell only once this time and was raised back to its position by one group mate through the instruction of the runner. On top of that the runners maintained a uniform acceleration as group rp A dropped three and group rp B dropped six stones respectively in all the three time intervals with the exception of group rp C who dropped nine, twelve and six for the first, second and third time interval.

After this activity all learners went back to the classroom where each group was asked to loudly pronounce the number of stones it dropped for each time interval in both activities. The researcher recorded them down on the chalkboard for other groups to copy such that each group recorded down

these for all groups. They were asked to calculate the total number of stones dropped by each group in sixty seconds for both activities followed by calculating the rates at which the stones were dropped in each group per sixty seconds both where there were chairs on the runway and when there were no chairs.

There was boundless cooperation among learners in their respective groups in the calculation stage which was proved by sharing of ideas and even coaching one another as to what to write and where. This lead to all groups becoming skilled at calculations as they all came with the identical precise answers. The number of stones dropped per time interval was greater where there were no chairs on the surface than where there were chairs on the runway path. It was the same case with the rate at which the stones were dropped in sixty seconds.



Immediately after the learners finished with calculations, the researcher explained, giving some examples that guided learners how to draw a graph and allowed them to draw graphs based on the role play. They made plans to save time by sharing responsibilities in their respective groups without being told by the researcher as they decided on their own to divide the drawing of graphs amongst the group members because each group was expected to draw four graphs. The rate at which stones were dropped in each sixty seconds increased with the number of stones each runner was given at a time.

Group A's rate was 0.21 stones per second, group rp B's rate was 0.31 stones per second and group rp C's rate was 0.55 stones per second. This indicated that all three runners had the same average speed as their rate of dropping the stones in sixty seconds would be equal to 0.2 stones per second if all three of them were given same number of stones at a time. When groups were asked to report how they related the three Ohms law terms which were electric current, voltage and resistance to the number of stones supplied to the runner, the path on which the runners run and the rate at which the stones

were dropped (i.e. the three portions of the role play), learners were reluctant to report.

After politely persuaded and motivated by the researcher they confidently reported and all the reporters volunteered to report for their groups. Each group discussed and came to a collective decision as to how to relate the three portions of the role play to Ohms law. Group rp C's reporter pointed out clearly that he was giving the group's views not his alone as he stated that 'during the discussion my group and I decided that....' before giving his report. He followed by expressing confidence in his report through a smile and gestures after reporting.

From the independent reports of the groups it appeared that about 67 percent of the class managed to correctly associate the term 'resistance' of Ohms law with the runway of the role play while approximately 33 per cent incorrectly thought that resistance should be associated with the rate at which stones were dropped. Two groups failed to recognise that the term 'electric current' of Ohms law should be associated with the rate at which stones were dropped on the role play. 33 percent (one group) of the class managed to associate the term 'voltage' of Ohms law with the number of stones that was supplied to the runner on the role play compared to the 67 percent (two groups) who incorrectly associated voltage with the rate at which stones were dropped.

During the reporting process some learners appeared to confuse certain terms or concepts as one reporter revealed to have no clear difference between resistance and resistor hence the researcher interrupted the reporting process by explaining electricity concepts including three basic Ohms law terms (i.e. voltage, current and resistance) and how they could be correctly associated with the role play portions which were the number of stones supplied to the runner, the path on which the runner runs and the rate at which the stones were delivered in this case. He exemplified his explanations by drawing an electric circuit, making use of the classroom's electric wiring and everyday home situations.

The researcher also used models, formulae, equations and symbols in the course of facilitating. When each group was probed to explain why they decided to relate each term to a specific portion of the role play the group rp C reporter was more confident than other members of his group by being the one who supports their answer while other groups failed to support their answers. The researcher concluded and re-emphasised the important points and facts (such as heading, labelling and correctly scaling the axis) that must be included when drawing graphs.

4.3.3. Phet ANIMATIONS

Learners did activities on a computer where they were drawing electric circuits. They manipulated voltage and resistance by changing the number of cells and the number of resistors according to the given instructions. They also changed the type of connection of the resistors. The data collected from those activities was then recorded down per group as they were working in groups of 6 learners per group.

They discussed and debated their observations and results as a class concerning the relationships between the electric current, voltage and resistance as they were working on the activity. Exchange of ideas and laughing in the class indicated that learners were free and relaxed. They maintained the cooperation they displayed in the other activities such as water analogue and role play. Some even enjoyed some jokes while continuing working on the given problems.

Learners enjoyed discussing animations and were tuned to the custom that the group's decision be owned by each and every individual in the group. One group member was heard saying in isiXhosa 'hayi bo ndiyavuma nje' meaning 'oh yes I also do agree' after the majority of the group members enquired whether he is for or against the group's decision.

The researcher on the other hand persisted to move around from group to group giving the necessary guidance and help. Learners occasionally asked

questions for clarity as the researcher explained and they indicated that they were satisfied by the researcher's answers. All the groups successfully managed to construct the electric circuits as instructed within the limited time but their circuits were not really similar in structure as shown figure 5, 6 and 7.

Each group's constructed circuit was constructed differently in structure from other groups but their readings were identical and correct. The lesson was vibrant because the whole class showed excitement as the readings changed. The results from all the three groups are displayed in table 25.

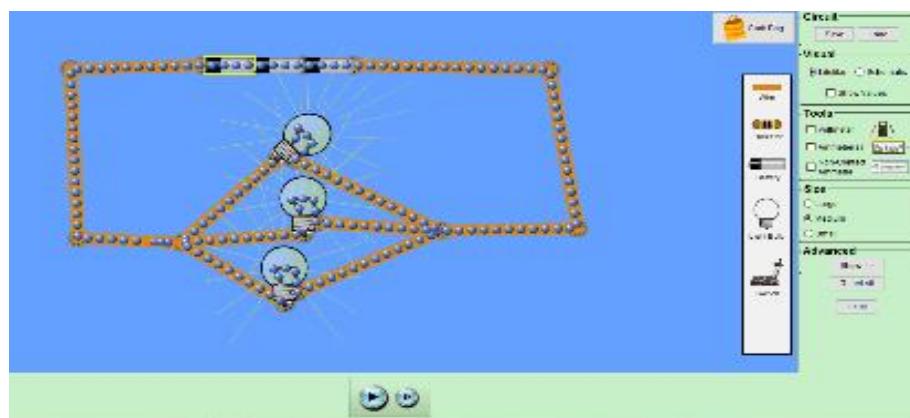


Figure 5. Group B electric circuit

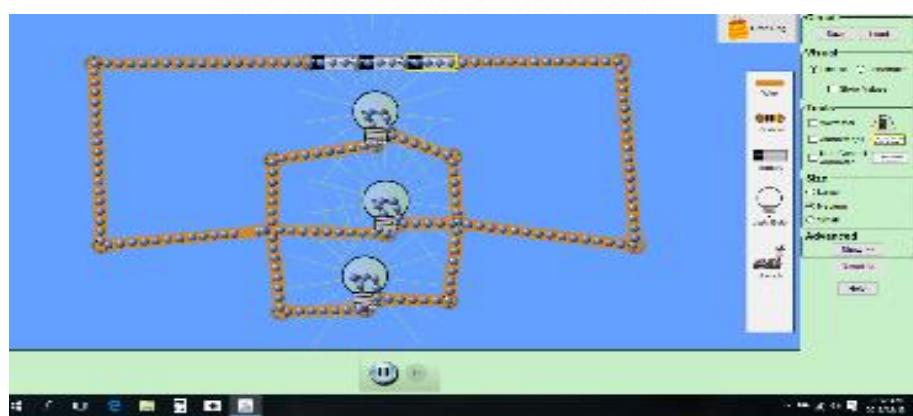


Figure 6. Group A electric circuit

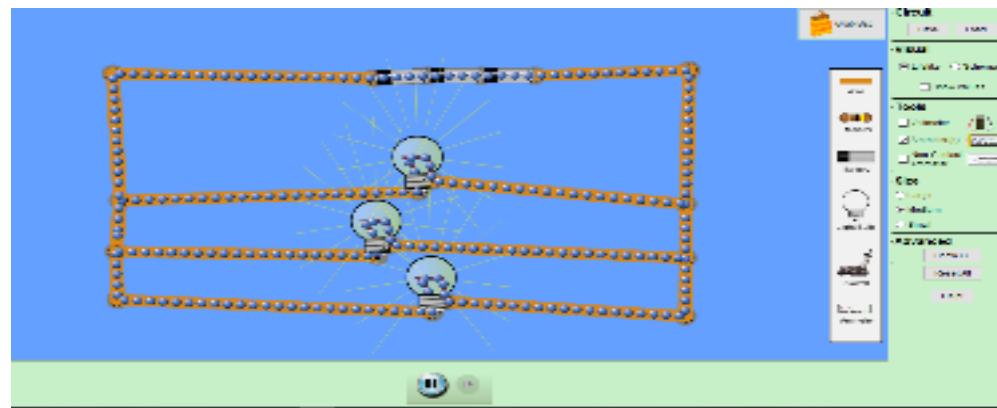


Figure 7. Group C electric circuit

When guided through questions to tell their observation, learners managed to tell that an increase in the number of cells in series increased the voltage of the circuit and this increase in the voltage also increased the electric current. Making use of the chalkboard the researcher also stressed this proportionality through Ohms law equation, $I=V/R$ which was followed by calculations using Ohms law equation. As learners were working on animations, they also discovered that the increase of the electric current was indicated by the brightness of the bulbs.

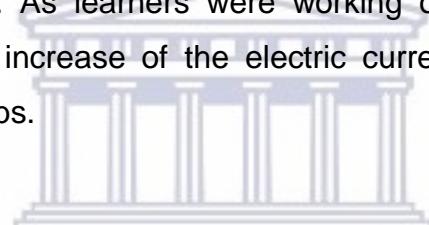


Table 20. Table of readings for both parallel and series connection of circuits.

PART 1	No. of cells	No. of resistors	Voltage	Resistance	Current
Constant series resistors, increasing voltage	1	3	1.5 v	6.0	0.25 A
	2	3	3.0 v	6.0	0.50 A
	3	3	4.5 v	6.0	0.75 A
PART 2	3	1	4.5 v	2.0	2.25 A
Increasing series resistors, constant voltage	3	2	4.5 v	4.0	1.12 A
	3	3	4.5 v	6.0	0.75 A

A great debate arose as learners were requested to estimate the effect of adding parallel resistors on resistance and current when both the temperature and the voltage were kept constant. One group, which is about 30% of the class thought that it would increase both the resistance and the electric current whereas about 40% of the class assumed that it will do the opposite. The remaining 30% of the class believed that it would drop the resistance and increase the electric current.

After they were allowed to test their beliefs on the animations by constructing electric circuits where resistors are added in parallel, an ‘aha’ expression was made by the majority of the learners. This led to the common conclusion by all of them, concluding that addition of parallel resistors decreases the resistance and increases the electric current. These findings concurred with Xongwana (2014) who asserted that learners in her research study were astonished while practical work enables learners to verify laws and theories to prove Ohm’s law on their own. Aha is a point in time, event or experience when one has a sudden realisation or has suddenly discovered a solution

(Colman, 2009). ‘Aha’ is a point in time, event or experience when one has a sudden realisation or has suddenly discovered a solution (Colman, 2009). Aha expression is the person’s manifestation or appearance when something is suddenly seen, understood or realised. Table 21 indicates learners’ results which lead to the class’ Aha expression.

Table 21. Table showing the effect of adding parallel resistors to the current and total resistance.

PART 3	No. of cells	No. of resistors	Voltage	Resistance	Current
Parallel resistors	3	1	4.5 v	2.00	2.25 A
	3	2	4.5 v	1.00	4.50A
	3	3	4.5 v	0.67	6.72 A

4.3. HOW WERE THE OHM’S LAW LESSONS TAUGHT USING TALK AND CHALK METHOD?

The majority of the learners here are isiXhosa speaking while few of them are Sesotho speaking. These few Sesotho speaking learners are fluent in isiXhosa. This lesson was conducted using code-switching meaning that the researcher teaches in English but explains some terms in the learners’ home language. The teacher who is also the researcher used isiXhosa during this lesson presentation as all the Sesotho speaking learners are fluent in isiXhosa and he is also an isiXhosa speaking person.

The researcher started the lesson by stating that “our lesson today will be on electricity”. He then wrote the word electricity in capital letters on the board. He reminded the class that the topic is not new to them as they dealt with it in the previous grade which is grade ten. The researcher continued the lesson by telling the learners that there are three basic and important terms or concepts in electricity. He then asked the learners to tell him those concepts.

They mentioned the voltage and the researcher told them it is also referred to as potential difference.

Learners also mentioned resistance and current. He wrote these terms on the board as the learners mentioned them. He told them that in that lesson they will look at the relationship between these three terms but emphasised that before looking at these relationships it is very important for them to be able to define these terms. He asked learners to define the terms thereafter. For some time, there was no response from the learners. The researcher asked learners to volunteer and give the definition of any of these three terms, pointing the terms as they were already written on the chalkboard. No one offered a response for a while until the researcher decided to point them as learners did not volunteer to define these electric terms.

The following were learners' definitions.

Learner A "current is *the flow of electric charge through a conductor*".

Learner B "resistance is *the difficulty encountered by moving charges*".

Learner C "*potential difference is the energy provided by the cell for charges to move*".

The researcher applauded learners for their definitions and continued to clarify each, referring to the electric circuit he sketched on the chalkboard. This electric circuit had two cells connected in series and joined to a light bulb. He emphasised that:

Whenever we have cells connected to a light bulb (illustrating on the diagram drawn on the board) through a conductor, the cells will provide energy to the charges that are in the conductor and the charges will move. So we have charges moving through the conductor then we say we have current. We only have current when the charges are moving.

Some learners were taking notes as the researcher was teaching while others were attentively listening. With regard to resistance, the researcher gave learners a second definition of resistance as 'something that opposes current' as defined in their text books and told learners that they have a choice to any

of the two definitions as they are both correct. He pointed in the direction opposite to the arrow indicating the direction of the current in the electric circuit on the chalkboard as he explained.

The researcher started to introduce Ohms law, gave them a brief history of the law with the aim to persuade, motivate and encourage them to become scientists. As the lesson progressed learners were still silent, listening cautiously and just answering questions only when they were asked. Some continued to take notes while others had their textbooks open as the lesson continued. The researcher stated Ohms law and wrote it on the chalkboard. He emphasised that this law applies only if temperature is constant. He further explained the dependent and the independent variable as far as these concepts (current and voltage).

From there he labelled the cell on the circuit as 1.5 V, drew a table with three columns. On the first column there was a number of cells, on the second was voltage and on third was current. He asked the learners to give the total voltage that the circuit will have if the number of cells increase one by one and filled the answers on the table as they were given by learners. Learners were also asked to find the electric current as voltage changes due to the addition of cells and answers were used to fill the table drawn on the chalkboard.as shown in figure 8.

Figure 8. Table showing relationship between electric current and voltage.

From this stage Ohm's formula, $I = V/R$ was introduced. The light bulb on the electric circuit was labelled as having a resistance of 1.5 ohms. After filling the table, the researcher taught learners how to draw the graph (he sketched the graph on the chalkboard as he spoke to them) using the data which was taken from the table. He emphasised the important points to be considered when one was drawing a graph.

Some of those points were: heading of the graph, appropriate labelling and scale usage on the x and y axis, correct labelling of the axis which includes the units and considering which one between the dependent and the independent variable was placed on the x axis and the y axis. Occasionally the researcher tested the learners' understanding of the lesson through verbal questions and proceeded. Using the graph drawn on the chalkboard he illustrated that it was a straight line graph which indicated the direct proportionality (the relationship between the independent and the dependent variables). He also showed them that as the x-independent values increases the y-dependent values also increased. The researcher asked the class to ask questions where they have not understood but all the learners assured him that they have understood him well.

Learners' understanding was finally tested through a written classwork which also indicated that they have really understood as the majority scored above 80% in that classwork. Three learners from the control group dropped out of the study while all experimental group learners finished the study.

4.4. LEARNERS' UNDERSTANDING OF OHMS LAW AFTER THE MULTIPLE REPRESENTATION APPROACH AND THE TALK AND CHALK LESSONS

A common post-test was written simultaneously by both the control and the experimental group. To ensure that assessment meets the standard, the post-test was moderated by three Physical Sciences experts. Post-test scores of the control group were then compared with those of the experimental group as a means of finding out which group understood Ohm's law better.

The three methods used for this purpose were:

- i) comparing the post-test scores of the control group with those of the experimental group.
- ii) comparing the groups' pre-test scores with the post-test scores per group.
- iii) comparing the groups' test scores question per question (categories) per group.

There were 48 learners on the first day of the study but only 45 wrote the post-test. This is because three learners from the control group quitted during the process of the study.

4.5.1. COMPARING THE POST-TEST SCORES PER GROUP

Experimental group's post-test scores were compared to the control group's post-test scores (see Table 22). These test scores were coded as categories.

The categories were test scores that were:

1. Above 50%.
2. 50%.
3. Below 50%.
4. 50% and above, to examine the total number of learners who could qualify to be admitted in science related fields in the universities

The results were as follows:

The majority of 52% from the experimental group learners scored above 50%, only 18% of the learners scored 50% while 30% scored below 50%. The percentage of learners who got $\geq 50\%$ in the experimental group was 70%.

In the control group no learner scored above 50%. The majority of 60% scored 50% while 40% scored below 50%. In this group 60% of leaners scored $\geq 50\%$. Figure 9 was drawn to give more clarity on the comparison of post-test scores in percentages.

Table 22. Table indicating the comparison of the post-test scores per group in percentages.

Category of scores	Post-test	
	Percentage of learners in experimental group	Percentage of learners in control group
Scores < 50%	30	40
Scores = 50%	18	60
Scores > 50%	52	0
% ≥ 50%	70	60

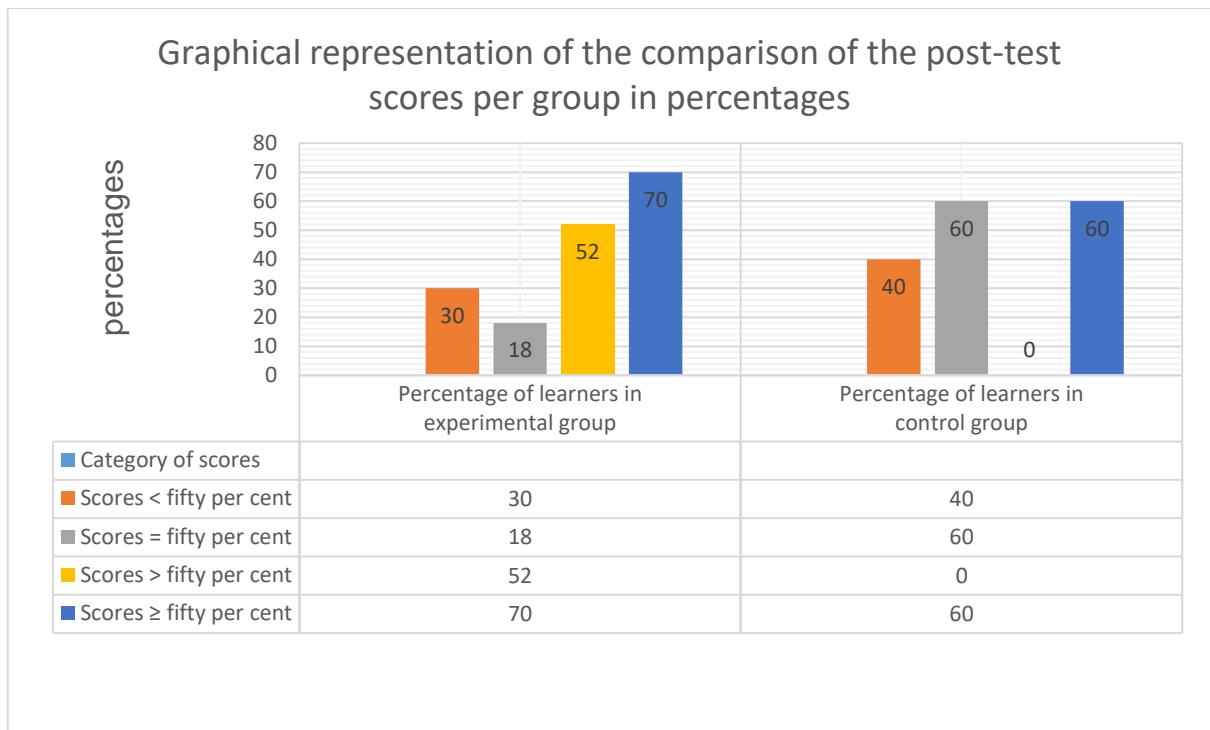


Figure 9. Graphical representation of the comparison of the post-test scores per group in percentages.

4.5.2. COMPARING GROUPS' PRE-TEST SCORES WITH THE POST-TEST SCORES

The pre-test and the post-test scores of both the experimental group and the control group were compared considering the percentage of learners who scored a specific range of marks in the pre-test and a change in their marks in the post-test. The debate on this respect will be useful to assist a further argument in the next section about the usefulness of a treatment received by the experimental group comparative to the treatment received by the control group.

Only the scores of the learners who wrote both the pre-test and the post-test from both groups were compared to eliminate biasness as three learners from the control group did not write the post-test. The percentage used was based on the number of learners in each group as the groups are not equally represented in the post-test.

When the learners were separated to form equal experimental and the control groups, 53% of learners whose score was less than 50% in the pre-test formed the experimental group while 47% formed the control group. 44% of those who scored 50% formed the experimental group and 56% formed the control group. The category of learners who scored greater than 50% was divided equally among the experimental and the control groups.

This lead to the formation of each group with this percentage of learners in each category. The experimental group had 33% of learners whose score was less than 50% in the pre-test while the control group had 29%. The experimental group comprised 17% of learners whose pre-test score was 50% whereas the control group comprised 21%. Both groups had 50% learners whose score was 50% in the pre-test.

The post-test scores per group indicated the following:

30% of the experimental group learners scored less than 50% compared to 38% of the control group learners who fell in the same category. Only 18% experimental group learners scored 50% in relation to 62% of the control group with the same score. 52% of the experimental learners scored above 50% while no learner from the control group managed to score more than 50%. This information is clarified in table 23 and figure 10.

Table 23. Comparison of pre and post-test scores per group in percentages.

	Percentage of learners in experimental group		Percentage of learners in control group	
	Pre-test	Post-test	Pre-test	Post-test
Category of scores				
Scores < 50%	33	30	29	40
Scores = 50%	17	18	21	60
Scores > 50%	50	52	50	0
% ≥ 50%	67	70	71	60

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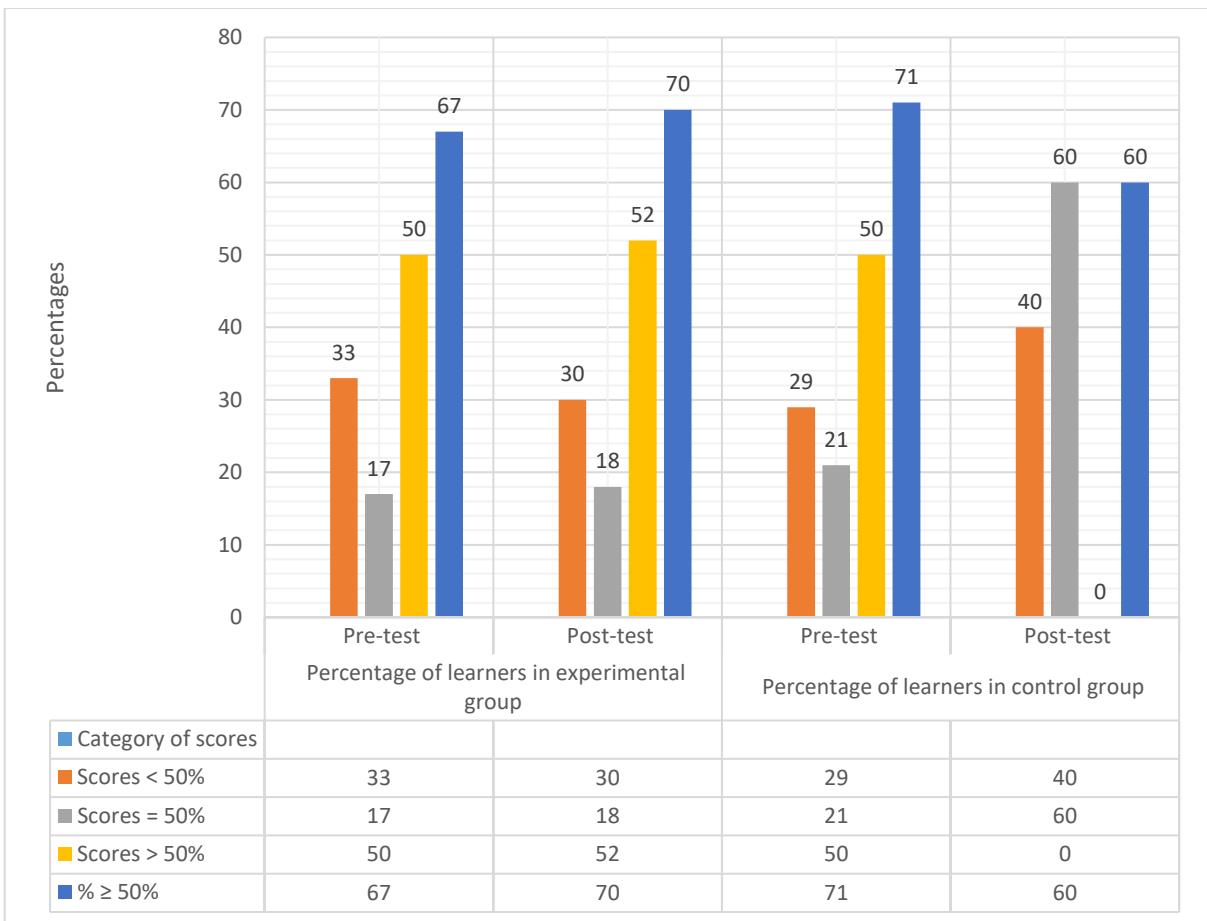


Figure 10. Representing the comparison of pre and post - test scores per group in percentages.

4.5.3. TEST SCORES PER QUESTION (CATEGORIES). CATEGORISING QUESTIONS AND COMPARING GROUPS' SCORES PER QUESTION CATEGORY

The test questions were then categorised into three different categories based on Bloom's taxonomy of the cognitive domain of classifying questions. Blooms taxonomy classifies questions into four categories which are recall; conceptual understanding only; application only, then conceptual understanding and application. In this study, recall type questions were categorised as lower order questions, those that required conceptual understanding were combined with the ones which required application to form middle order questions while questions that required both understanding and application were classified as higher order questions.

Consult Appendix L for more clarity for this paragraph. Question items 2.1, 2.3, 2.4 and 4.1 formed lower order questions and their total mark was 13. Question items 1.1, 1.3, 2.2 and 4.2 formed middle order questions and they sum up to 8 marks. Higher order questions were formed by question items 1.2, 1.4, 3 and 4.3 and they summed up to 9 marks.

The percentage of learners with correct responses was found to be as follows in each category:

- In the lower order questions 43% of the experimental group compared to 44% for control group had correct responses.
- It was 67% from the experimental group and 61% for control group in the middle order questions.
- It was 43% for experimental group and 33% for control group in the higher order questions as shown in table 25 and the graph of figure 11.

Table 24. Summary of the Comparison of the groups' post-test scores per question categories in percentages

	EXPERIMENTAL GROUP %	CONTROL GROUP %
Lower order	50	51
Middle order	67	58
Higher order	42	29

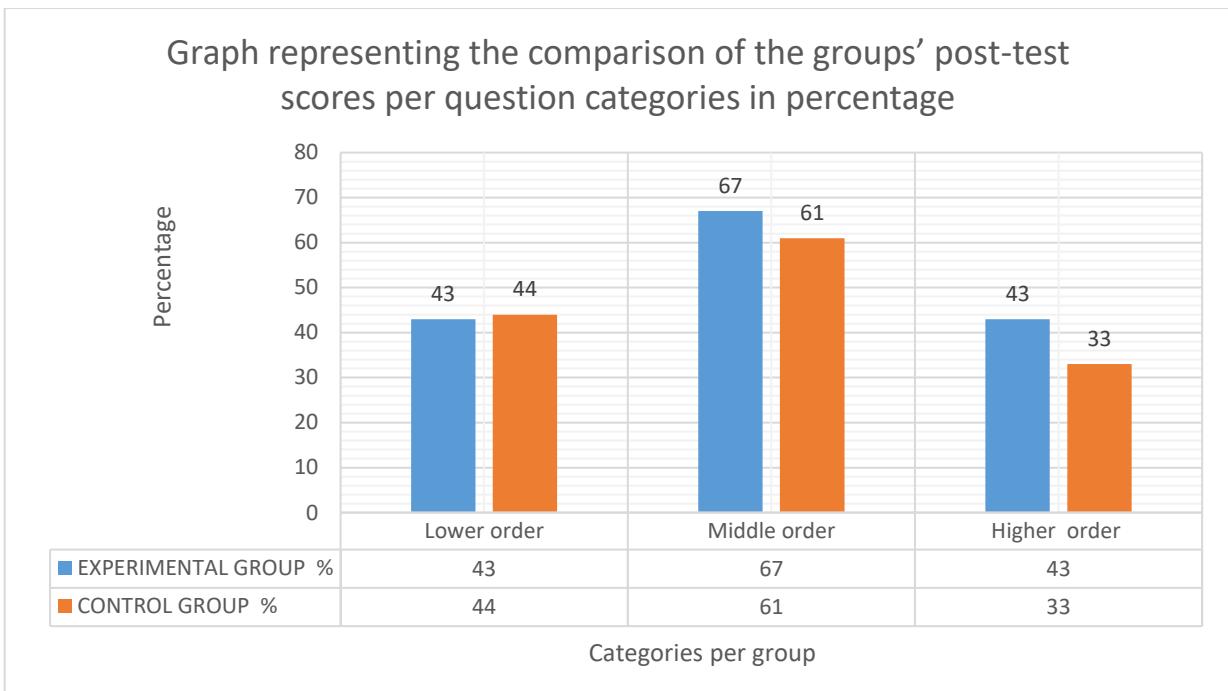


Figure 11. Graph representing the comparison of the groups' post-test scores per question categories in percentages.

4.6. EXAMINING LEARNERS' PERCEPTION OF MULTIPLE REPRESENTATIONS

Learners' perception of multiple representations was examined through two separated focused group interviews. The interview with the experimental group learners was conducted on the same day after writing an assessment task based on Ohms law whereas the control group was interviewed sometime later after they were taught through the Multiple Representations Approach. Appendix H provides with the focus interview schedule while appendix I provides with the sample of interview responses.

The researcher began the interview with an opening question that expected a reflection from the learners with regard to their test scores:

Researcher: How do your pre-test and post-test marks compare? (50%, less than 50% or greater than 50%).

Experimental group learners took about 30 seconds before responding and there was only response to this question from both groups.

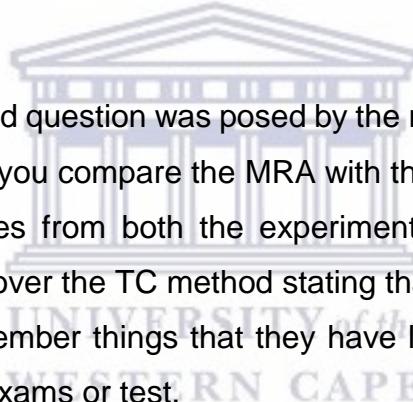
F_{MRA} L₁: I started from 50% but now suddenly I am changing to greater than 50% score. (The learner felt very satisfied with her progress).

According to her response she upgraded her score from 50% in the pre-test to above 50% in the post-test.

F_{TCM}L₁: In the pre-test I got the half which is 50% and in the post-test is where that I was below the half.

Learners felt uncomfortable or shy to talk about their test scores as the researcher requested further responses from the learners and he even code switched to isiXhosa: "Omnye", yet there was still no response from learners.

The researcher then moved from the discussion around marks to comparing the MRA with the TCM of teaching. The researcher started by explaining the difference between the two approaches (MRA and the TCM) as they were used in the lessons.



This is how the second question was posed by the researcher to the learners:

Researcher: How do you compare the MRA with the TCM?

67% of the responses from both the experimental and the control group recommended MRA over the TC method stating that:

- It is easy to remember things that they have learnt through MRA when they are writing exams or test.
- It improves conceptual understanding of what is taught especial to slow learners compared to talk and chalk method.
- MRA allows them to visualise abstract concepts like electricity unlike when the teacher writes on the board or paper using TCM.

This is one of the learners' responses:

MR is very good because when it comes to the test you then remember what you have viewed and what you have seen. But concerning TCM, it is a bit difficult to remember when you are writing a test. F_{TCM} L₂

On the other hand, 37% of the answers recommended TCM over MRA stating the following reasons:

- TCM is time saving compared to MRA.

- They argued that TCM sharpens their memory and trains their minds to remember things easily.
- It improves their logical thinking.

This is how one learner responded:

F_{MRA} L₃: I prefer TCM because it saves a lot of time and it trains our minds to remember fast. TCM trains our minds to think logically and very fast.

The researcher appreciated the learners' responses and opened a chance for other responses to the item but there were no more responses.

There was a contradiction of ideas as to which one between MRA and TCM helps learners best to remember things that has been taught. F_{TCM}L₂ and one learner from the experimental group recommended TCM stating that it trains their minds to remember things the manner said. On the other hand, another learner from the control group claim that MRA assists learners to remember science concepts because they have viewed and seen these as MRA is practical. This is how these two learners expressed themselves.

F_{TCM} L₂: MRA is very good because if you are working on different things, when it comes to test you then remember what you have viewed and what you have seen. But coming to TCM, it is hard to remember when you are writing a test.

F_{MRA} L₂: I prefer TCM because it saves a lot of time sir and it trains our minds to remember fast. TCM trains us to remember things as they were said.

A theme where TCM is favoured over MRA because it is seen as time saving was notices from these interviews. Although few interviewed learners noticed this, it caught the researchers' attention as it concurred with many Physical Sciences teachers' beliefs as mentioned by some researchers. refer to 1.4.7.

The researcher moved to the 3rd item which had two purposes. The first purpose was for learners to rate the subject Physical Sciences as difficult or easy according to their own views. The second purpose seek to find type of

teaching approach that can make Physical Sciences easy to understand. The researcher asked:

Researcher: Look at the Physical Sciences as a subject and state whether it is an easy or difficult subject for you and state whether the teaching methods used (either MRA or TCM) had an effect on how you perceived the subject. Which method will bring change to your understanding of Physical Sciences?

Learner 1, ($F_{MRA} L_1$) continued to show her boldness by responding to the item and indicated that Physical Sciences was a difficult subject to her, but the combination of both the MRA and the TCM may make the subject easy for all students. The greater percentage of the class applauded her response. This is how she responded.

$F_{MRA} L_1$: Physical Science is a difficult subject but if schools or teachers could use both MRA and TCM, maybe it can be easy for all of us as students who are learning Physical Science.

She continued to emphasise that MRA as a practical activity helps them as learners to understand the abstract part of the subject which is difficult to understand if only TCM is used. There was no further response to this item as most learners believed and indicated through the clapping of hands that $F_{MRA} L_1$ represented them well in her response.

The researcher moved on to the next item which was rather the same as the previous one, but instead of Physical Sciences as subject it looked at electricity and Ohm's law as topic. There was no response for some time as learners looked at those who have already responded to respond again to this item but the researcher discouraged that and pleaded with them requesting that they should all participate. This seemed to help as the answer came from someone who has never answered before. This learner, $F_{TCM} L_3$ tried to reply but asked for the researcher to repeat the question. On his response this clowning learner confirmed that electricity is a difficult topic for him. He

believed that the use of MRA may make this topic easy for him. The whole class laughed because of the boy's joking style of talking.

This seemed to have reminded them of their Physical Sciences teacher as they imitated one of his talking style "khuluma" and laughed at it. Khuluma is a Zulu word which means speak. F_{TCM} L₃ continued to state that TCM is also vital and recommends that it should not be thrown away but combined with MRA for better conceptual understanding in every lesson.

The researcher went on to further interview learners investigating their views on which other chapter or chapters will the use of MRA can benefit them in the conceptual understanding of Physical Sciences. This question was posed in this way:

Researcher: Look at Physical Science, think about the chapter or chapters that you knew in Physical Science and tell us which one or ones do you think will be better understandable for you, if we are using MRA?

One learner cheered F_{MRA} L₁ in isiXhosa who continued to prove her confidence by repeatedly offering answers to posed items by saying "thetha nje, betha sigoduke" in isiXhosa which means: do not be afraid of anything, just talk. In her response, this F_{MRA} L₁ thought that chemistry especially chemical bonding could be better understood to her if MRA is used as it helps visualising theory as it may provide them with visuals of both the reactant and the products. Nearly all the learners clapped their hands as means of showing their support to her response.

After being probed by the researcher to elaborate on her answer, she further indicated that learners do not easily forget things that they have seen compared to what they have heard. This is how F_{MRA} L₁ replied:

F_{MRA} L₁: I think the chemistry part will be better understood if it is taught with MRA. In chemistry we have got substances that are balancing with each other, so for us to see the real reproduction we have to see what is really going on there. Like for some of us we are not critical

thinkers. Others can do with TCM but others need to see the real thing. [F_{MRA} L₁]

The last item of the interview schedule wanted learners to state the manner in which the use of the MRA has inspired their Physical Sciences related careers and how. Two learners responded to this question, F_{MRA} L₁ indicated that she had a little interest in either chemical or electrical engineering but the use of MRA had increased her interest in engineering. This learner went on to state that her interest has been increased by the fact that MRA provided them with practical learning of things.

The last respondent was F_{MRA} L₃ who specified that her interest was to become a medical doctor, but that wish was overhauled by becoming a presenter as she thought that Physical Sciences was too difficult for her. As MRA hooked their attention, F_{MRA} L₃ noticed that paying attention to what one was doing during the lesson enabled her to get accurate results and that re-boosted her confidence in becoming a medical doctor again.

4.7. SUMMARY

This chapter presented the thick description of the results of the study. The next chapter will discuss results of the data analysis.

CHAPTER 5

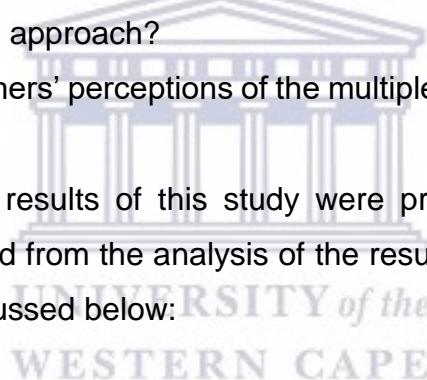
DISCUSSION

5.1. INTRODUCTION

This study attempted to investigate how could a Multiple Representations Approach be used to teach Ohms law in grade 11 Physical Sciences? More precisely, this study has been attempting to answer magnificently the following sub questions as advocated in chapter one:

- (i) What was learners' initial understanding of electricity?
- (ii) How were the Ohms law lessons taught using (a) the Multiple Representations Approach and (b) the traditional method?
- (iii) What were learners' understanding of Ohms law after the multiple representation approach?
- (iv) What were learners' perceptions of the multiple representation lessons?

The comprehensive results of this study were presented in chapter four. Themes that emerged from the analysis of the results which were presented in chapter 4 are discussed below:



5.2. LEARNERS' INITIAL UNDERSTANDING OF OHMS LAW

The pre-test scores revealed that grade 11 learners partly still remember some of the grade 10 electricity concepts while at the same time they have partly forgotten some. In the pre-test, half of the class scored less than 50% while the other half scored 50% and more (see Section 4.2). These results concur with Koopman (2004) who said in the South African context, learners are taught in a way that does not often allow them to develop knowledge and skills required in the next grade.

5.3. COMPARING THE TEACHING OF OHMS LAW USING BOTH THE MRA AND THE TCM

The MRA approach as it was shaped to be a hands-on group activity, created a conducive environment to facilitate constructive learning. The way in which this happens is briefly discussed below from section 5.3.1. to section 5.3.6. with these topics:

5.3.1. LEARNERS WERE FREE DURING THE MRA LESSONS COMPARED TO TCM LESSON

In all the three activities of the MRA approach in 4.3 all learners were actively involved as each had a role to play in the group from the first stage to the last stage of each activity. MRA is a hands-on activity which promoted maximum participation of learners in the learning process. Despite the fact that each one was assigned a duty to perform, it is indicated in 4.3 that all learners were free during the MRA. Their freedom boosted their confidence and they were free to ask for clarity whenever there was a need. As a result of their freedom and relaxation, learners cooperated and freely exchanged their ideas which led to spontaneous constructive learning (refer to 4.3.3).

There was a controllable chatting among group members in the MRA activities while TCM was dominated by silence. This means contrary to MRA lessons, TCM created dull learners (such that the researcher created jokes trying to stimulate their interest and make them feel at ease, refer to 4.4), who expect the teacher to spoon-feed them with information. MRA created learners who are responsible for their learning.

5.3.2. MRA'S AND CONCEPTUAL TEACHING STRATEGIES ARE MORE CONDUCIVE TO CONSTRUCTIVE LEARNING COMPARED TO THOSE OF TC METHODS

- *Discovery method, estimations, communicating, writing and listening through discussions and debates*

During Phet animations activity, learners estimated the effect of adding parallel resistors on resistance and current when both the temperature and voltage were kept constant. This aroused a great debate as they had different opinions. In this case some learners knew that adding resistance decreases the electric current and adding parallel resistors decreases the total resistance. After they were given a chance by the researcher to prove their beliefs through manipulating Phet animations on the laptops in their respective groups, they discovered that the addition of parallel resistors decreases the resistance and increases the electric current. Learners' observations while they were working on Phet animations lead to them discovering that the increase of the electric current was indicated by the brightness of the bulbs. They were also required to estimate the time that would be taken to fill the 1500 ml bottle if the 3 m and the 5 m long pipes respectively were used instead of 1m, 2 m and 4m long pipes. Learners communicated their results and understanding of Ohms law through writing, discussions and debates and used that to draw conclusions with the researcher facilitating which lead to learners discovering Ohms law. In these MRA activities, formulae, equations and symbols were used to convey understanding since science is a visual subject.

Section 4.3.1.4 started with learners taking control of their groups' sitting arrangements in the classroom. In their respective groups some learners spontaneously gave directions on what and how they should argue concerning multiple representations and science concepts learning hence presenting their leadership skills which were also strengthened during that process. In all the three activities of the MRA (i.e. water analogue, role play and Phet animations) learners observed, calculated, estimated, discussed, listened, investigated, recorded and reported. They solved problems through calculations, debates and estimations based on these activities and these indirectly gave learners a chance to reflect what they have learnt. Skills developed from these activities are among others which are considered essential for meaningful learning as Le Grange (2014) asserted that through reflections, inquiry and action on the part of the learner, meaningful learning takes place. It can therefore be concluded that MRA helped learners to

develop, exercise or show their leadership skills through communication, debate and discussion during the lesson.

- *Graph drawing and interpretation, formulae, equations and symbols.*

Learners related parts of both the role-play and water analogue with terms of Ohms law. The researcher believes that this was critical at these phases to link the parts of the water analogue and the role-play with the particular parts of the Ohms law so that the learners should not be left with an impression that they were simply playing a game (Guerra-Ramos, 2011). They drew graphs (in 4.3.1.4 and 4.3.2.) then interpreted those graphs both verbal and in writing during discussion session in 4.3.1.4 and Phet animations.

These graphs were drawn from the data they have collected from those three MRA activities unlike in the TCM where learners were given data to draw graphs instead of generating that data themselves. Generating data by learners on their own as in 4.3.3, also indicated their conceptual understanding of electric circuits. In these MRA activities, formulae, equations and symbols were used to convey understanding since science is a visual subject.



- *Representations*

Role-play, water analogue and Phet animations were the main three MRA activities used as representations in this study to teach Ohms law. All these aforementioned MRA activities lead to constructive learning by learners as cited in 2.3 and 2.4 in the literature review of this study.

- *Scaffolding*

During the MRA, probing questions were used among other things as a scaffolding technique. This scaffolds based into assessment offered support which facilitated students to respond to questions that were originally beyond their grasp. By incorporating scaffolding into assessment, learners were empowered to reason about the concepts and to an assessment promptly.

For example: i) Learners were asked to relate or associate electricity terms to what they have done in the water analogue and role play,

ii) They were asked what happens to current when the resistance changes in the Phet animations.

5.3.3. MRA OVERCOME SPECIFIC LEARNING DIFFICULTIES AND PROVIDE A STANDARD ASSESSMENT OF STUDENT UNDERSTANDING

- *Assessing learners' prior knowledge*

MRA lessons started by learners investigating the relationship between the electric current and resistance which were represented by the rate at which the 1500 ml bottle and the length of the pipe (longer or shorter), number of dropped stones and the path where runners run both in water analogue (4.3.1.) and role-play (4.3.2.) respectively. The comparison in these activities falls under the factors affecting resistance, a topic learnt by learners in grade 10 hence the MRA lessons are believed to consider learners' prior knowledge on which Ohms law is built. Furthermore, a pre-test which was conducted as indicated in 4.2. helped the researcher to determine the knowledge of students' understanding, conceptions, and misconceptions of electricity which is vital as basis of Ohms law.

- *Assessing learners' understanding of Ohms law*

Learners' understanding was assessed through a post-test. Its questions were based on what was taught to both groups and the language used was equivalent to their standard (Witzig et al., 2014). This was an up-to-standard post-test which was moderated by Physical Sciences specialists as indicated in 4.5. The test questions were categorised into three different categories based on Bloom's taxonomy of the cognitive domain of classifying questions as pointed out in 4.5.3.1.

As learners debated, discussed and shared information about the MRA activities, their level of understanding of Ohms law was unveiled, so through these activities including estimations and manipulation of apparatus in

experiments their level of understanding in Ohms law was frequently assessed throughout the lessons before the formal assessment.

- *MRA overcomes learners' learning difficulties*

There are two learning difficulties or challenges that have been noticed in the process of this study. They are language and overcrowded classroom and they are both discussed below:

i) Language

It is argued that language, through which meaning is communicated, negotiated and shared, is essential in the construction of scientific knowledge (Mc Dermott & Rakgokong 1996). To minimise learners' learning difficulties, code-switching was used during the teaching of Ohms law in both the MRA and TCM as indicated in 4.3.1. because learners indicated that English was a language barrier. Learners were also allowed to code-switch to their home language when reporting and discussing in 4.3.1.4. and throughout the process.

Through this practise of code-switching Diwu (2010) discovered that learners have a tendency to get higher marks than those who have not used code switching especially when they are required to show an understanding of the relationship between terms. The learner performance in a subject is affected by home language of a learner and the medium of instruction or Language of learning and teaching (LoLT) at schools. The chance of learners providing the correct explanation is not good when they are unable to interpret a question in the examination because of LoLT (Dhurumraj 2013).

ii) Class size and limited resources.

The grade 11 Physical Sciences class of this school is an overcrowded classroom as it exceeds 50 learners though only 48 learners participated in this study (refer to 4.5.1). Limited resources in this school as indicated in 3.1 and large classes make both MRA (practical) and TCM (theory) lessons to become very difficult while the availability of resources in schools for both theory and practical lessons is essential for the success of the subject. Although the class was overcrowded, MRA involuntarily made learners to

work on groups, it also promoted cooperative learning and sharing of ideas. As a learner-centered approach, MRA drew and retained learners' attention and interest and that overcame the disadvantages of overcrowded classroom like noise, loss of interest, minimum participation etcetera.

5.3.4. LEARNERS' INTEREST WHICH WAS DISCOVERED DURING THE MRA REDUCES DROP OUT RATE OR NUMBER OF SCHOOL LEAVERS

When the groups' pre-test and post-test scores were compared in 4.5.2, the following data emerged: 24 experimental group learners against 21 control group learners wrote the post-tests as they were 24 learners in both groups in the pre-test. This indicates that the control group has decreased by 3 learners. Although the difference in these groups is only 3, this means a great loss if the study was taken;

- i) For all classes and grades instead of one class.
- ii) As a full academic year program instead of just a special study as it was.

Retaining more learners in the experimental group than the control group in this study may be attributed to the interest created by the MRA lessons to learners as shown in analogy, role-play and Phet animations compared to the dullness which is noticed in TCM as 4.4 indicates that learners were silent and only spoke when answering questions or responding to the researcher's command. Moreover, MRA lessons in this study were designed such that they were fun by making science to be both attractive and exciting to learners as indicated in MRA activities. That could be another reason that retained more learners to continue with the study up to the end compared to the control group as Dolo (2012) suggested that curriculum pedagogy should make school science attractive (as to retain learners from dropping out), stimulating and a rewarding experience. Maseko 2017 that the key to encourage learners to be interested in science is building curiosity through experiments.

5.3.5. MRA IS RELEVANT TO THE CURRENT SA CURRICULUM (CURRICULAR SALIENCY)

Frequently in the MRA activities learners spontaneously and volunteered to perform their duties while they only responded to the researcher's instruction in the TCM lessons. This means MRA produced learners who are responsible for their learning hence the envisaged responsible citizens as advocated by CAPS are being produced through it.

All the MRA activities involved in this study were practical experiment or investigation which were hands-on activities in nature. Learners were actively involved during those practical hands-on activities as they were investigating, demonstrating and experimenting. This practical work was integrated with theory as the researcher continuously explained and re-emphasised to strengthen certain content knowledge in the progress of the lesson.

Learners created their own meaning by means of reducing knowledge to order, from the information supplied to them through the use of questioning. This promoted knowledge and skills in scientific inquiry and problem solving. MRA is contrary to rote-learning which was the backbone of the pre-democracy curriculum and is in accordance with the current South African curriculum CAPS (2011) which is discussed as the rational of the study in chapter 1.6. as it promotes a teaching pedagogy that promotes development of critical thinking, scientific reasoning and strategic abilities among learners

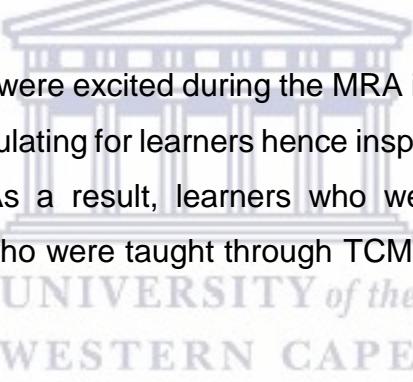
5.3.6. MRA LESSONS PLANNING STRUCTURE

All the three MRA activities were planned such that they have three steps which are:

- Hands-on activities like: engaging learners through play in role play, doing the activity in water analogue and working on computer in Phet animation as the first step of each activity.

This step was followed by recording their observations including data collection, doing calculations, estimations, discussions, making relationships between the activity and the electricity terms, drawing and interpreting graphs from the data collected from the activity.

The last step was drawing conclusions as to what happens to one part of Ohms law when one part is manipulated and this was based on the observation made on activities. All these steps were purposefully planned to lead learners to the desired learning outcome which shows how the output depends on the input. In Ohms law the input is voltage and the output is electric current therefore activities of MRA lead learners to discover that an increase in the input leads to the increase in the output. These steps were designed in such a way that they lead learners towards the discovery of Ohms law.



The fact that learners were excited during the MRA indicates that the learning environment was stimulating for learners hence inspired them to learn science (Dhurumraj, 2013). As a result, learners who were taught through MRA outperformed those who were taught through TCM as appeared in the post-test outcomes.

The results in 4.3 display that learners were actively involved throughout the MRA lessons hence the MRA lessons were not planned to transfer knowledge to learners but were planned for learners to create knowledge. Scientific thoughts cannot be “transferred into” a passive learner instead they need to be mentally active for learning to take place as they were both mental and physical active by being engaged in finding out what was happening instead of just witnessing something being presented to them (Kollöffel & de Jong, 2013).

The act of predicting or estimating by learners in 4.3.1, 4.3.1.3 and 4.3.3. including analyzing and interpreting the collected data in 4.3.1.3, proved that they were engaged in a process of inquiry learning and that concurs with (Jaakkola, Nurmi, &, 2010) and (Trundle & Bell, (2010). A stimulating teaching

environment is revealed in 4.3.1.1 and 4.3.3 as learners were free, relaxed and talking loudly. Knowledge is acquired with the assistance or scaffolding provided by an adult or more mature learners (Charlesworth & Lind, 2007). Through the use of computer animations in 4.3.3, giving pre-cautions in 4.3.1.1 and preparing field in role play, learners' safety was ensured and costs were minimised through the use of less expensive and less hazard equipment in all MRA activities compared to laboratory equipment. Metiouii and Trudel (2012) are concerned with the safety of learners and cost effectiveness of learning material.

Learners were sharing ideas and coaching each other during the role play and those actions revealed cooperation among learners (Smith, 2001). Knowledge construction was ensured as per Brown et al. (1989) who claim that social constructivism is the origin of knowledge construction as it is the social intersection of people and interactions that involve sharing.

5.4. COMPARING EXPERIMENTAL AND CONTROL GROUPS' PERCENTAGE CHANGE FROM THE PRE TO POST-TEST SCORES

The post-test scores indicated that the control group improved by 11% in the category of < 50% scores from the pre-test scores to the post-test scores whereas the experimental group dropped by 3%. The control group also improved by 39% as they increased from 21% in the pre-test to 60% in the post-test in the category of scores which are = 50%. Contrary to this, the experimental groups improved by 1% only as it moved from 17% in the pre-test to 18% in the post-test.

In the post-test scores, 52% of the experimental group learners scored > 50% against 0% of the control group, making a difference 52%. In addition to this, results from the comparison of the groups' pre-test with post-test scores indicated that the experimental group improved its scores more compared to the control group in the category of learners who scored $\geq 50\%$. The experimental group improved by 13%, moving from 67% in the pre-test scores to 70% in the post-test scores while the control group decreased by 9%

moving from 71% to 60% in the post-test scores (See 4.5.2). This may result from the fact that the experimental group was exposed to MRA while the control group was only treated using the traditional teaching method.

Although the control group outperformed the experimental group by 1% in the lower order question, the experimental group outperformed its counterparts in the other two categories which are middle and higher order questions by 9% and 13% respectively (see 4.5.3). Table 25 and figure 12 give further clarity for this. This indicated that:

- MRA helped learners perform better in both the middle and the high order questions hence developed and improved learners' reasoning and created critical thinkers
- MRA improved learner attainment compared to traditional teaching approach as this is also indicated by F_{AL1} during the interviews.

Table 25. Table indicating the percentage change per group from the pre-test scores to the post-test scores.

Categories	Experimental group	Control group
Scores < 50%	-3	11
Scores = 50%	1	39
Scores > 50%	52	-50
Scores ≥ 50%	13	-9

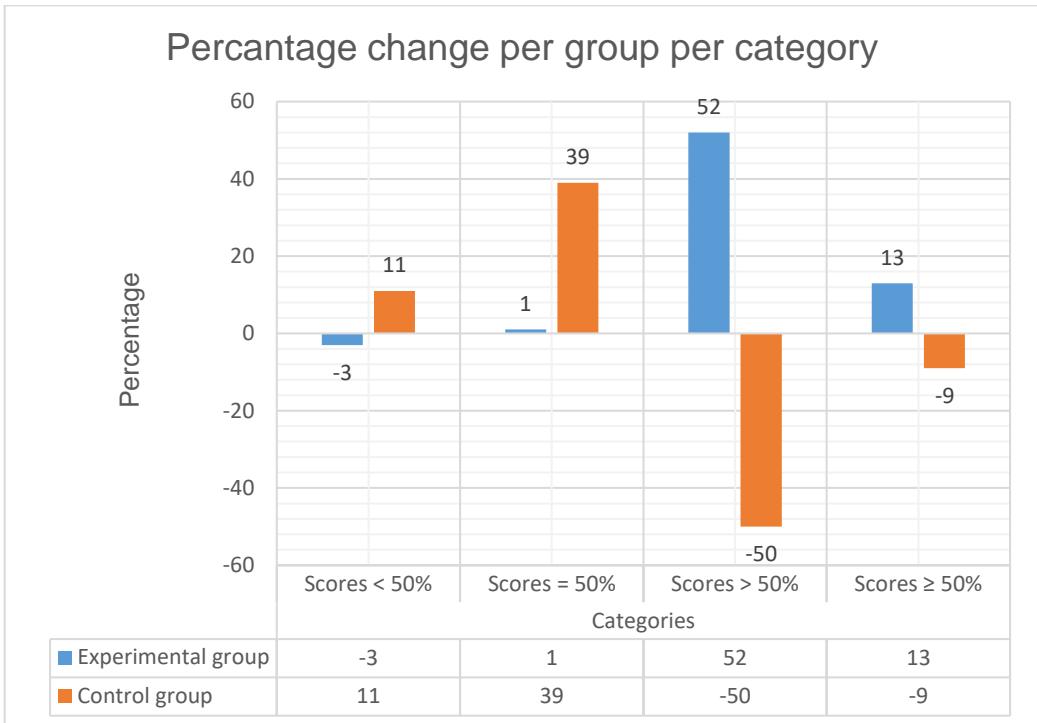


Figure 12. Figure showing the percentage change per group per category.

5.5. LEARNERS' PERCEPTION OF MULTIPLE REPRESENTATIONS

Sections 5.5.1 to 5.5.3. below give brief details of the themes that emerged from the learners when they were interviewed.

5.5.1. MRA IS PRACTICAL AND HELPS VISUALISING THE ABSTRACT THINGS/ CONCEPTS

Phet animations of Ohms law supported learners in their conceptual learning as it helped them to see abstract concepts like movement of electrons. This was revealed by the majority of the learners who supported FA L1 during interviews in 4.6. when she said MRA helped them to visualise theory. She went on to estimate that it could help them to visualize the reactants and the products in chemistry part of Physical Sciences. This concurred with one of the teachers who were interviewed by Waight and Gillmeister (2013) in their study who stressed that the models allow the learners at least to visualize some of the conceptual things

5.5.2. MRA IS RECOMMENDED OVER TCM EVEN THOUGH TCM CONSUMES LESSER TIME COMPARED TO MRA

During interviews in this study, 67% of the learners recommended MRA over the TC stating different reasons like improving their conceptual understanding and developing sustainable learnt knowledge among others.

Although MRA is recommended by the majority of learners over TCM, 37% of the class indicated that it consume a lot of time compared to TCM. These learners concurred with many teachers who are claimed to possess the same belief (Sibam, 2014). Results indicated that this time consuming disadvantage of MRA can be decreased or even nullified if MRA is not rarely but rather frequently used as 4.3.1.2, a four meter - long pipe activity of water analogue took less time to be completed compared to 4.3.1.1 although they were the identical activity. The researchers' strong command and control over his or her class may also help in this problem as it is indicated three times in 4.3.1.3, and in other parts of the MRA.

5.5.3. MRA ASSISTS TO MAKE DIFFICULT THINGS EASY TO UNDERSTAND

As a response to item 3 of the interview schedule, four learners itemized electricity and chemistry as difficult chapters while two some indicated that Physical Sciences as a whole is a difficult subject. Irrespective of these difficulties, these learners boldly believe that the use of MRA will help to make the aforesaid chapters and Physical Sciences easy to understand respectively. Their argument was based on the facts that MRA visualizes the abstract phenomena hence not easy to forget what they have seen and it is practical as opposed to theory and inactiveness of TCM.

In the TCM, the researcher stated Ohms law and wrote it on the chalkboard while learners wrote notes and had their textbooks open as the lesson continued. This is contrary to MRA where learners through the hands-on activities discovered Ohms law among other things with the researcher's guidance and consolidation of the discovered information.

5.11. SUMMARY

Chapter 5 dealt with the discussion and interpretation of the results. Themes emerged from the data collected were analysed and explained in details in this chapter. The following chapter will deal with conclusion, recommendations and implications of the study.



CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. INTRODUCTION

In chapter 5 the results of the study were discussed and interpreted. This chapter presents summary of the results and results reported and discussed from chapters 4 and 5 respectively. In addition, implications of the results and limitations pertaining to the study are discussed, conclusions are drawn and recommendations for further studies are presented.

The aim of this study was to address the research problem by answering the following research question: How can a Multiple Representations Approach be used to teach Ohms law in grade 11? More specifically, the research questions as advocated in chapter one that this study has been attempting to answer were the following:

The sub-questions being the following:

- (i) What was learners' initial understanding of electricity?
- (ii) How were the Ohms law lessons taught using (a) the Multiple Representations Approach and (b) the traditional method?
- (iii) What was learners' understanding of Ohms law after the multiple representation approach?
- (iv) What were learners' perceptions of the multiple representation lessons?

6.2. OVERVIEW OF THE SCOPE OF THE STUDY

6.2.1. CHAPTER 1: RATIONALE FOR THE STUDY

This chapter delivered a background on the recent teaching in multiple representations in the teaching of Ohms law in grade 11 Physical Science. Description of the research problem within the context of the school, current practices and limitations lead to the formulation of the research questions for this specific study.

6.2.2 CHAPTER 2: LITERATURE REVIEW

Relevant literature was reviewed in this chapter the aim of which is to provide a theoretical framework for the study. Both the pedagogical content knowledge, By Shulman and constructivist views based on the theories of Piaget and Vygotsky including the current literature are presented to support the development of multiple representations in science. Global and national studies highlighted some of the research conducted on multiple representations.

6.2.3 CHAPTER 3: METHODOLOGY

A detailed description of the methodology employed to investigate the use of a Multiple Representations Approach to teach Ohm's law in Grade 11 Physical Sciences is provided in this chapter. In addition to that, the data collection procedures, theoretical framework and data analysis employed to answer the research question were described.

6.2.4 CHAPTER 4: RESULTS

The results of the research are reported on this chapter. These results were established on the data collected and the process of analysis integrated in this study.

6.2.5 CHAPTER 5: DISCUSSION

The discussion chapter focused on how Multiple Representations Approach was used to teach Ohms law in grade 11 learners and how they responded to it.

6.2.6 CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Summary of the study is provided and the major results as well as the implication and limitations are highlighted in this chapter of the study. Recommendations for future study were also provided.

6.3. MAJOR RESULTS (FINDINGS) OF THE STUDY PER RESEARCH QUESTIONS

It is evident from the structure of the research report that the research questions formed a central focus of the research process. As cited in chapter three, two groups that were involved in the study namely, an experimental and control groups wrote a pre- and post-test. The experimental group received a treatment as an intervention and the new instructional strategy involving a Multiple Representations Approach was exposed to them while the control group was taught using TCM, a traditional teaching method before they both wrote the post - test.

In order to achieve the overall objective of the study, the literature from the fields of science education, constructivism theory, pedagogical content knowledge (PCK) were reviewed and the outcomes of this review helped the researcher to formulate the design of the study.

The major results of the study can be summarized as follows:

- LEARNERS' INITIAL UNDERSTANDING OF OHMS LAW.

The pre – test results scores indicated that learners have partly forgotten some of the content knowledge they learnt in the previous grade as 50% of the class achieved less than half of the total mark of the pre-test (see 4.2.).

- THE TEACHING OF OHMS LAW USING BOTH THE MULTIPLE REPRESENTATIONS APPROACH AND TALK AND CHALK METHOD (TRADITIONAL TEACHING APPROACH).

When comparing the teaching of Ohms law using both the Multiple Representations Approach and talk and chalk method the results exposed that the learners' performance in Physical Sciences is positively affected by the MRA as outlined below. The experimental group outclassed MRA is in accord with the current South African current curriculum (CAPS). MRA lessons are specially planned bearing in mind the learners' needs and challenges such as class size and available resources. MRA overcomes most

learning difficulties science learners are faced with compared to TCM. It assesses a variety of learners' skills in different forms and at different stages of the lesson.

MRA helped learners to develop, exercise or show their leadership skills through communication, debate and discussion during the lesson. The number of learner who participated in the study from the initial stage to the last stage in both the MRA and TCM indicated that many learners from the TCM group withdrew from participating up to the last stage of the study compared to the MRA. As MRA lessons progressed experimental group learners displayed a great interest and motivation compared to the control group in the TCM. This lead to the deduction that MRA minimizes drop outs or school leavers as it arouses learners' interest.

- LEARNERS' UNDERSTANDING OF OHMS LAW AFTER TAUGHT THROUGH MRA.

The post-test results indicated that MRA helped learners perform better in high order questions and improves learner attainment compared to traditional teaching approach.

- LEARNERS' PERCEPTION OF MULTIPLE REPRESENTATIONS

The discussions that took place in the interview revealed that learners taught and exposed to MRA, found this method useful and facilitative to their learning. They proclaimed that MRA simplifies difficult concepts because it is practical and helps to visualise the abstract things/ concepts. They recommended MRA over TCM even though TCM was credited for consuming lesser time.

6.4. IMPLICATION OF THE STUDY

The data results provided in chapter four of this study have the implications on instructional practice that are discussed below.

Data analysis and interpretation of learner diagnostic pre-tests indicated that learners only holds half of the previous grade's knowledge of electricity (Ohms law) and that helped the researcher to structure his lesson based on both the

learners' prior knowledge and the expected lessons outcome in the current grade.

- The implications of this study are that Physical Sciences teachers should first diagnose, make use of learners' existing knowledge and acknowledge its importance for learners to learn more easily as this concurs with (Fourie et al 1991).

Learners informally acquired science knowledge during the MRA representations. For example, in role-play they concluded that the number of the rate at which stones were dropped is directly proportional to the number of stones supplied to the runner. This was later associated with Ohms law to indicate that electric current is directly proportional to the voltage supplied.

- This implicates that formal science lessons should be designed such that they trigger and stimulate learners to informally acquired and display science knowledge which in turn should be accepted and strategically shaped by the teacher for acceptance in the formal school science.

Learners' interests were aroused in the MRA lessons compared to TCM and by so doing it could motivate them not to drop out of the school.

- The implication is that teachers should create fun and plan interesting hands-on practical lessons to catch learners' focus hence minimises drop outs. These hands-on activities accommodate changes brought by shift from traditional approach to CAPS because they are practical hence equipping learners with scientific inquiry, intellectual and investigative skills.

The experimental group outclassed the control group by 10% compared to 6% in middle and higher order questions. This same experimental group's post-test score improved by 20% from the pre-test score in the category of learners who scored $\geq 50\%$ compared to 10% of the control group.

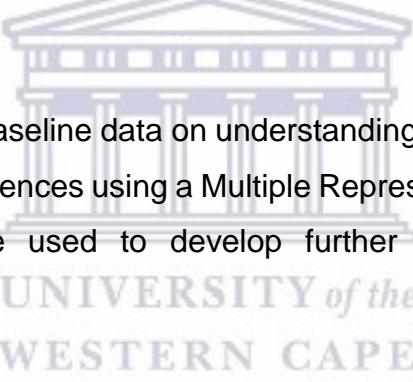
- The implication is that MRA increases the number of learners who attain more than 50% and that increases their chances to enter higher

education institutions (HEI) as this 50% attainment per subject is the minimum threshold to enter the majority of science careers in HEIs. This addresses the TIMMS 2011 report where they argued that science learners have limited future possibilities in science careers.

- MRA addresses the South Africa's department of education minister's concern of Physical Sciences low pass rate as it is discussed in 1.6 because it increases the passing rate of Physical Sciences.

The MRA lessons used inexpensive material for the water analogue while the material that was used for role play costed no money yet served the purpose.

- The implication is that Physical Sciences teachers as experts should create lessons that are non-sophisticated, suitable for rural learners yet relevant to science curriculum using inexpensive self-innovated material according to their school needs.



This study provided baseline data on understanding of teaching Ohm's law in Grade 11 Physical Sciences using a Multiple Representations Approach. This study could also be used to develop further studies to explore this understanding.

6.5. LIMITATIONS OF THIS STUDY

The limitations of this study are that this is a case study hence only one school is used. The duration of investigation allowed by the school was only one academic school term and the investigation was conducted only on weekends. This gap between weekends could have affected the study negatively and an extended continuous period of research may have added greater significance to the data collected and analysed.

However, the nature of this mixed research allowed for the emergence of thick descriptions of the individual. This study does not infer any generalizations based on the results. Another limitation is that learners were unfamiliar to the

equipment used as it was the first time they used it. Learners had an English language barrier hence code-switching was used in this study.

6.6. RECOMMENDATIONS

Based on the results of the study, the following is recommended:

Similar research studies could be conducted with a larger sample size and in different high schools for the comprehensive view of the results to a larger population. Multiple Representations Approach could be implemented for different, science topics and for teaching different subjects. During the interviews learners proclaimed that MRA simplifies difficult concepts and helps to visualise abstract concepts. It is therefore recommended that MRA should be used in the lower grades too so that learners could be in a position of doing science subjects at high school level. In turn, this will give them chances to enrol in science careers at HEI levels. This study was a short-term study; long-term Multiple Representations Approach research studies could be tested for more data collection.

Additional attention from the curriculum designers, LTSM developers and teachers on the topic electric current (Ohms law) could improve learners' mark attainment (Hesse & Anderson, 1992). It is recommended that a free learning environment be created where science learners could be afforded a chance to communicate what they have learnt, through investigative discussions and debates which are characteristics of constructive classroom. In this way learning will resemble the work conditions as people always work in groups and communicate in their work place as oppose to the silence many teachers practice in their classrooms because of the traditional teaching approach's influence. Educators are expected to consolidate and shape the information discovered by learners in these investigative debates and discussions to be an acceptable science concept.

Shulman (1987) recognises the critical role played by the development of pedagogical content knowledge for teachers in training and also for those who

are already in practice as vital for teaching and learning (Depaepe et al., 2013). Teachers should be creative enough to innovate and improvise where a shortage of resources is experienced as it is the case in this rural school. This is impossible where teachers do not master the subject content knowledge they are expected to teach. It is therefore recommended that curriculum designers in HEIs should design a curriculum that will produce teachers who will be able to create/ develop fun, interesting informal science play activities to encourage the love of science in learners.

Furthermore, continuous professional development (CPD) by the department of education is recommended to nurture teachers' PCK and advance their competence in the subject (Loughran et al., 2012; Novak, 2010; Summers et al., 1997). It is recommended that these CPDs should in addition focus on identifying and handling science learners' learning barriers, subject content knowledge and topic specific content knowledge so that ESL learners can benefit from new teaching strategies as Lee (2005) claims that the lack of command of the English language will create learning barriers which could hinder progress of ESL learners in Sciences.

3.7. CONCLUSION

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This study considered a Multiple Representation Approach to teaching Ohm's law to learners. This was conducted in a rural school in an education district of the Eastern Cape. The results indicated that the MRA could be useful to learners in this context specifically to improve learners' understanding of abstract science concepts.

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APPENDICES

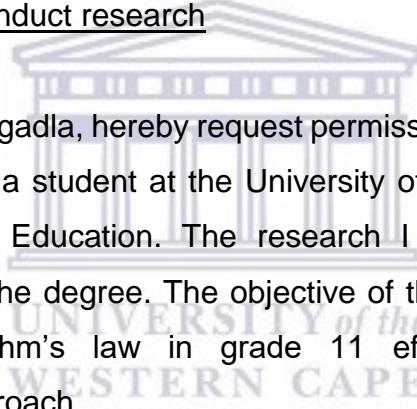
APPENDIX A. LETTER TO THE SCHOOL PRINCIPAL

P.O. Box 893
Matatiele
4730

The Principal
Magadla High School.
P.O. Box 729
Matatiele
4730

Dear Sir

Re: Permission to conduct research



I, Anadin Zakhele Magadla, hereby request permission to conduct a research in your school. I am a student at the University of Western Cape studying Masters in Science Education. The research I wish to carry out is a requirement to fulfil the degree. The objective of the study is to investigate the teaching of Ohm's law in grade 11 effectively using Multiple Representations approach.

I pledge and promise not to disrupt any programs of the department and the school. I will use the time I get with the learners, while I conduct the study, to benefit the learners and the school. I will work within the framework of the school and department's disciplinary arrangements.

I have also written a letter to the Education Head Office in this regard.

Yours in Education

A.Z. Magadla
0723429505,
azmagadla@gmail.com

APPENDIX B. LETTER TO THE ETHICS COMMITTEE

P.O. Box 893
Matatiele
4730

The Chairperson - Ethics Committee
University of the Western Cape
Bellville
Cape Town, 7493

Dear Sir / Madam

Re: Permission to conduct research

I, Anadin Zakhele Magadla, hereby request permission to conduct a research at a school. I am a student at the University of the Western Cape studying Masters in Education. The research I wish to carry out is a requirement to fulfil the degree. The objective of the study is to investigate the teaching of Ohms law in grade 11 effectively using Multiple Representations approach. I pledge and promise not to disrupt any programs of the department and the school. I will work within the framework of the department's disciplinary arrangements and the parents of the learners.

I have also written a letter to the school in this regard. I have a strong belief that the research will benefit the school and other schools that may be affected by the challenge in question.

Yours in Education
A.Z. Magadla
0723429505,
azmagadla@gmail.com

APPENDIX C.**LETTER TO LEARNER'S PARENT**

P.O. Box 893

Matatiele

4730

Dear Sir/Madam

Re: Permission to conduct research

I, Anadin Zakhele Magadla, hereby request permission to involve your child in a research I am conducting in his/her class.

I am a student at the University of Western Cape studying Masters in Education. The research I wish to carry out is a requirement to fulfil the degree. The objective of the study is to investigate the teaching of Ohms law in grade 11 effectively using Multiple Representations approach.

I pledge and promise not to disrupt any learning time of your child. I will use the time I get with the learners, while I conduct the study, to benefit the learners and the school. I will work within the framework of the school and department's disciplinary arrangements.

I have also written a letter to the Education Head Office in this regard.

Yours in Education

A.Z. Magadla

0723429505

azmagadla@gmail.com

APPENDIX D. PARENT CONSENT FORM

UNIVERSITY OF WESTERN CAPE
FACULTY OF EDUCATION

CONSENT FORM

I, _____ (Full name of parent/guardian in print), hereby give permission for my child to participate in a research study which is conducted by Anadin Zakhele Magadla (M Ed) who is a student of the University of the Western Cape and is involved in the planning and implementation of this research project. I understand that the above research project has been explained and specified and those involved intend to share the research in the form of publications.

I also understand that:

- My child's participation is a personal decision and entirely voluntary.
- There are no rewards for granting permission.
- S/He will not be penalised for granting permission.
- S/He have the 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.
- His/her own identity shall remain anonymous.

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

Signature _____

Date _____

APPENDIX E. LEARNER CONSENT FORM

I, _____, a learner at Magadla High School in grade 11 herewith grant permission to be a participant in the research study of Mr A. Z. Magadla, a MEd. degree student at the University of the Western Cape. I am aware that my participation in this study will not influence my results at school.

Signed:

Learner: _____

Date :_____



APPENDIX F.

OBSERVATION SCHEDULE

Talk and chalk method (TCM)	Dimension	Indicator	Tally	Comments
	1. Learner participation.	i) Asking questions		
		ii) Giving explanations		
		iii) Discussing		
		iv) Debating		
		v) Hands-on. (i.e. practically)		
		vi) Taking or writing notes		
	2. Teacher participation.	i) Asking questions		
		ii) Giving explanations		
		iii) Discussing		
		iv) Debating		
		v) Hands-on. (i.e. practically)		
		vi) Taking or writing notes		

Role play (MRA).	Dimension	Indicator	Tally	Comments
	1. Learner participation.	vii) Asking questions		
		viii) Giving explanations		
		ix) Discussing		
		x) Debating		
		xi) Hands-on. (i.e. practically)		
		xii) Taking or writing notes		
	2. Teacher participation.	vii) Asking questions		
		viii) Giving explanations		
		ix) Discussing		
		x) Debating		
		xi) Hands-on. (i.e. practically)		
		xii) Taking or writing notes		

Water analogue (MRA).	Dimension	Indicator	Tally	Comments
	1. Learner participation.	xiii) Asking questions		
		xiv) Giving explanations		
		xv) Discussing		
		xvi) Debating		
		xvii) Hands-on. (i.e. practically)		
		xviii) Taking or writing notes		
	2. Teacher participation.	xiii) Asking questions		
		xiv) Giving explanations		
		xv) Discussing		
		xvi) Debating		
		xvii) Hands-on. (i.e. practically)		
		xviii) Taking or writing notes		

Phet simulations. (MRA)	Dimension	Indicator	Tally	Comments
	1. Learner participation.	xix) Asking questions		
		xx) Giving explanations		
		xxi) Discussing		
		xxii) Debating		
		xxiii) Hands-on. (i.e. practically)		
		xxiv) Taking or writing notes		
	2. Teacher participation.	xix) Asking questions		
		xx) Giving explanations		
		xxi) Discussing		
		xxii) Debating		
		xxiii) Hands-on. (i.e. practically)		
		xxiv) Taking or writing notes		

APPENDIX G. INTERVIEW SCHEDULE

ITEM 1.

How do you compare your pre-test scores with your post-test scores? (achieved 50%, less than 50% or greater than 50%).

ITEM 2. (For the experimental group only).

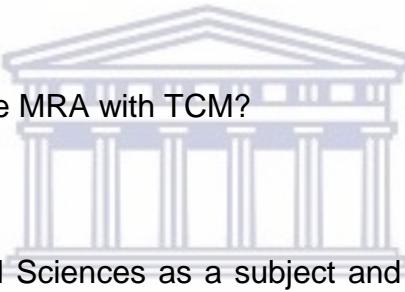
How would your post-test score be affected if you were taught through TCM only before writing the post-test?

ITEM 3. (For the control group only).

How would your post-test score be affected if you were taught through TCM and MRA before writing the post-test?

ITEM 4.

How do you compare MRA with TCM?



ITEM 5.

Look at the Physical Sciences as a subject and state whether it is an easy or difficult subject for you and state whether the teaching methods used will have an effect on how you perceive the subject physical Science. Which method will bring change to your understanding and explain?

ITEM 6.

Look at electricity as a chapter (ohms law) I know it is not the first time for you to meet it. You have done it in grade 10. State whether the teaching methods used will have an effect on how you perceive the chapter (ohms law) /electricity.

Which method MRA or TCM will bring change to your understanding and explain?

ITEM 7.

Look at Physical Science, think about the chapters that you know in Physical Science and tell us which chapters in Physical Sciences you think they may be better understandable for you if we are using MRA.

ITEM 8.

Do you have any interest in a career which is related to Physical Science? Explain your answer.

ITEM 9.

Whether you answered yes or no, now that you have been taught in MRA. has that type of teaching changed you (discouraged or boosted you), to become more interested in Physical Sciences careers?



APPENDIX H. CODED INTERVIEW (SAMPLE)

Themes represented by their colours.

Colour represents that MRA is practical and visual.

Colour represents that Recommends MRA over TCM.

Colour represents that combine both TCM and RMA.

Colour represents that prefer TCM.

Colour represents that Physical Sciences is difficult.

Colour represents that MRA helps one to easily remember what has been taught.

Colour represents that MRA consumes more time compared to TCM.

ITEM 1: How do you compare your pre-test scores with your post-test scores?

(50%, less than 50% or greater than 50%). Learners took about 30 seconds before responding to this question, only one learner responded.

F_{MRA} L₁: I started from 50% but now suddenly I am changing to greater than 50% score.

Researcher: Are your marks now more than 50% in the post-test?

F_{MRA} L₁: Yes, sir.

The researcher asked for some more responses but there was no response from the learners. He then moved on to the next item.

ITEM 4: How do you compare MRA with TCM?

F_{MRA} L₂: Uh sir I prefer uh... TCM method because it saves a lot of time sir and it trains our minds to remember fast.

Researcher: (making a follow up question). Does it save a lot of time?

F_{MRA} L₂: Yes.

Researcher: Does that means the MRA consumes a lot of time?

F_{MRA} L₂: Yes, teacher! it is time wasting.

Researcher: And what do you say about TCM, what does it do to your minds?

F_{MRA} L₂: It trains us to think logically and very fast. TCM trains us to remember things as they were said.

ITEM 5: 'Look at the Physical Sciences as a subject and state whether it is an easy subject for you or it is difficult and state whether the teaching methods used will have an effect on how you perceive the subject Physical Sciences. Which method will bring change to your understanding? Explain.'

F_{MRA} L₁: Physical Science is a difficult subject but if schools or teachers could use both MRA and TCM method, maybe it can be easy for all of us as students who are learning Physical Science, because it has chemistry part where we have done practical so it would be easy.

The majority of the class says Injalo (meaning we agree with her).

F_{MRA} L₂: If both methods are used, maybe it can be easy for all of us as students who are learning Physical Science. (Pause and continues)yes because it has the chemistry part where MRA is mostly done. do practical and the theory part which is Physical Sciences so if we use both MRA and chalk and... (got stuck) and continued TCM and learner continues so it could be easy.

Learner: Nantso ke!! one learner said that in IsiXhosa which means "That is it".

Researcher: Another one.

F_{TCM} L₂: uhh! MRA is very good because if you are working on different things, when it comes to test you then remember what you have viewed and what you have seen. But coming to... talk and chalk method it is kinder hard to remember when you are writing a test. There was a cheering and clapping of hands by the majority of the class showing that they agree with her on what she said. (one learner shouted Halala).

F_{TCM} L₂: I recommend the MRA because it helps us learners to understand things differently because we see them unlike when you (teacher) write them on the board or the paper.

ITEM 6: Look at electricity (ohms law) as a chapter, I know it is not the first time you come across or meet it. You have done it in grade 10. State whether the teaching methods used will have an effect on how you perceive the chapter (ohms law) /electricity. Which method MRA or TCM will bring change to your understanding and explain?

There was no response again.

Researcher: Can someone respond please.

All learners look for a response from the learners who have responded already, no new learner was prepared to respond.

Researcher: It will be Siphelelo, Zodidi and Abongile. (learners laugh as there is no Zodidi but Zizipho in their class, 'Come Matubatuba.' A new learner stood up not the one called by the researcher. (all these are pseudonym).

Some learners indicated that someone is ready to respond by saying, shhh... shh (quite quite).

Researcher: Ok let us give her a chance.

This learner indicated some un-comfortability as it was his first attempt to respond.

F_{TCM} L₃: Kanene iquestion ibithini sir? Meaning what was the question sir?

This is the learner's response after the researcher repeated the question for him.

F_{TCM} L₃: Awesome, for me electricity is a challenging topic. But I think MRA will make electricity much easier. I am talking about myself.

Learners laugh at this until the researcher has to strongly calls their attention back.

F_{TCM} L₃: continues, uhm MRA is much easier "kodwa nayo i-TCM iyazama" (this means "but even this TCM method is trying") but ingena kancinci (but

slowly it gets there) they laugh at her until the researcher calls for another learner's response.

In short this learner believes that MRA is much easier but TCM is also trying a lot to make things easy.

Researcher: Another answer please. (no response)

ITEM 7: Look at Physical Science, think about the chapters that you know in Physical Science and tell us which chapter(s) in Physical Sciences may be better understandable for you if we are using MRA?

Researcher: yes, sisi (yes sister)

Learner at the background: Betha sigoduke, meaning talk/say everything. (referring to the one responding)

F_{MRA} L₁: I think the chemistry part will be better if teaching with MRA, in chemistry we have got substances that are balancing with each other so for us to see the real reactions and products formed we have to see what is really going on there. Like for some of us we are not critical thinkers. Other can do well with TCM but others need to see the real thing.

F_{MRA}L₁: Yes, and clapping hands for her to show that they agree with what she says.

Researcher: So you all say you?

F_{MRA}L₁: Yes.

Researcher: So you say some of these things cannot be seen, they are only theoretically? Yet you need to see these things sometimes.

F_{MRA}L₁: Yes.

Researcher: So the MRA helps you to see things as they are?

F_{MRA}L₁: You do not easily forget things that you see.

Researcher: Is there anyone? There was no answer.

Researcher: The last question is.....

Learners: Yes!!! Yes!! (leaners indicated that they were tired by being happy when the researcher announces that this was the last interview item.

Researcher: Do you have any interest in a career which is related to Physical Science?

Learners: yes

Researcher: Whether your answer is yes or no, now that you have been taught in MRA. has that type of teaching changed or give you anything concerning your career in Physical Sciences, has it changed you or boosted you to be more interested in Physical Sciences. I want you to compare your levels of interest in Physical Science careers now before you were taught using this type of teaching and now after you were taught.

Researcher: Is my question clear or not clear?

Learners: No not clear, but some says clear.

Researcher: If it is clear come with an answer now, (there was no answer).

Researcher: Let me repeat again. Do you have any interest in Physical Sciences career? Do you want to further your studies, to do something that has something to do with Physical Sciences after you have passed matric?

Learners: some learners indicated that they understood the question while indicated the other way round.

Researcher: But now whether you say yes or no, I want you to look at you before I taught you using MRA and then after that. Maybe you say before I was taught using MRA I was not interested in Physical Sciences careers but now I am or you say yes I was interested in Physical Science careers but less than now or more before now. May be I have discouraged you now, you say no this one I have seen now it is difficult, I do not want anything after I have taught you using this, that is what I want you to say. Is it clear now or it is still not clear?

Learners: Clear.

Researcher: Can someone come with an answer. (pointing a learner who indicated that she is ready to respond) come on.

F_{MRA}L₁: I have interest in careers involving Physical Sciences, but it was less than now, I want to be chemical engineering or electrical engineering, but I never taught I could ... literally be able to use the **Physical Science equipment practically** because we never used **MRA method**, but now it is **easier**.

Researcher: Follow up question is when we were dealing with MRA, what is it in MRA that you think it rose your interest. Which... what thing exactly in this MRA that you think it boosted your interest in Physical Sciences career.

F_{MRA}L₁: Because we talked about something then **we did it practically, we are able to observe** what we just learnt or what we are talking about during the process.

Researcher: Ok which one comes first now between the two?

F_{MRA}L₁: Electrical engineering comes first.

Researcher: Ok, thank you very much. Then let us gives a chance to another learner to respond. Abongile was also on the line. Come on Abongile give us your answer.

F_{MRA} L₃: Uh mh I have been interested in that has something to do with Physical Science. I have two careers that I was interested in. That is Doctorate and Presenting. By doctorate the learner refers to medicine or studying towards being a doctor.

Researcher: And presenting? Ok (the researcher nodded his head giving a go ahead to the learner to continue.

F_{MRA} L₃: Continues I was never too much in the doctorate until you **were taught MRA**. because when I do. When there is talk and chalk I do not pay much attention but since there is MRA you see that for **the results to be accurate** you have to pay more attention on what you are doing.

Researcher: Ok, thank you very much. That was the end of the interview

APPENDIX I.**POST-TEST**

Answer all questions.

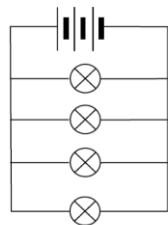
QUESTION 1

There are four possible options for each answer in the following questions. Each question has only ONE correct answer. Choose the correct answer and write only the letter A, B, C or D next to the question number to represent your answer.

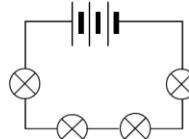
1.1. A set of identical light bulbs are connected as shown in the circuit diagrams below. The internal resistance of the battery is negligible. In which ONE of these circuits will the light bulbs glow the brightest?

(2)

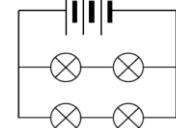
A



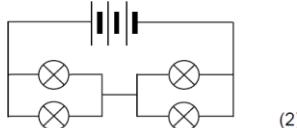
B



C



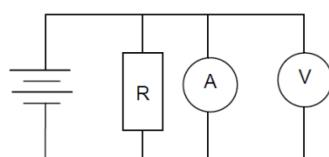
D



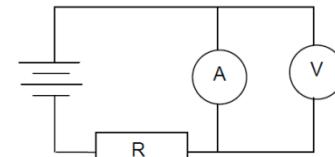
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1.2. A learner wants to measure the current and the potential difference across a resistor **R** in a circuit. In which ONE of the following circuits will the learner be able to take these readings? (2)

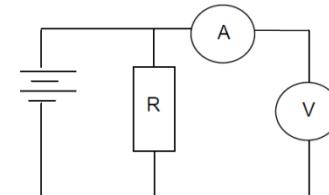
A



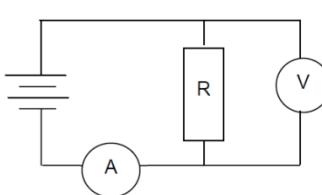
B



C

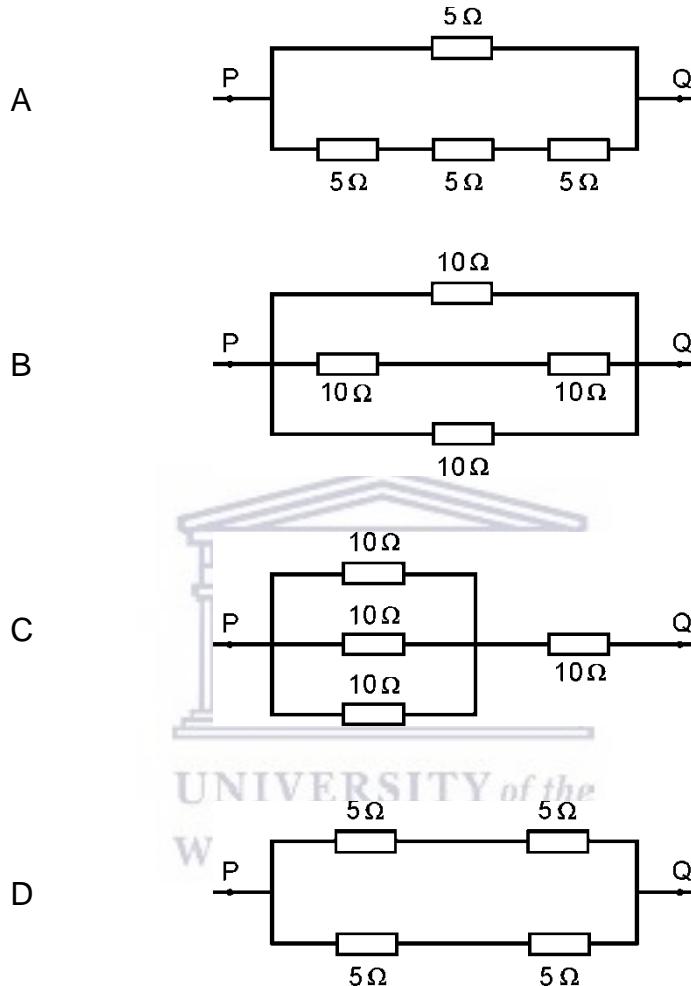


D



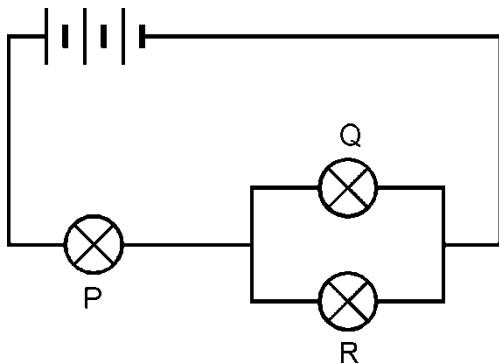
1.3.

Which combination of resistors has a total resistance of 4Ω between points P and Q? (2)



1.4.

The following electric circuit contains three light bulbs and a battery. The battery has very little internal resistance, so you can ignore its effects..... (2)



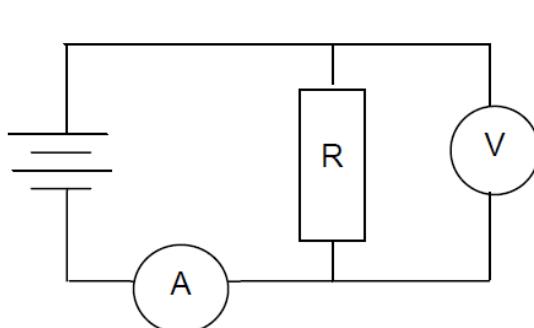
The filament of light bulb R breaks. Therefore, light bulbs P and Q will_____ (2)

	Light bulb P	Light bulb Q
A	burn more brightly	burn less brightly
B	burn unchanged	burn more brightly
C	burn less brightly	burn more brightly
D	burn less brightly	burn less brightly

[8]

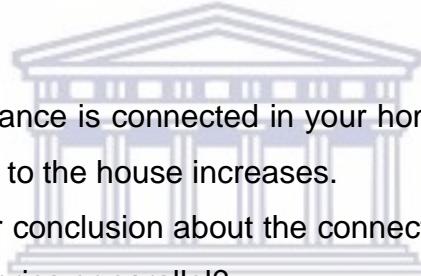
QUESTION 2

Study the electric circuits below and answer questions based on it. The battery has an emf of 12 volts and the ammeter reads 6 A



- 2.1 State Ohms law in words. (3)
- 2.2 Calculate the resistance of the light bulb R. (2)
- 2.3 Resistance of the light bulb R is doubled by adding another similar resistor in series to this one as shown below, what effect will that have on the
 a) Ammeter reading? Explain.
 (2)
 b) Voltmeter reading? Explain.
 (2)
- 2.4 A second light bulb of the same resistance is connected parallel to resistor R; what effect will that have on the
 d) Brightness of the light bulb? Explain. (2)
 b) Voltmeter reading? Explain. (2)

QUESTION 3.



A new electric appliance is connected in your home and when you switch it on, the current supplied to the house increases.
 What would be your conclusion about the connection of the appliances? i.e. are they connected in series or parallel? (2)

[15]

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QUESTION 4.

Three similar electric kettles are connected to different energy sources of A = 100J, B = 200J and C = 300J respectively for 60 seconds.

- 4.1. What is power (2)
 4.2. Draw on the same set of axis a graph of time taken (seconds) to transfer energy versus the amount of energy transferred (joules) over 60 seconds. (2)
 4.3. If a kettle needs a power of 3.8 Watts to boil, show by calculating the gradients of the graphs that ONLY kettle C will boil. (3)

[7]

TOTAL MARKS

/30/

APPENDIX J. POST TEST MEMORANDUM

Total 30 marks

Question 1

- 1.1. A ✓✓
1.2. D ✓✓
1.3. B ✓✓
1.4. D ✓✓

Question 2

2.1. For a conductor at constant temperature, the current is in the conductor is directly proportional to the potential difference (voltage) across it. ✓✓✓

2.2. $R = I/V$
 $= 6/12 \checkmark$
 $= 0.5\Omega \checkmark$

2.3. a) Decrease ✓. Resistors in series increases the resistance therefore causes a decrease in current. ✓

b) Remain the same ✓; the total resistance is not affected. ✓

2.4. a). Increases ✓. Resistors in parallel decreases the resistance therefore causes an increase in current. ✓
b). Remain the same ✓; the total resistance is not affected ✓.

QUESTION 3.

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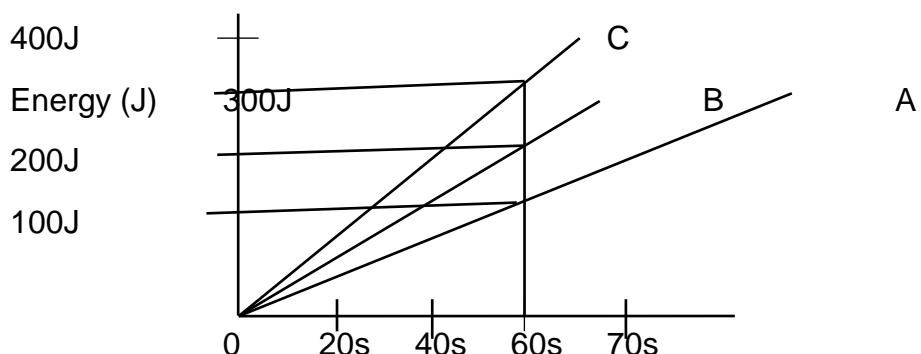
Parallel. ✓✓

QUESTION 4

4.1. Power is the rate at which work is done ✓✓.

OR it is the rate at which energy is transferred.

4.2.



2 marks if all things are correct ✓✓.

1 mark if there 1 or more are correct while and 1 or some are wrong ✓.

No mark if everything is wrong

$$4.3. \text{Gradient} = y_2 - y_1 / x_2 - x_1$$

$$= 100 - 0 / 60 - 0$$

$$= 1.6 \text{ W} \checkmark$$

$$\text{Gradient} = y_2 - y_1 / x_2 - x_1$$

$$= 200 - 0 / 60 - 0$$

$$= 3.3 \text{ W} \checkmark$$

$$\text{Gradient} = y_2 - y_1 / x_2 - x_1$$

$$= 300 - 0 / 60 - 0$$

$$= 5 \text{ W} \checkmark$$



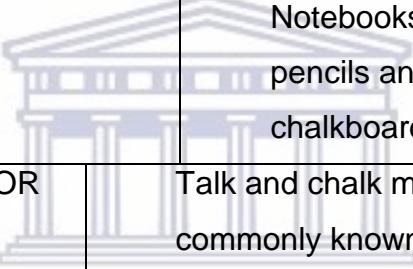
APPENDIX K. QUESTION CATEGORIES

Categories of questions	Question items	Percentage of learners with correct responses in each question item per group.		
			EXPERIMENTAL GROUP	CONTROL GROUP
		T	%	%
Lower order	2.1	3	78	72
	2.3	4	17	22
	2.4	4	23	33
	4.1	2	80	75
	Sub total	13	Average % = 50	Average % = 51
Middle order	1.1	2	67	52
	1.3	2	27	31
	2.2	2	100	100
	4.2	2	73	50
	Sub total	8	Average % = 67	Average % = 58
High order	1.2	2	47	36
	1.4	2	23	31
	3	2	46	38
	4.3	3	53	18
	Sub total	9	Average % = 42	Average % = 29
	Total test mark	30		

Key: T = Total mark per question; % = average percentage per question per group.

LESSON PLANS

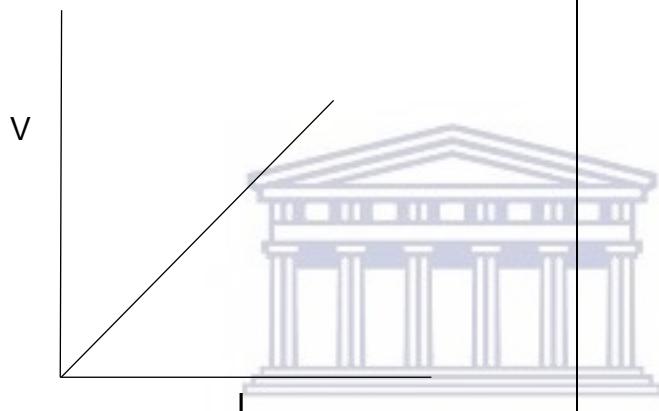
APPENDIX L. TALK AND CHALK METHOD (TCM)

NAME OF SCHOOL:				
SUBJECT: Physical Sciences.		GRADE : 11		
TOPIC :	OHM'S LAW			
CONTENT :	ELECTRICITY			
OBJECTIVES:				
At the end of the lesson, learners are expected to be able:				
<ul style="list-style-type: none"> • to state Ohm's law ($I=V/R$). • solve series and parallel resistor calculations • apply Ohm's law. • identify dependent and independent variables in Ohm's law. • draw and interpret graphs based on Ohm's law. 				
APPARATUS :	 Notebooks and textbooks, pencils and pens, calculators, chalkboard and chalk.			
TEACHING METHOD OR APPROACH :	Talk and chalk method (TCM) commonly known as lecture method			
RESEARCHER'S ACTIVITY <ol style="list-style-type: none"> 1. The researcher asks some questions on grade 10 electricity concepts to diagnose learners' existing knowledge and to remind them of those terms. Some of these terms are electric current, potential difference and resistance, 2. The researcher introduces Ohm's law ($I=V/R$) and how current, potential difference and resistance are related. He shows and explains how each term is dependent on one another (i.e. dependent and independent variables). Some examples of Ohm's law 		LEARNERS' ACTIVITY <ol style="list-style-type: none"> 1. Learners answer questions. 2. Learners listen to the researcher and do some calculations on the board. They 		

calculations $I=V/R$ were done by the researcher and learners were offered a chance to do some calculations on the chalkboard.

3. Using the chalkboard, the researcher showed the class how this interdependence of Ohm's law terms is represented using graphs.

Graph of current versus potential difference



He also emphasises the important aspects when drawing graph. Some of these are that graphs must have a heading, vertical and horizontal axis. He illustrated to them which variable is placed on the vertical axis and horizontal axis.

4. The researcher gives learners some exercises to do.

5. The researcher corrects the classwork with learners giving answers to the questions.

are also taking some notes.

3. Learners are listening attentively to the researcher and they are taking notes.

4. Learners
write the
classwork.

5. Learners
give answers to
the questions



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APPENDIX M. ROLE PLAY

NAME OF SCHOOL:		
SUBJECT: Physical Sciences	GRADE : 11	DURATION :
TOPIC :	OHM'S LAW	
CONTENT :	ELECTRICITY	
OBJECTIVES :	<p>At the end of the lesson, learners are expected to be able:</p> <ul style="list-style-type: none"> • to state Ohm's law ($I=V/R$). • solve series and parallel resistor calculations • apply Ohm's law. • identify dependent and independent variables in Ohm's law. • draw and interpret graphs based on Ohm's law. 	
APPARATUS :	<p>Notebooks and textbooks, pencils and pens, calculators, chalkboard and chalk, instrument boxes, about $100 \times 3 \text{ cm}^3$ gravel stones, stop watch, whistle, tape measure. 4 X chairs per group.</p>	
TEACHING METHOD OR APPROACH :	Multiple Representations Approach. Role play.	
THE RESEARCHER'S ACTIVITY	THE LEARNERS' ACTIVITY	
	<ol style="list-style-type: none"> 1. Refer to 3.6.2. and observe the role play activity for both the researcher's and learners' activity. 2. Refer to appendix N for exercises based on this lesson. 	

APPENDIX N. ROLE PLAY WORKSHEET

ACTIVITY 2. Fill in the role-play worksheet and answer questions below.

	Smooth surface			Surface with chairs		
	Group			Group		
	a	B	c	d	e	f
Group number	A	B	C	A	B	C
Number of stones carried at a time						
Total time taken to drop all stones.						
Number of stones dropped in the 1 st 20 seconds						
Number of stones dropped in the 2 nd 20 seconds						
Number of stones dropped in the 3 rd 20 seconds						
Total number of stones dropped in 60 seconds						
Rate at which stones are dropped (stones/seconds) or (no. vii/ no. iii)						

1. Associate each of the electricity terms with this activity terms by filing in the table below.

HINT. The activity terms are: rate at which stones are dropped, runway/path and number of stones carried at time. Discuss what you have observed and explain it in relation to Ohm's law terms. Emphasise on what happens to I when R changes.

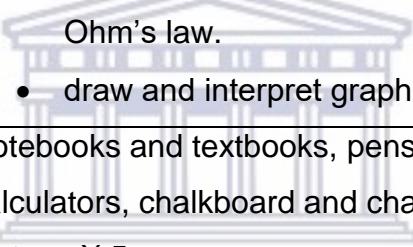
	Ohm's law terms	Role-play terms/ activity
A	Resistance	
B	Electric current	
C	Voltage	

2. Using the information in your worksheet, plot the graph of

- a) The number of stones dropped in 60 seconds versus the time taken to drop the stones for columns a, b and c on the same set of axis.
 - b) The number of stones in dropped 60 seconds versus the time taken to drop the stones for columns a and d, b and e then c and f on the same set of axis.
3. Calculate the gradient of each graph.
 4. Compare your gradients with the rate at which the stones were dropped.
 5. What is your conclusion?



APPENDIX O. (PHET) COMPUTER SIMULATION

NAME OF SCHOOL:		
SUBJECT :Physical Sciences	GRADE : 11	DURATION :
TOPIC :	OHM'S LAW	
CONTENT :	ELECTRICITY	
OBJECTIVES :	<p>At the end of the lesson, learners are expected to be able:</p> <ul style="list-style-type: none"> • to state Ohm's law ($I=V/R$). • solve series and parallel resistor calculations • apply Ohm's law. • identify dependent and independent variables in Ohm's law. • draw and interpret graphs based on Ohm's law. 	
APPARATUS :	 <p>Notebooks and textbooks, pens, instrument boxes, calculators, chalkboard and chalk, stop watches X 4, laptops X 5.</p>	
TEACHING METHOD OR APPROACH :	<p>Multiple Representations Approach. Computer simulation (Phet).</p>	
RESEARCHER'S ACTIVITY	<p>1. The researcher gives learners equipment and instructions to follow as they do the experiment.</p> <p><u>Procedure</u></p> <p>Refer to 3.6.2.2. for all steps of this lesson plan.</p> <p>Learners complete the activity by doing exercise in their groups. (refer to appendix P.)</p>	<p>LEARNERS' ACTIVITY</p> <p>1. Learners do according to the instructions.</p>

APPENDIX P. Phet WORKSHEET

ACTIVITY 3. Phet simulations

Record your readings and results in the provided worksheet.

PART 1. Series	Number of cells	Number of light bulbs	Voltage	resistance	Current
PART 2. Parallel	Number of cells	Number of light bulbs	Voltage	resistance	Current
PART 3. Parallel	Number of cells	Number of light bulbs	Voltage	resistance	Current

Questions and Discussion

In your groups discuss and compare the following:

- i) part 1 and part 2
- ii) part 1 and part 3
- iii) part 2 and part 3 then with reference to the following.
 - a) Number of cells
 - b) Voltage
 - c) Number of resistors
 - d) Resistance
 - e) Current
 - f) Connection (parallel and series)

Write a conclusion with reference to current, voltage and resistance.

Expected answers for Phet/ computer simulation worksheet.

	Number of cells	Number of light bulbs	Voltage	resistance	Current
PART 1. Series resistors	1	3	1.5 v	6 Ω	0.25 A
	2	3	3 v	6 Ω	0.5 A
	3	3	4.5 v	6 Ω	0.75 A
PART 2. Series resistors	Number of cells	Number of light bulbs	Voltage	resistance	Current
	3	1	4.5 v	2 Ω	2.25 A
	3	2	4.5 v	4 Ω	1.12 A
PART 3. Parallel resistors	Number of cells	Number of light bulbs	Voltage	resistance	Current
	3	1	4.5 v	2 Ω	2.25 A
	3	2	4.5 v	1 Ω	4.5 A
	3	3	4.5 v	0,67 Ω	6.72 A

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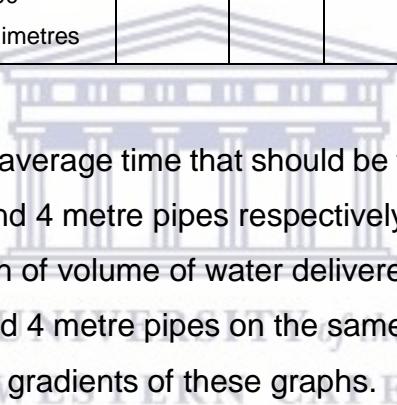
APPENDIX Q. WATER ANALOGUE

NAME OF SCHOOL:		
SUBJECT :Physical Sciences	GRADE : 11	DURATION :
TOPIC :	OHM'S LAW	
CONTENT :	ELECTRICITY	
CONTEXT :		
OBJECTIVES : :	<p>At the end of the lesson, learners are expected to be able:</p> <ul style="list-style-type: none"> • to state Ohm's law ($I=V/R$). • solve series and parallel resistor calculations • apply Ohm's law. • identify dependent and independent variables in Ohm's law. • draw and interpret graphs based on Ohm's law. 	
APPARATUS :	<p>Notebooks and textbooks, pens, instrument boxes, calculators, chalkboard and chalk, one stop watches per group, funnels X 4,</p> <p>1500ml bottles X 8,</p> <p>1-metre-long plastic pipe X 1,</p> <p>2-metre-long plastic pipes X 4,</p> <p>4-metre-long plastic pipes X 4. Knife/scissor.</p>	
TEACHING METHOD OR APPROACH :	Multiple Representations Approach. Water analogue.	
RESEARCHER'S ACTIVITY Refer to for the activities of this lesson plan.	<p>LEARNERS' ACTIVITY</p> <p>Learners do according to the instructions.</p>	

APPENDIX R. WORKSHEET WATER ANALOGUE

ACTIVITY 1. Fill the water analogue worksheet table below. **NB.** We only fill for 1, 2 and 5 metre pipes only.

Length of the pipe	Volume of water	Time taken to fill the bottle				Rate at which the bottle is filled
		T1	T2	T3	Average time	
1. 1 metre	1500 millimetres					
2. 2 metre	1500 millimetres					
3. 3 metre	1500 millimetres					
4. 4 metre	1500 millimetres					
5. 5 metre	1500 millimetres					

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1. Estimate the average time that should be taken to fill the 1500 millilitre bottle for 3 and 4 metre pipes respectively.
 2. Plot the graph of volume of water delivered into the 1500 ml bottle for both the 2 and 4 metre pipes on the same set of axis.
 3. Compare the gradients of these graphs.
 4. Compare these gradients with the rate at which the bottles were filled and discuss your comparisons.
 5. Calculate the gradient of each graph. (i.e. no. of millilitres/time).
 6. Associate what you have just done with electricity/Ohm's terms. i.e. electric current, potential difference and resistance.

	Ohm's law terms	Water analogue terms/ activity
1	Resistance	
2	Electric current	
3	Voltage	

7. Discuss what you have observed and explain it in relation to Ohm's law terms. Emphasise on what happens to I when R changes.

APPENDIX S.

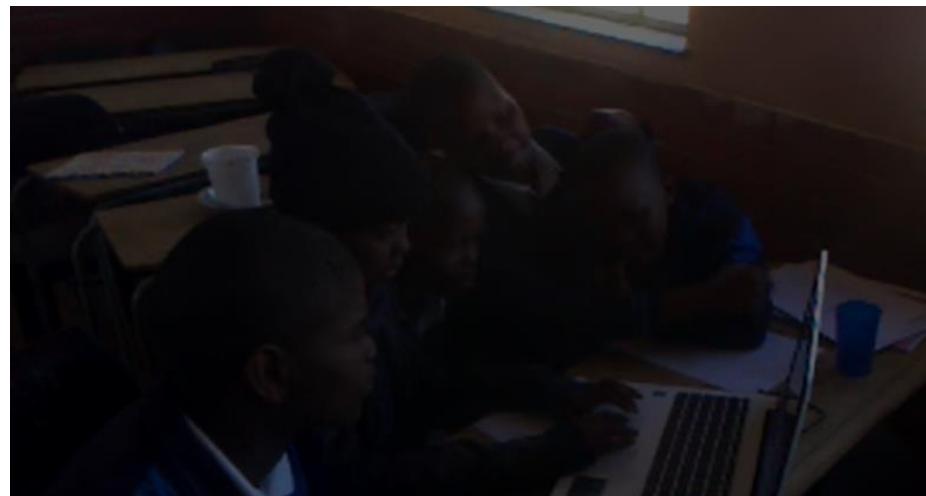
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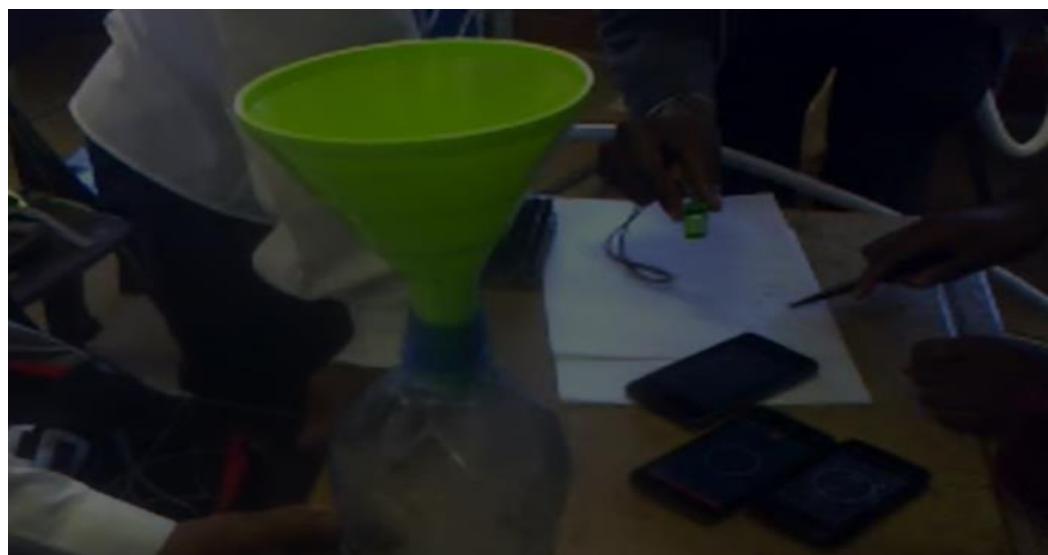
Appendix S (i). Overcrowded classroom in a formal sitting arrangement.



Appendix S (ii). Normal formal sitting arrangement.



APPENDIX S (iii). Learners doing Phet animations.



APPENDIX S (iv). Taking down recording times for water analogue.



APPENDIX S (v). A 1-metre-long-pipe water analogue.



APPENDIX S (vi). Role play.