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 Nathamiel (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

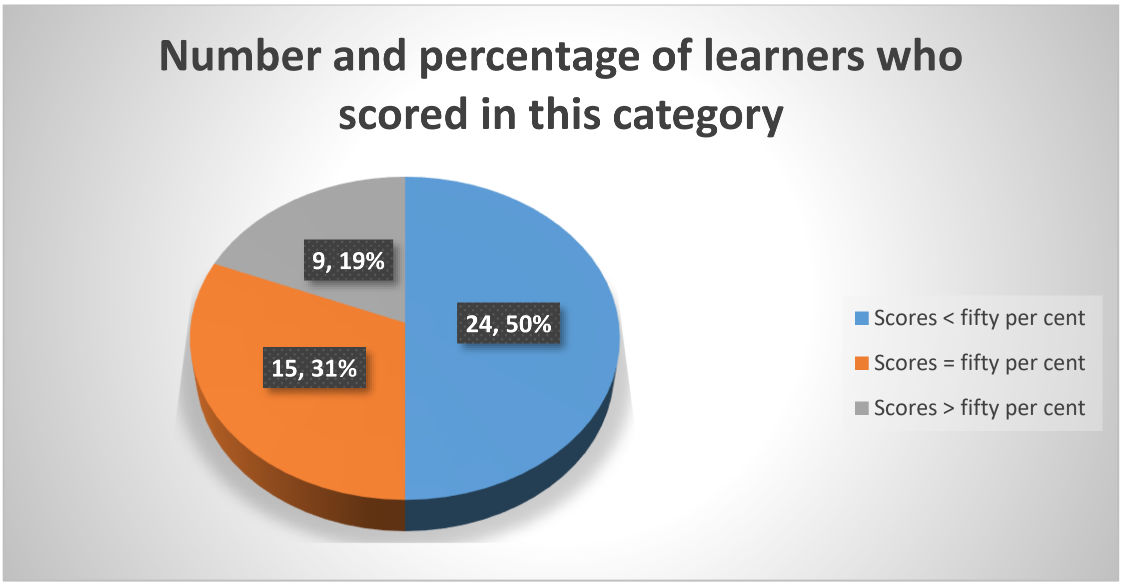


Figure 4. Figure representing numbers and percentage of learners' scores in the pre-test.

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.

	Volume of water in the filled bottle	Time taken to fill the bottle				Rate at which the bottle is filled
Length of the pipe		T 1	T 2	T 3	Average time	
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 I" …. 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.

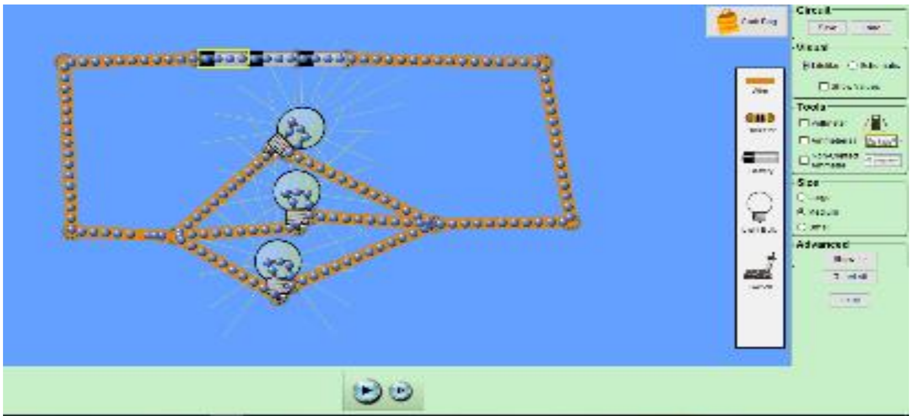


Figure 5. Group B electric circuit

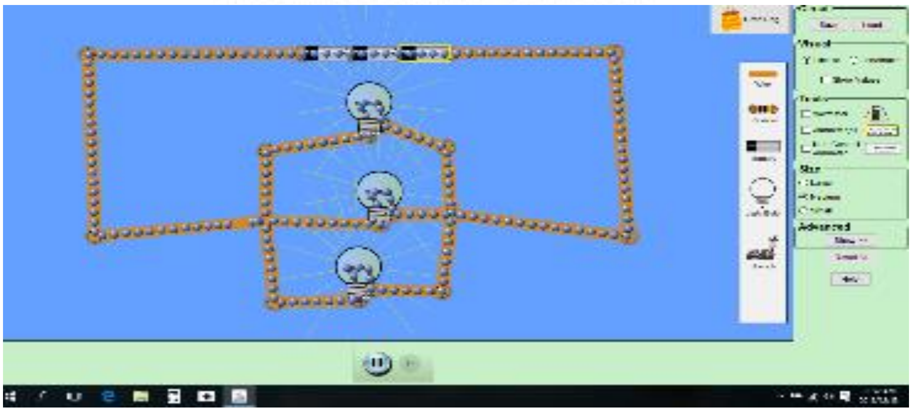


Figure 6. Group A electric circuit

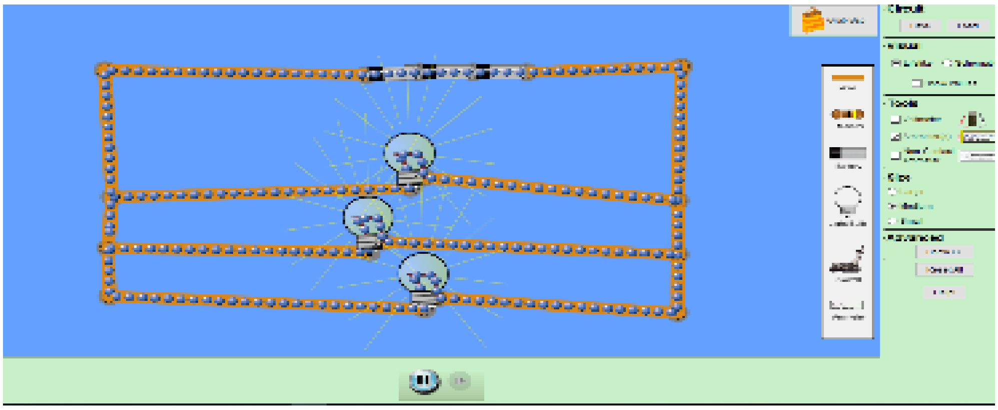


Figure 7. Group C electric circuit

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	050 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

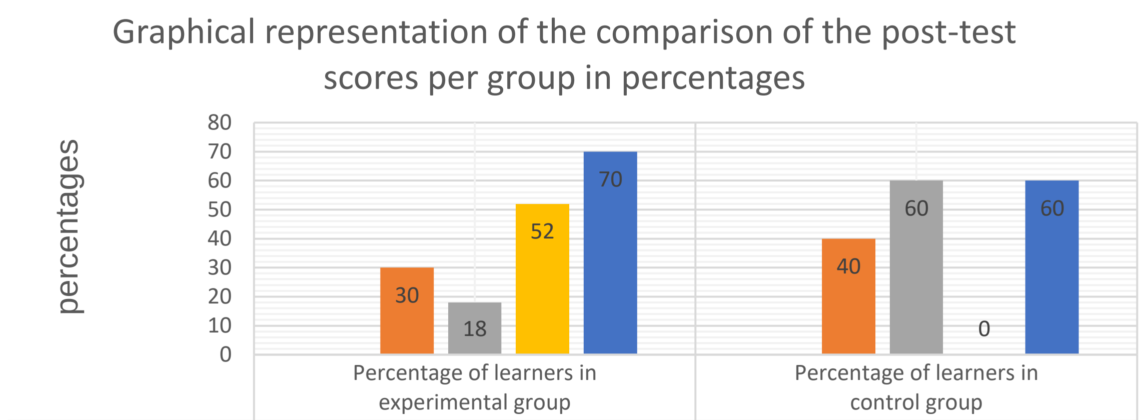
The results were as follows:

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 ≥ 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 ≥ 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.

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



	Percentage of learners in experimental group	Percentage of learners in control group
Category of scores		
Scores < fifty per cent	30	40
Scores = fifty per cent	18	60
Scores > fifty per cent	52	0
Scores ≥ fifty per cent	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.

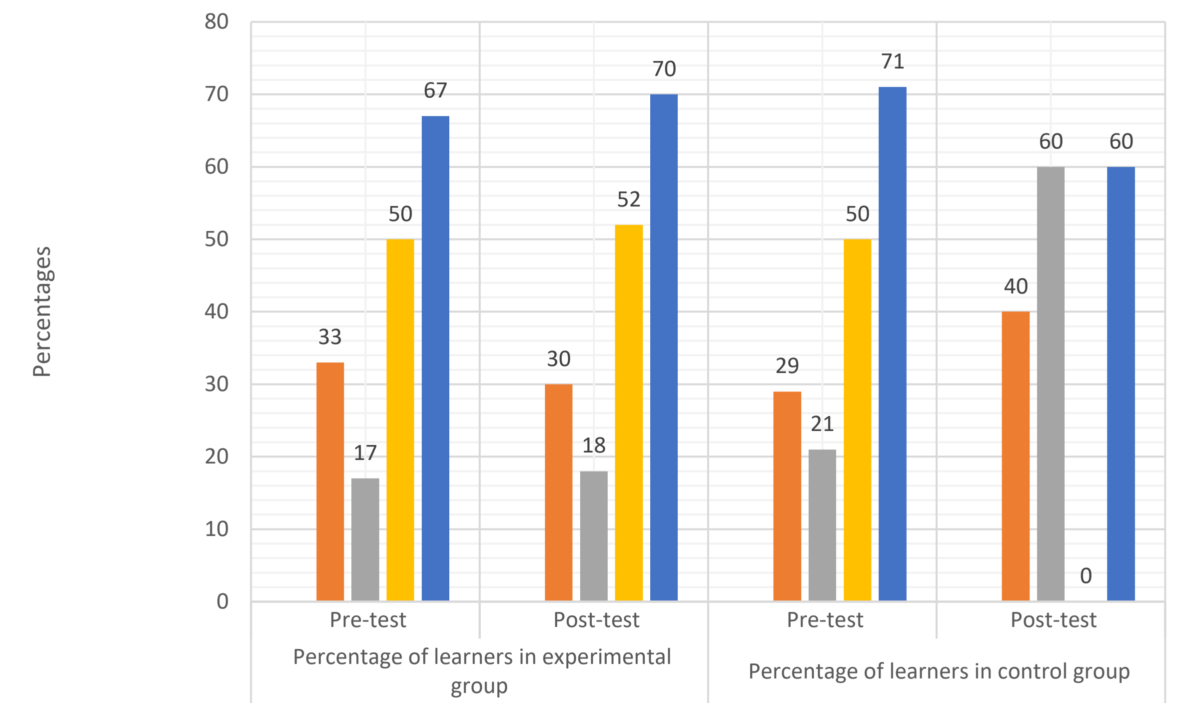
This lead to the formation of each group with this percentage of learners in each category. The experimental group had 33% of learners whose score was less than 50% in the pre-test while the control group had 29%. The experimental group comprised 17% of learners whose pre-test score was 50% whereas the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



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

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

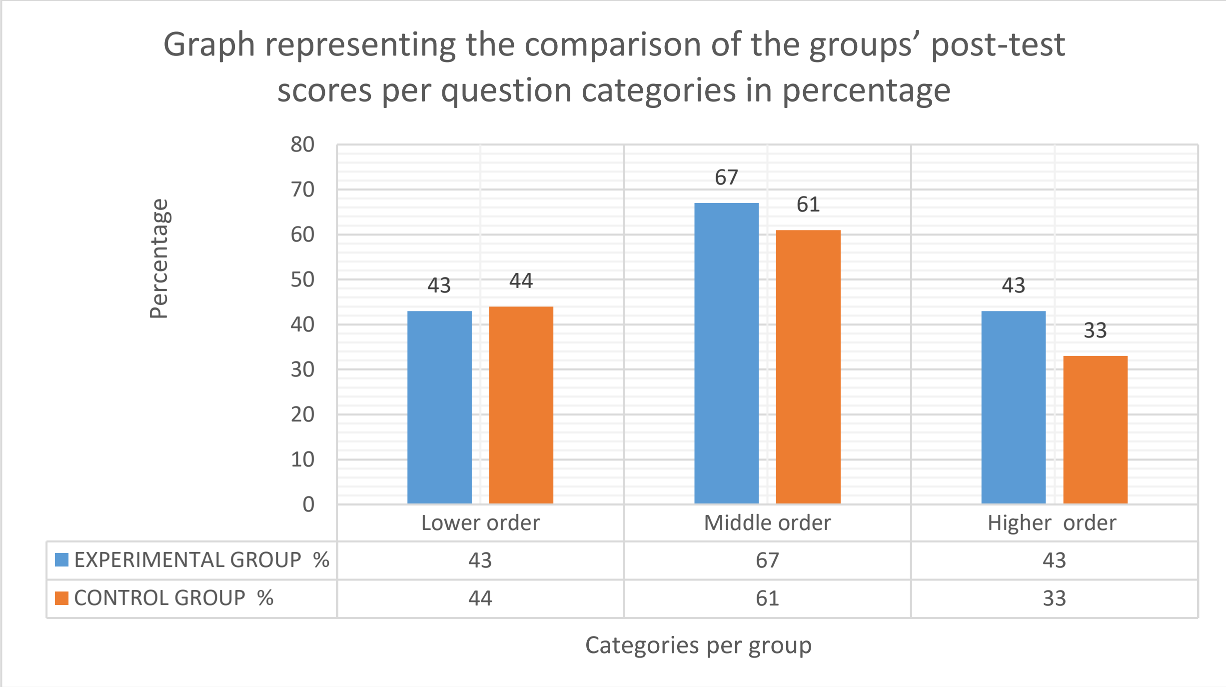


Figure 11. Graph representing the comparison of the groups' post-test scores per question categories in percentages.

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} L_1: 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.

$F_{TCM}L_1$: 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} L_2

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} L_3: 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. $F_{TCM}L_2$ 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} L_2: 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} L_2: 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, may be 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} L_3 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} L_1 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} L_1 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} L_1 replied:

F_{MRA} L_1: 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} L_1]

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} L_1 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} L_3 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} L_3 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 section5.3.1. 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 stimulates 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 RELEVENT 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 ≥ 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_AL_1 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

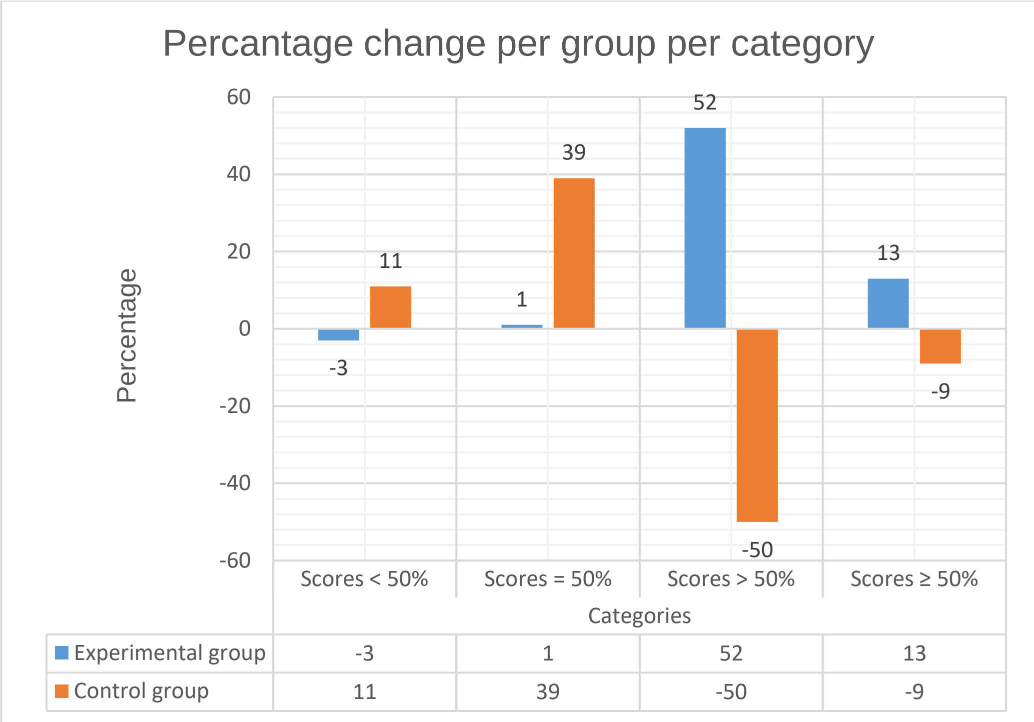


Figure 12. Figure showing the percentage change per group per category.

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 ≥ 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 consolidated 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

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

	Dimension	Indicator	Tally	Comments
Talk and chalk method (TCM)	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		

	Dimension	Indicator	Tally	Comments
Role play (MRA).	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		

	Dimension	Indicator	Tally	Comments
Water analogue (MRA).	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		

	Dimension	Indicator	Tally	Comments
Phet simulations. (MRA)	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?

TEM 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} L_1: 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} L_1: 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} L_2: 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} L_2: Yes.

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

FMRA L2: Yes, teacher! it is time wasting.

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

FMRA 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.

FMRA L1: Physical Science is a difficult subject but if schools or teachers could use both MRA and TCM method, may be 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).

FMRA 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.

FTCM 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).

FTCM 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 Siphelo, 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.

FTCM 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.

FTCM 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.

FTCM 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} L_1: 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.

$F_{MRA}L_1$: Yes, and clapping hands for her to show that they agree with what she says.

Researcher: So you all say you?

$F_{MRA}L_1$: Yes.

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

$F_{MRA}L_1$: Yes.

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

$F_{MRA}L_1$: 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.

$F_{MRA}L_1$: 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.

$F_{MRA}L_1$: 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?

$F_{MRA}L_1$: 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} L_3: 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} L_3: 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

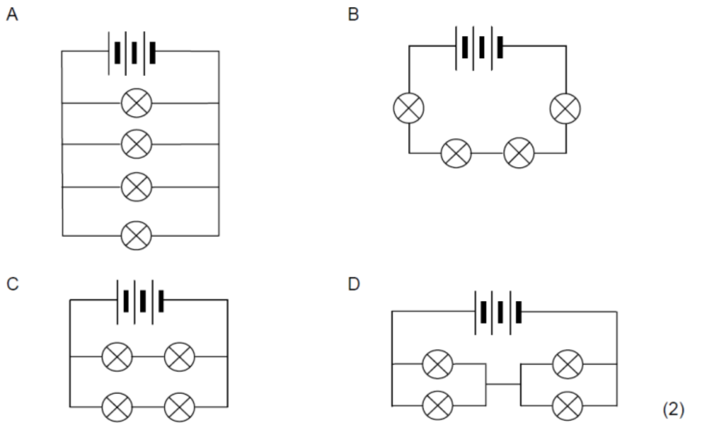
APPENDIX I. POST-TEST

Answer all questions.

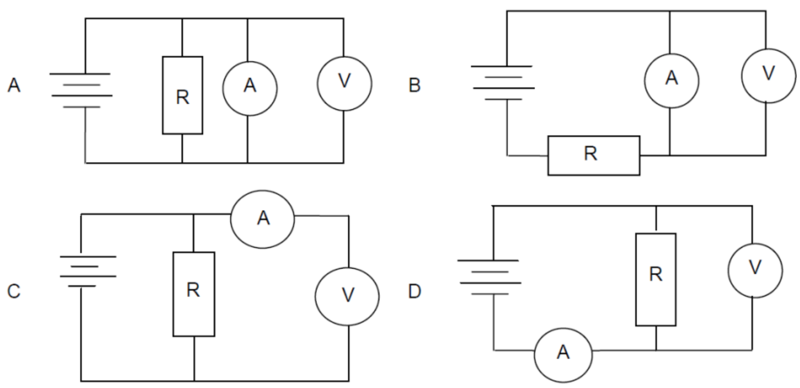
QUESTION 1

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)



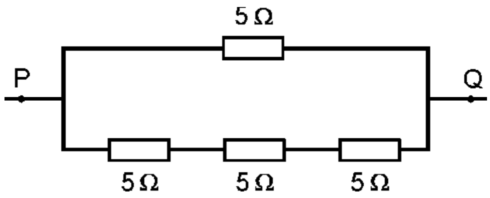
1.2. A learner wants to measure the current and the potential difference across a resistor **R** in a circuit. In which ONE of the following circuits will the learner be able to take these readings? (2)



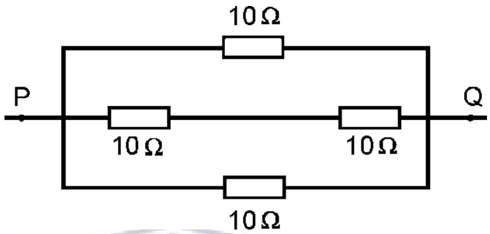
1.3.

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

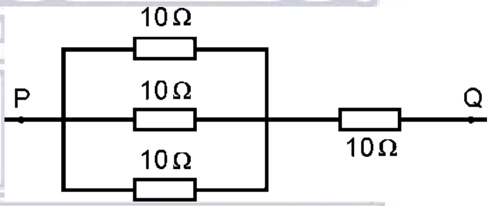
A



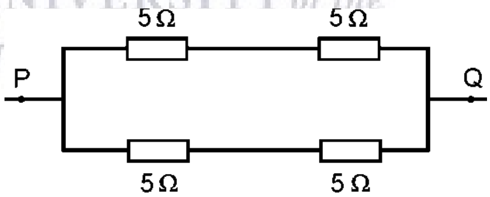
B



C

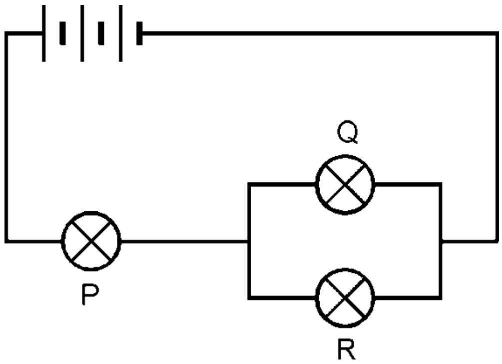


D



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)



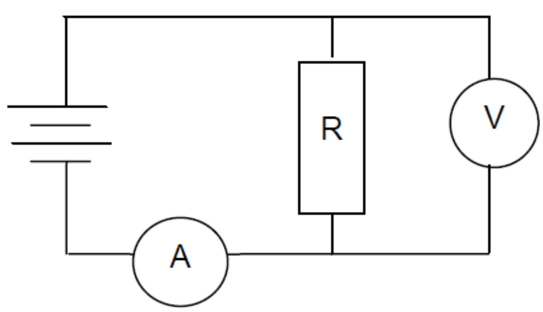
The filament of light bulb R breaks. Therefore, light bulbs P and Q will________________ (2)

	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]

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 √

=0.5Ω √

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.

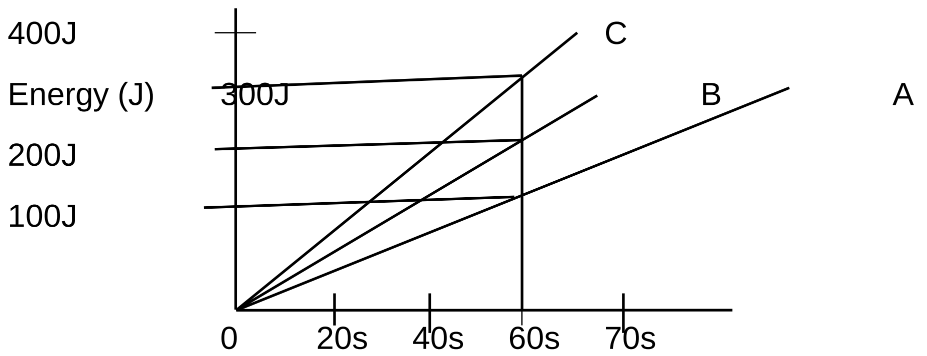
Parallel. √√

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. Gradient=y_2-y_1/x_2-x_1

= 100-0/60-0

= 1.6 W √

Gradient=y_2-y_1/x_2-x_1

=200-0/60-0

= 3.3 W √

Gradient=y_2-y_1/x_2-x_1

= 300-0/60-0

= 5 W √

APPENDIX K. QUESTION CATEGORIES

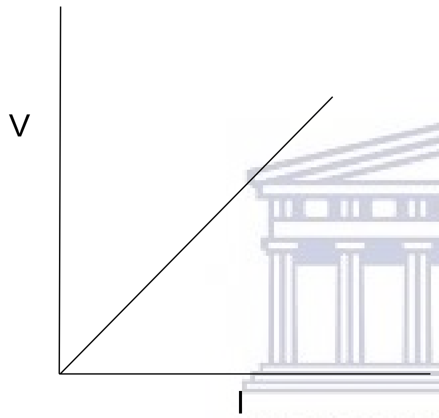
Categories of questions	Question items	Percentage of learners with correct responses in each question item per group.		
			EXPERIMENTAL GROUP	CONTROL GROUP
		T	%	%
Lower order	2.1	3	78	72
	2.3	4	17	22
	2.4	4	23	33
	4.1	2	80	75
Sub total		13	Average % = 50	Average % = 51
Middle order	1.1	2	67	52
	1.3	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: • 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 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 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

APPENDIX M. ROLE PLAY

<table>
<tr><td>NAME OF SCHOOL:</td><td colspan="2"></td></tr>
<tr><td>SUBJECT: Physical Sciences</td><td>GRADE : 11</td><td>DURATION :</td></tr>
<tr><td>TOPIC :</td><td colspan="2">OHM'S LAW</td></tr>
<tr><td>CONTENT :</td><td colspan="2">ELECTRICITY</td></tr>
<tr><td>OBJECTIVES :</td><td colspan="2">At the end of the lesson, learners are expected to be able:
• 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.</td></tr>
<tr><td>APPARATUS :</td><td colspan="2">Notebooks and textbooks, pencils and pens, calculators, chalkboard and chalk, instrument boxes, about 100 X 3 cm^3 gravel stones, stop watch, whistle, tape measure. 4 X chairs per group.</td></tr>
<tr><td>TEACHING METHOD OR APPROACH :</td><td colspan="2">Multiple Representations Approach. Role play.</td></tr>
<tr><td>THE RESEARCHER'S ACTIVITY</td><td colspan="2">THE LEARNERS' ACTIVITY</td></tr>
<tr><td colspan="3">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.</td></tr>
</table>

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 1st 20 seconds						
Number of stones dropped in the 2nd 20 seconds						
Number of stones dropped in the 3rd 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

<table>
<tr><td>NAME OF SCHOOL:</td><td colspan="3"></td></tr>
<tr><td>SUBJECT :Physical Sciences</td><td>GRADE : 11</td><td colspan="2">DURATION :</td></tr>
<tr><td>TOPIC :</td><td colspan="3">OHM’S LAW</td></tr>
<tr><td>CONTENT :</td><td colspan="3">ELECTRICITY</td></tr>
<tr><td>OBJECTIVES :</td><td colspan="3">At the end of the lesson, learners are expected to be able:
• 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.</td></tr>
<tr><td>APPARATUS :</td><td colspan="3">Notebooks and textbooks, pens, instrument boxes, calculators, chalkboard and chalk, stop watches X 4, laptops X 5.</td></tr>
<tr><td>TEACHING METHOD OR APPROACH :</td><td colspan="3">Multiple Representations Approach. Computer simulation (Phet).</td></tr>
<tr><td colspan="3">RESEARCHER’S ACTIVITY
1. The researcher gives learners equipment and instructions to follow as they do the experiment.
<u>Procedure</u>
Refer to 3.6.2.2. for all steps of this lesson plan.

Learners complete the activity by doing exercise in their groups. (refer to appendix P.</td><td>LEARNERS’ ACTIVITY
1. Learners do according to the instructions.</td></tr>
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APPENDIX P. Phet WORKSHEET

ACTIVITY 3. Phet simulations

Record your readings and results in the provided worksheet.

	Number of cells	Number of light bulbs	Voltage	resistance	Current
PART 1. Series					
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
	3	3	4.5 v	6 Ω	0.75 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

APPENDIX Q. WATER ANALOGUE

NAME OF SCHOOL:		
SUBJECT :Physical Sciences	GRADE : 11	DURATION :
TOPIC :	OHM’S LAW	
CONTENT :	ELECTRICITY	
CONTEXT :		
OBJECTIVES :	At the end of the lesson, learners are expected to be able: • 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, pens, instrument boxes, calculators, chalkboard and chalk, one stop watches per group, funnels X 4, 1500ml bottles X 8, 1-metre-long plastic pipe X 1, 2-metre-long plastic pipes X 4, 4-metre-long plastic pipes X 4. Knife/scissor.	
TEACHING METHOD OR APPROACH :	Multiple Representations Approach. Water analogue.	
RESEARCHER’S ACTIVITY Refer to for the activities of this lesson plan.		LEARNERS’ ACTIVITY Learners do according to the instructions.

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.

		Time taken to fill the bottle				
Length of the pipe	Volume of water	T1	T2	T3	Average time	Rate at which the bottle is filled
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					

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	

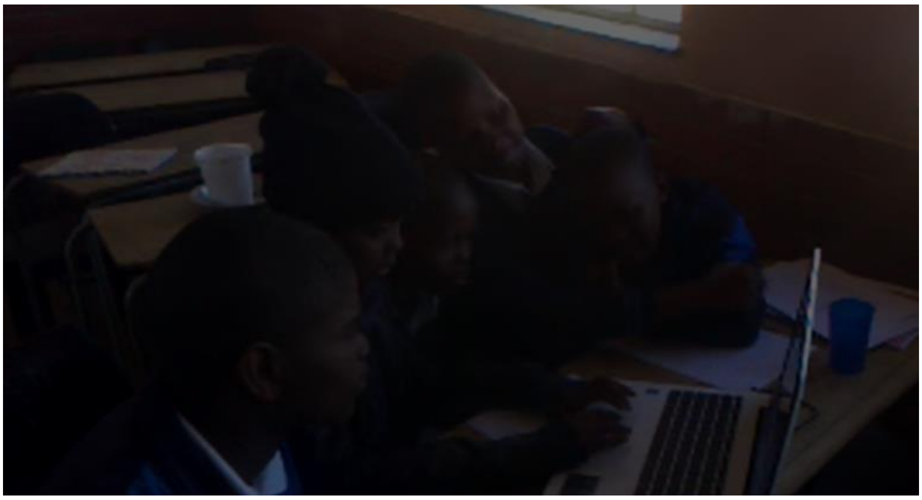
7. Discuss what you have observed and explain it in relation to Ohm's law terms. Emphasise on what happens to I when R changes.

APPENDIX S.

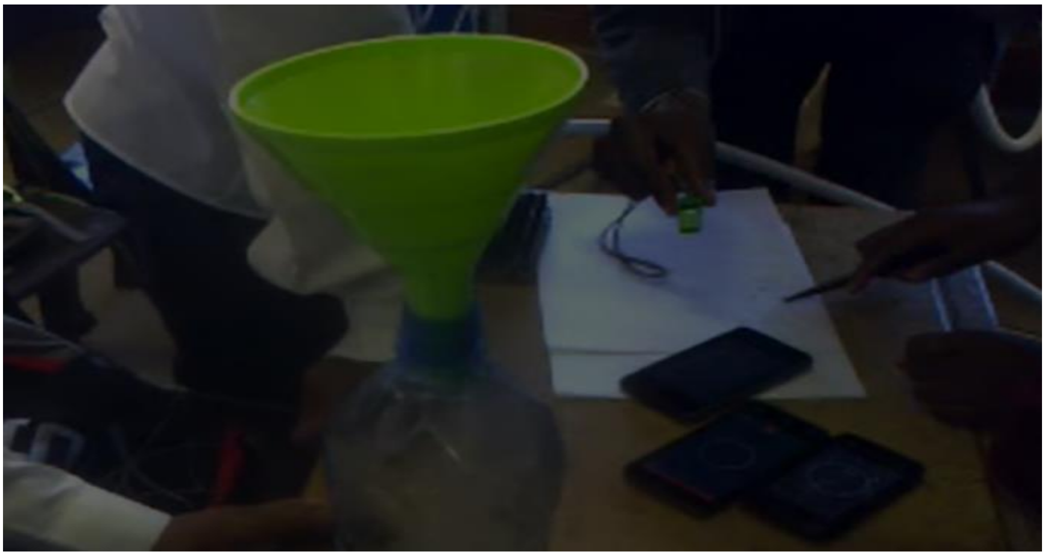
PHOTOS

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.