Investigating how Grade 10 Physical Science teachers help learners to make sense of concepts of electromagnetism using easily accessible materials in under-resourced schools

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By

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DECLARATION OF ORIGINALITY

I, ***Paulo Samuel (10s7301)*** declare that this thesis has not been submitted for a degree in any other University apart from Rhodes University and I declare that it is my own work, written in my own original words. Where I have cited the words or ideas of other researchers, these have been acknowledged using complete references according to the Departmental guidelines.

Signature: Date: 07/04/2017

ABSTRACT

This study sought to explore teachers' perceptions and experiences of using easily accessible materials and how they might collaboratively develop learning and teaching support materials using easily accessible materials. The study explored three aspects. Firstly, the views, experiences and factors which influence grade 10 Physical Science teachers' perceptions and experiences of teaching the topic of electromagnetism. Secondly, to find out what teachers can do to improve teaching and learning of electromagnetism in grade 10 Physical Science using easily accessible materials. Thirdly, to look at what enables or constrains grade 10 Physical Science teachers in under-resourced schools when dealing with electromagnetism, from using easily accessible materials.

A qualitative method approach was adopted, underpinned by an interpretive paradigm but using some quantitative methods as well. Within the interpretive paradigm a case study approach was used. The study was carried out in Swakopmund and Gobabis education circuits of the Erongo and Omaheke Regions respectively. Data were collected using questionnaires, lesson observations and stimulated-recall interviews. The data obtained were validated in two ways, firstly, by triangulation from different data gathering techniques, and secondly, validation was done by member checking of the transcripts. To make meaning from the data generated, Vygotsky's (1978) socio-cultural theory was used as a lens to analyse the data. The quantitative data generated were presented in figures, tables; whereas the qualitative data were coded inductively into descriptive texts to make meaning.

It was found that teachers's perceptions and experiences are that the topic of electromagnetism is quite challenging. Teachers reported that their learners find it difficult to comprehend phenomena associated with electromagnetism, thus making it difficult for their learners to grasp concepts associated with it. Lack of resources to do practical activities in the topic of electromagnetism was found to be a major contributing factor to teaching and learning of this topic. The use of easily accessible materials among teachers was found to be very limited. Easily accessible locally sourced materials were found to have the potential to enable grade 10 Physical Science teachers to help learners to make sense of concepts of electromagnetism in under-resourced schools. In light of the

above findings, the study recommends that science teachers should make use of easily accessible materials which can minimise their dependence on standard laboratory equipment which is unaffordable anyway by most schools.

DEDICATION

This thesis is dedicated to my late mother, Virginia Dominga Nzamba Paulo who, after her passing left me wondering how I would face life without her. Mom, your inspiration and strictness have shaped me to be the responsible man I am today. I also dedicate this work to my three lovely sons, Samuel Paulo Samuel, Alfons Samba Samuel and Paulino Samuel for being the light for me to continue the struggle to this level and beyond. And finally, to my lovely wife Theresa Mpambo Kamwi for always giving me the assistance whenever I needed it. I love you all and may God bless you all!

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ABBREVIATIONS AND/OR ACRONYMS

ACE – Advanced Certificate in Education

BETD – Basic Education Teacher's Diploma

DNEA – Directorate of National Examination and Assessment

e.m.f. - electromotive force

ETSIP - Education and Training Sector Improvement Programme

FDE – Further Diploma in Education

JSC – Junior Secondary Certificate

LCE – Learner Centered Education

LTSM – Learning and Teaching Support Materials

MBEC – Ministry of Basic Education and Culture

MBESC – Ministry of Basic Education, Sport and Culture

MEC – Ministry of Education and Culture

MoE – Ministry of Education

NBEC - Namibian Basic Education Curriculum

NCBE – National Curriculum for Basic Education

NIED – National Institute for Educational Development

PCK – Pedagogical Content Knowledge

S1 – School 1

S2 – School 2

T1 – Participant Teacher One

T2 - Participant Teacher Two

ZPD – Zone of Proximal Development

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CHAPTER ONE: SITUATING THE STUDY

1.1 Introduction

The focus of this study was to explore how Grade 10 Physical Science teachers in under-resourced schools can help learners to make sense of concepts on electromagnetism, using easily accessible materials. The Namibian Junior Secondary school Examiners' reports for Physical Science have over the years reported that little or no practical activities take place in science lessons. For example, the Namibian Grade 10 Physical Science Examiners' reports (Namibia [MoE] Examiners' reports, 2010, 2011, 2012, 2013, 2014, 2015) have over the years indicated that at National level, the electromagnetism topic was one of the areas where learners often failed to perform satisfactorily. These Examiners' reports have regularly ascribed this weakness to lack of practical activities in science teaching and learning. For instance, the Examiners' reports (Namibia. [MoE], 2011), pointed out that lack of practical work was a contributing factor to learners' inability to distinguish and understand electromagnetic concepts in examinations.

Aiming to contribute to remedying this, the study introduced easily accessible materials to enable science teachers to include practical activities in their lessons. I have personally observed that most science teachers do not include practical activities in their lessons, particularly in electromagnetism topic, due to the lack of science resources in their schools. The chapter outlines the context of the study followed by the problem statement, the significance of the study, research goal and questions, and definitions of key concepts. In discussing the contextual background, reference is made to international and national reports, the Namibian Curriculum and earlier research findings related to the topic. To sum up, the structure of the study is presented with a brief summary of each chapter.

1.2 Background of the study

This study was motivated by my experiences while working with Physical Science teachers over the last 10 years. During this time, I observed that most schools visited lack laboratory equipment which ought to enable teachers to conduct practical activities during their science lessons. Most teachers I interacted with repeatedly requested assistance in the topic of electromagnetism.

The following extract reflects learners' misconceptions in electromagnetism:

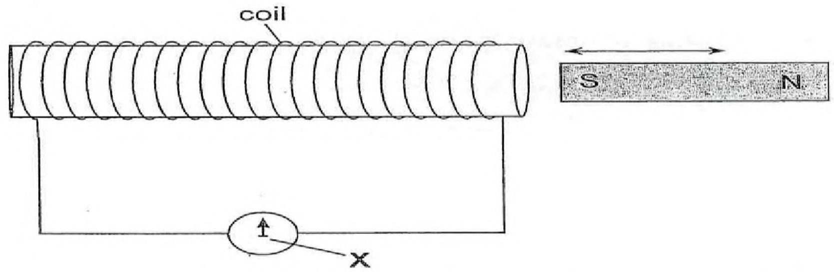
> *"Induced magnetism' was the answer that commonly appeared as opposed to 'electromagnetic induction' which was the required answer. The labelling of the poles seemed to be a guessing game by a number of candidates, as one could find the labels anywhere on the circuit. This somehow gave an indication that the 'right-hand rule has not been mastered by the candidates in determining the poles on the electromagnet"* (Namibia. Ministry of Education [MoE], 2012, p. 240).

Analogous errors were ascribed to the lack of practicals in the 2013 Examiner's report (MoE, 2013):

> *"The doing of practicals will always be to the benefit of the learners and this area in teaching and learning should not be neglected. One would also recommend that the use of everyday practical examples in teaching gives some relevance of the subject to the learners, which in turn makes the subject interesting and better understood"* (Namibia MoE, 2013, p. 249).

A lack of standard science laboratory equipment and most probably the inability of teachers to improvise in most Namibian schools have been reported in a local media (Ashipala, 2015). The 2014 Examiner's report (Namibia MoE, 2014) revealed that only 0.25% of learners across the country achieved full marks in the electromagnetism question. Learners failed to incorporate the link of the coil and the magnet in their answers while describing the generation of electricity in the question: *'When a bar magnet is inserted in and out of a coil, an electric current is produced. Explain what happens to the needle of the component X when the bar magnet is moved in and out of the coil'* (Namibia. [MoE], 2014, p. 12). Figure 1.1 below shows the examination question as discussed above.

(c) When a bar magnet is inserted in and out of a coil, an electric current is produced.



(i) State the name of the component labelled X.

.... [1]

(ii) Explain what happens to the needle of the component X when the bar magnet is moved in and out of the coil.

....

.... [2]

Figure 1.1: Part of question 11 of the JSC Physical Science end of year exam paper (p.19)

The main problem learners faced in answering this particular question (Figure 1.1) was identified in the Examiner's report of 2014 as: "*the technical description of electricity generated was not well expressed by most candidates as learners failed to incorporate the involvement of the coil and magnet in their answer. The use of the term 'alternative current' instead of 'alternating current' caused marks to be lost*" (Namibia MoE, 2014 p. 281). Based on learners' written responses in the 2013 National examination, the national markers for Physical Science concluded that most learners had not understood electromagnetism concepts well during teaching and learning. The Examiner's report suggested various improvements to prevent such errors reacurring in future examinations. One of the suggested improvements was to include practical activities during teaching and learning. Despite the examiners pointing out this weakness, learners continued to perform poorly in electromagnetism, repeating similar mistakes of previous years.

My own experiences agree with these findings by authorities that the lack of exposure to practical activities in science lead to learners performing poorly in Grade 10 Physical Science, particularly in electromagnetism and hence the focus of this study. In view of Examiners' reports even prior to 2013 warning teachers that *"practical activities and demonstrations were key factors which have the potential to enhance understanding and interest of learners in the subject",* one would have expected teachers to have responded to the suggestions and have incorporated practical activities in their teaching as much as possible. However, this was not the case and learners have continued to fail questions on electromagnetism in following exams.

The 2012 Examiner's report addressed concerns reported in previous reports, warning teachers that:

> "*the doing of practical activities will always be to the benefit of the learners and this area in teaching and learning should not be neglected. One would also recommend that the use of everyday practical examples in teaching gives some relevance of the subject to the learners, which in turn the subject interesting and better understood*" (Namibia MoE 2012, p. 249).

After speaking to some science teachers it became clear as to why they did not incorporate practical activities in their teaching, particularly in the topic of electromagnetism. It was for this reason that this study sought to investigate the introduction of everyday easily accessible materials for practical activities in the absence of expensive conventional laboratory equipment which is unaffordable to many schools.

My personal experience while working with teachers during the Rössing Foundation Outreach Programme, is that most Physical Science teachers were unable to improvise teaching and learning resources. In the absence of conventional laboratory equipment, many did not recognise that materials such as old speakers, unused solenoids, discarded electronic materials, transparent slides, videos on YouTube and so forth, which could be easily accessed, could be used to replace conventional and expensive laboratory equipment. In those schools that did have adequate science equipment to teach electromagnetism, such apparatus were either under-utilised or not utilised at all. To this end, teachers indicated that they were either not familiar with the equipment or were just unable to carry out practical activities.

In their study on factors influencing the quality of practical work in science classrooms in Mpumalanga South Africa, Hattingh, Aldous and Rogan (2007) found out that some teachers did not conduct practical activities in their classrooms despite the schools having laboratories. In a study of how teachers use everyday knowledge and manage the difference between formal science and everyday knowledge in South African schools, Stears, Malcolm and Kowlas (2003), discovered that teachers incorporated little or no everyday knowledge in their lessons, despite everyday knowledge having the potential to mediate sense making of new concepts.

Hodson and Hodson (1998) investigated ways to create opportunities for learners to explore own ideas, provide stimuli for learners to develop, modify and, where necessary, change their ideas and views; and support their attempts to re-think and reconstruct own ideas and views. These promote learner-centeredness approach as encouraged by National Institute for Education Development (NIED) (Namibia. MBEC, 1999) and the Namibian curriculum (Namibia. MoE, 2009). In a case study on learning interactions in community contexts, O'Donoghue, Lotz-Sisitka, Asafo-Adjei, Kota and Hanisi (2007) established that when learners learn through social interactions, science sense making is enhanced.

The lack of practical activities, particularly in electromagnetism as highlighted in the Physical Science Examiners' reports above, can reasonably be considered as a contributing factor to learners' poor performances in Physical Science in most Namibia schools. In the absence of standard science laboratory equipment and the inability of teachers to improvise, the central purpose for this study was to make use of easily accessible resources to help teachers to incorporate practical activities in science education, particularly in the electromagnetism topic. Hence, this study investigated the use of learning and teaching support materials (LTSMs) in the form of easily accessible materials such as discarded electronic materials, transparent slides, concept mapping and communication media such as videos as additional and alternative tools to fill the gaps left by lack of materials and textbooks in many Namibian schools.

1.3 The international context

According to Hofstein and Mamlok-Naaman (2007), science activities have long been playing a distinctive and central role in science education. Science educators have suggested many benefits as a result of engaging learners in science activities. For instance, science investigations allow learners to form scientific hypothesis, design and conduct inquiry and scientific investigations, formulate and revise scientific explanations, and communicate and defend scientific arguments (ibid). Woodley (2009) claimed that most practitioners agree that only quality practical activities which engage learners, help them understand important scientific skills, understand the process of scientific investigation and develop own understanding of science concepts.

In a study conducted in the United Kingdom on effectiveness of practical activities, Abrahams and Millar (2008) found that most learners enjoyed science lessons as compared to theoretical science lessons and that practical activities help learners to understand scientific concepts better. In their research project in the Eastern Cape, South Africa, Maselwa and Ngcoza (2003) found that learners enjoyed science lessons which included components of practical activities. These authors reiterated of course that emphasis needs to be on conceptual development during such practical activities.

In order for practical activities to be meaningful, Millar (2004), Abrahams and Millar (2008) warned that effective practical activities require clear objectives (what learners are going to do), practical task (what learners are intended to do), classroom actions (what learners actually learn) and learners learning (what learners actually learn). To create such instructional processes successfully, it is recognized that teachers need to possess professional knowledge about the stimulation and the coordination of learning-based and multiform activities (Oser & Baeriswyl, 2001). Hence, there is a need for teachers to have adequate content knowledge in their subjects.

For example, electromagnetism can be demonstrated by moving a wire through a magnetic field which induces an e.m.f. in that wire, and a current will flow if the wire is a closed circuit. The direction of the current flow can be determined by using Fleming's right hand rule (Grounds & Kirby, 1990). This electromagnetic principle is widely used, for example, in loudspeakers, relays, telephones, door bells, amplifiers, in motor contained appliances and in generating electricity, so there is a need to make science resources available for proper teaching and learning of electromagnetism.

Research has shown that learners develop misconceptions when learning electromagnetism (Allen, 2001; Prosser, 1994; Van Niekerk, 2011) and in grasping the relationship between electric and magnetic fields (Erinosho, 2013; Raduta, 2005), understanding magnetic flux, the induced e.m.f.

and how it is produced (Albe, Venturini & Lascours, 2001; Raduta, 2005; Saglam, 2010). Such misconceptions may lead learners to inaccurately interpret key concepts in electromagnetism.

According to Raduta (2005), these misconceptions are due to ambiguous presentations in textbooks. The mathematics involved in electromagnetism is also blamed for learners' misconceptions (Raduta, 2005). In the Namibian context, the Examiners' reports (Namibia. Ministry of Education, 2014) pointed to learners' failure to link the coil and the magnet while describing the generation of electricity in a particular national examination question. In the next section, the Namibian education system and teaching and learning of electromagnetism is discussed.

1.4 The Namibian Context

In this section, the requirements outlined in the Namibian curriculum and syllabus are discussed and how the topic is assessed in the end of year examinations. Data from these documents are used to contextualise my study.

1.4.1 The Namibian curriculum

The Namibian curriculum (Namibia, MoE, 2009) stipulates that the learner-centred education (LCE) approach is a preferred teaching and learning methodology in Namibian schools. LCE methodology entails that learners are at the centre of learning; and hence lessons ought to involve practical tasks as often as possible. Nyambe (2008) argued that LCE should be practically orientated whereby learners physically participate in the lessons. As has been noted, teachers ought to prepare and present science lessons with corresponding activities which promote effective construction of science knowledge.

1.4.2 JSC Physical Science syllabus

The junior secondary certificate (JSC) syllabus for Physical Science guides teachers on what content and level to teach. The syllabus is systematically presented in three columns; respectively indicating the themes/topics, general learning objectives and specific basic competencies. In the Grade 10 section of the syllabus, Electromagnetism is covered under theme/topic 6 of the Electrical and Magnetism sub-topic and Magnetic effect of an electrical current. Table 1.1 below shows the layout of the basic competencies of this sub-topic in the syllabus.

Table 1.1: Basic competencies for the topic of electromagnetism as laid out in the JSC Physical Science syllabus for grade 10

Themes and Topics	**Learning objectives** Learners will:	**Basic competencies** Learners should be able to:
6. 8 Magnetic effect of an electrical current	• know the magnetic effect of an electrical current in a straight conductor and a solenoid • know how to build electromagnets in loudspeakers electrical motors.	• Investigate the magnetic effect of an electrical current in a straight conductor • Investigate, sketch and compare the magnetic field around a bar magnet and a current carrying solenoid (both shape and direction of magnetic field lines are required) • describe how to build an electromagnet and outline its uses • investigate and explain the difference between the electromagnet properties of iron and steel and predict the difference between a temporary and a permanent magnet

The syllabus also provides suggestions for practical activities, but not limited to those stated in each topic. So, teachers are encouraged to prepare as many practical activities as they deem needed. Table 1.2 below shows suggested practical activities as outlined in the syllabus under theme 6.8 (see table 1.1 above).

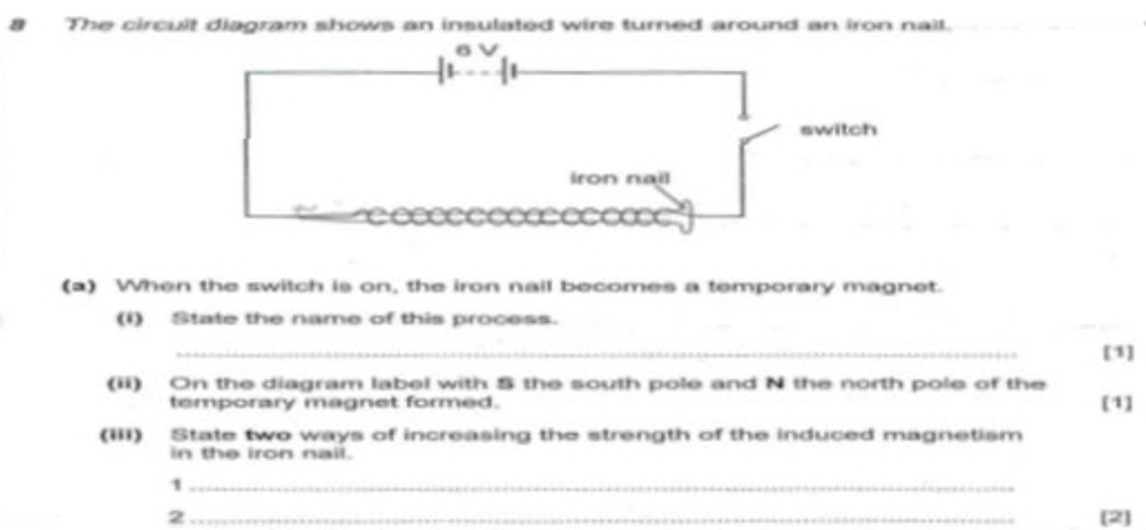
Table 1.2 Practical activities in electromagnetism topic as suggested in the JSC Physical Science syllabus for grade 10

Magnetic effect of an electrical current	• investigate the magnetic effect of an electrical current in a straight conductor • investigate the magnetic field around a magnet and a current carrying solenoid • build an electromagnet • investigate the difference between a temporary and a permanent magnet • make a simple electric motor

1.4.3 Grade 10 national exam papers

The end of year examinations test whether learners' basic competencies in the subject reach a minimum content knowledge for them to proceed to the next grade. It is recognised, however, that how subject content is assessed influences how teachers present lessons so as to reach the standard set by the particular assessment requirements.

From a brief review of past exam papers, it was noticed that questions on electromagnetism were often similar to those in previous years. For instance, the 2012 questions were a little different from 2015 and 2016 papers as shown in Figures 1.2, 1.3 and 1.4. Questions were often straight forward and learners were simply required to reproduce memorised concepts and rules during the examinations. For instance, the application of motors/generators which is a major component of electromagnetic induction were rarely assessed.


8 The circuit diagram shows an insulated wire turned around an iron nail.

(a) When the switch is on, the iron nail becomes a temporary magnet.

(i) State the name of this process.

.... [1]

(ii) On the diagram label with **S** the south pole and **N** the north pole of the temporary magnet formed. [1]

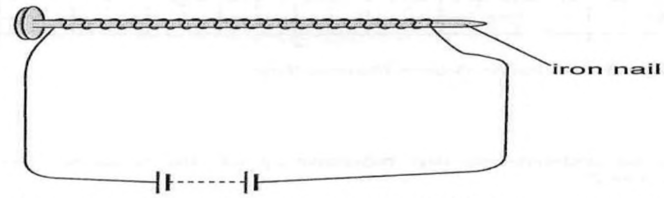
(iii) State **two** ways of increasing the strength of the induced magnetism in the iron nail.

1 ....

2 .... [2]

Figure 1.2 An extract of the 2012 Physical Science end of year exam

(b) In an experiment a wire carrying current is coiled around an iron nail as shown in the diagram.



(i) On the diagram, draw **four** magnetic field lines around the iron nail to indicate the poles of the temporary magnet formed.

Draw **two** lines on each side of the nail. [2]

(ii) State **two** ways of increasing the strength of the induced magnetism in the iron nail.

1 ....

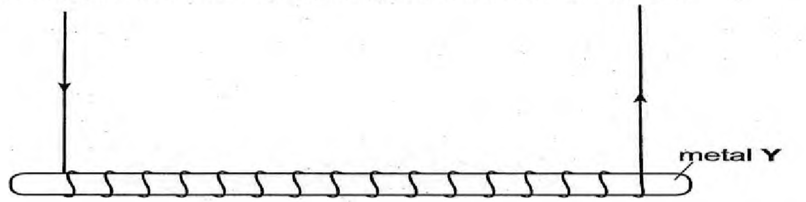
2 .... [2]

(iii) State any **one** application of electromagnetic induction.

.... [1]

Figure 1.3 An extract of the 2015 Physical Science end of year exam

(b) The diagram shows a metal bar in a coiled wire. The wire is carrying an electric current which induces magnetism in the metal bar.



(i) State the name of the suitable metal that can be used as metal **X**.

.... [1]

(ii) On the diagram, clearly label **the poles** of the induced magnet. [1]

(iii) State **one** way of increasing the magnetic field induced.

.... [1]

(c) Give **two** uses of electromagnets.

1 ....

2 .... [2]

Figure 1.4 An extract of the 2016 Physical Science end of year exam

The stereotypical examination questions do not seem to support the requirement that upon completion of the JSC for Physical Science, learners are expected to demonstrate certain level of competencies in electromagnetism as outlined in the syllabus as indicated in Table 1.1 or the syllabus (Namibia. MoE, 2010) that encourages teachers to, where applicable, use local everyday prototypes to enhance scientific knowledge and comprehension.

1.5 Statement of the problem

Most Physical Science teachers from Grade 8-12 might not have been exposed to the use of easily accessible (locally sourced) materials or the benefits of such resources. Instead, they might still associate practical work with standard laboratory equipment which in most schools is unavailable. Such teachers would then still be teaching science in the absence of practical activities which are believed to better help knowledge construction. Instead of using easily accessible materials in practical activities in their science lessons, teachers would be left grappling with how to help learners construct science knowledge in the absence of practical activities.

Despite assertions by Millar (2004), Woodley (2009) and Oloruntegbe and Ikpe (2011) that learners learn better when they are involved in the learning process, most often science lessons are conducted without practical activities in some Namibian schools. Similarly, the use of easily accessible materials to enhance construction of science knowledge through practical activities in Namibian schools is still under-researched. This study thus sought to close these gaps and to promote the use of easily accessible materials to encourage practical activities in science lessons.

1.6 Significance of the study

The challenges facing science education in Namibia include a real lack of standard science laboratory equipment in most schools (Namibia. MBEC, 1999). Moreover, most science teachers in Namibia lack proper science laboratory facilities and find themselves using ordinary classrooms with no storage facilities for science equipment and chemicals and portable water. My experiences working in various regions has revealed that no primary school I visited had laboratories. This often meant such schools also lacked science resources. Moreover, the Ministry of Education, Arts and Culture continues to elevate such schools to include JSC classes. Indeed, I have come across many teachers in both remote and urban areas find themselves teaching in makeshift classrooms such as in tents, thatched huts or under trees .

Despite assertions in various studies (Millar, 2004; Sigel & Cocking, 1977; Treagust, 1993; Woodley, 2009) that learning science is enhanced by practical activities, most science teachers in Namibia teach science theoretically, due to the factors alluded to above.

In order to understand how Grade 10 Physical Science teachers in under-resourced schools could help learners to make sense of electromagnetic concepts by using easily accessible materials, I collaborated with two Grade 10 Physical Science teachers in the Swakopmund Circuit of the Erongo region to develop learning and teaching support materials (LTSMs) (Czerniewicz, Murray & Probyn, 2000) using easily accessible local materials. The significance of this study thus lay in:

- Informing teachers on the potential of using easily accessible materials as alternatives to standard science laboratory equipment in the teaching of electromagnetism concepts;
- Informing the curriculum designers of the importance of the inclusion of easily accessible materials in Physical Science lessons;
- Helping teachers develop their own easily accessible LTSMs to enable them to incorporate practical activities in the science lessons;
- Paving the way for other studies on the intervention needed when including easily (locally) accessible materials in the Physical Science curriculum; and
- Helping the me as a Physical Science teacher to improve my teaching strategies.

1.7 Research Goal and Questions

In this section the research goal, main question and sub-questions are presented.

1.7.1 Research Goal

The main goal of this study was to understand how Grade 10 Physical Science teachers help learners to make sense of concepts of electromagnetic topic through the use easily accessible materials in under-resourced schools.

1.7.2 Main Research Question

How do Grade 10 Physical Science teachers help learners to make sense of concepts on electromagnetism through using easily accessible materials in under-resourced schools?

1.7.3 Research sub-questions

- What are Grade 10 Physical Science teachers' perceptions and experiences of teaching the topic electromagnetism?
- What factors influence Grade 10 Physical Science teachers' perceptions and experiences of teaching the topic electromagnetism?
- What can Grade 10 Physical Science teachers do to improve teaching and learning of electromagnetism in under- resourced schools?
- What enables or constrains Grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible resources in under-resourced schools?

1.8 Definition of key concepts

Electromagnetism: Interaction between electricity and magnetism, as when an electric current or a changing electric field generates a magnetic field, or when a changing magnetic field generates an electric field.

Learner centred education (LCE) is an approach to teaching and learning that comes directly from the National goals of *equity* (fairness) and *democracy* (participation). An approach that requires teachers to put the needs of the learners at the centre of learning.

Learning and teaching support materials (LTSMs): Any materials or resources which are used to enhance learning by the teachers or learners (Czerniewicz *et al*., 2000).

Mediating tools: The tools through which mediating of learning is achieved, which can be physical tools or psychological.

Mediation of learning: The process in which the teacher interacts with the learner(s) in order to scaffold their intellectual development.

Pedagogical Content Knowledge: A concept which describes the way in which teachers present and formulate subject content in order to make it understandable by learners.

Practical activities: Prepared activities by the teachers or educators which enable learners and students to be actively involved in the learning process.

Scaffolding is the process of helping learners to move from one level of schema to the next and so achieve what they could not do before.

Sense making: The ability of learners to relate science concepts to their existing knowledge structures and/or life experiences.

Social constructivism: A sociological theory of knowledge that considers how social phenomena or objects of consciousness develop in social contexts. A social construction (also called a social construct) is a concept or practice that is the construct of a particular group.

Teaching strategies: The methods that a teacher or teachers use to help learners to master concepts in the classroom.

1. 9 Thesis Outline

This thesis comprises of six chapters and these are outlined below:

Chapter One: Situating the study

This chapter outlines the research context, the aim and significance of the study. The reasons for carrying out the research are outlined and the research goals listed. The chapter ends with a review of the definitions of concepts used in the thesis.

Chapter Two: Literature review

This chapter discusses the literature relevant to the study. Firstly, it focuses on the curriculum's views using easily accessible materials for teaching science. Secondly, the literature on electromagnetism and electromagnetic induction is presented. The significance of practical activities in science and PCK in science subject is examined. The chapter also discusses the theoretical framework that informed the study.

Chapter Three: Research methodology

This chapter narrates the methodology used to collect data for the research, which used mixed methods with qualitative dominant over quantitative. It also clarifies the methods used to gather data to answer the research questions. The methods of data generation such as questionnaires, workshops, lesson presentations and stimulated-recall interviews are discussed in more detail in this chapter. The sampling techniques used to select the participants for both the questionnaires and lesson presentations are described. The chapter concludes with a description of the triangulation methods used to validate the data and the ethical considerations. It also highlights some limitations that appeared during the data generation process.

Chapter Four: Data presentation, analysis and discussion from questionnaires (Phase 1)

This chapter presents, analyses and discusses the data generated from questionnaires. I critically analysed and categorized data into categories to be examined using the theoretical framework and literature. The findings of the research are presented in relation to the literature discussed in Chapter Two.

Chapter Five Data presentation, analysis and discussion from the workshops, lesson presentations and stimulated-recall interviews (Phase 2)

This chapter presents, analyses and discusses the data generated from workshops and lesson presentations, and interviews. As in chapter four, I critically analysed the data using my theoretical framework and literature to respond to my research questions. The findings of the research are presented in relation to the literature discussed in Chapter Two.

Chapter Six: Summary of findings, recommendations and conclusions

In this chapter the findings, recommendations, reflections and conclusion are summarized in detail. Recommendations are offered for areas of future research and reflections on the overall research process. The limitations of the research are discussed.

1.10 Concluding remarks

In this chapter, I discussed the study as situated in the Namibian framework. The research goal, questions, and the significance of the study as well as the data generation techniques used in the study were presented. Key concepts used in the thesis were defined followed with a thesis outline.

The next chapter discusses the literature that was consulted on practical activities and the inclusion of easily (locally) accessible materials in Physical Science.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

According to Bless and Higson-Smith (1988), before a researcher embarks upon conducting research of any kind, it is imperative to conduct a contextual check of the issue(s) to be investigated. Hence, consulting scientific literature is essential to acquire necessary knowledge on the research topic. According to Bless and Higson-Smith (1988), a researcher is able to gain an overview of various theories and models which can be used in the research while at the same time able to identify the theoretical framework on which the research will be based.

The main goal of this study was to explore how grade 10 Physical Science teachers help learners to make sense of concepts on electromagnetic through using easily accessible materials. Hence, this chapter explores views from literature about how teachers conceptualize and enhance the understanding of electromagnetism by using easily accessible materials. Essentially, the chapter discusses key aspects of practical activities, what electromagnetism is about and the social constructivism theory that was used to make sense of the data. I start by presenting a brief history of the Namibian Education system after independence.

2.2 A brief Namibian Education History

At independence in 1990, Namibia inherited an education system characterised by major inequalities in educational opportunities and facilities among various sectors of the Namibian society. The provision of education and training was highly slanted in racial and regional terms, to fundamentally privilege a few. After independence, education and particularly basic education, became one of Namibia's priorities for reform. Education became universal as expressed in the Namibian Constitution, Article 20(1) which states that: "…all persons shall have the right to education…" (Namibia, 1990, p. 14). Education reform was guided by the Ministry of Education's five goals, of which two are of interest to this study and are listed below:

(a) "Improve quality in the education system; and

(b) Improve efficiency in the education system" (Zaaruka, Biwa & Kalenga, 2001, pp. 9-10).

2.3 Namibian Curriculum and Education Policy Expectations

This section discusses the educational requirements as underlined in the Namibian Basic Education Curriculum (NBEC) and the syllabus.

2.3.1 Curriculum and learner centred education (LCE)

The Namibia Basic Education Curriculum (NBEC) (Namibia, Ministry of Education [MoE], 2009) promotes the empowerment of learners for the development of Namibia as a knowledge-based society. In order to acquire and learn how to apply knowledge creatively and innovatively, the curriculum (Namibia, MoE, 2009) encourages the use of learner-centred education (LCE) as a methodology for teaching and learning. According to the National Institute for Education Development (NIED), LCE is an approach whereby learners are placed on the forefront of all activities associated with learning.

Accoridng to the policy for LCE at the time of formulation in (Namibia. Ministry of Education and Culture, 1999), teachers ought to put the needs of learners at the centre of teaching and learning, rather than the learner being made to fit whatever needs the teacher has decided upon. The LCE policy meant that teachers ought to prepare activities which put the learner at the centre of teaching and learning must begin by using or finding out the learners' existing knowledge, skills and understanding of the topic. That is, teachers are responsible to develop learners' abilities by building of learners' prior knowledge.

According to Mubita (1998), when designing the curriculum, learners's situation should be placed at the centre. That is, their experiences both outside school and in school should be taken into consideration. In support of this, Namibian Institute for Educational Development (NIED) (Namibia. NIED, 2003) indicates that teachers should be able to choose learning and teaching content and methods on the basis of collective analysis of learners' needs. Furthermore, teachers should make use of natural resources and locally as alternative materials for teaching and learning. Likewise, in a LCE environment, learners are expected to learn and share ideas from each other. The Namibian Institute for Educational Development (NIED, 2003) says that learning should be seen as an collaborative, collective and fruitful process. Consequently, teachers ought to create learning environments conducive to learners being creative, innovative, and exploring their environment in such a way that they build from what they know in ways that aid them to learn new knowledge.

Contributing to the rich foundational literature on LCE have been Vygotsky (1978) and Bruner (1966), who assumed that learning is via a constructivist prototype (Schweisfurth (2013).Schweisfurth (2013) refers to “learning in a constructivist paradigm contrues knowledge as co-developed by and amongst learners, and where learners and teachers play a social, interpersonal and facilitative rather than whole-class instructive role” (p.2).

LCE entails carefully designed teaching and learning materials which teachers can use to support learners in building and constructing new knowledge (Namibia. Ministry of Basic Education, Sport and Culture [MBESC], 1999). Nyambe (2008) emphasises that LCE should be practically orientated whereby learners physically participate using all the scientific skills of learning such as observation while critiquing and reflecting on the learning materials. However, lack of learning resources (science equipment and chemicals), scarcity of skilled science teachers remain a challenge to the Namibian Education System. This research, however, not only sought to understand LCE, but to develop practices in which LCE could influence learning of science concepts through the use of easily (locally) accessible materials.

Despite Namibia’s learner-centred curriculum having stipulated LCE for over 20 years, Chisholm and Leyendecker (2008) asserted that it is frequently not effectively practiced. Nyambe (2008) argued that LCE has not been successfully implemented in Namibia, finding that teachers had difficulties interpreting and practicing LCE. In their study conducted in Namibia, Nyambe and Wilmot (2012) revealed contradictions in teacher educators’ interpretations and practice of LCE and within the official ministerial policies.

In their study of new pedagogy versus old pedagogy in Namibian college of education, Nyambe and Wilmot (2012) posited that the same official policies which require teachers to adopt learner-centred pedagogy, college authorities mandate the duration of lessons, impose strongly framed schemes of work and time-tabling and strict expectations in terms of syllabus coverage in a way that turns a blind eye to the student teachers' measure of learning. Nyambe and Wilmot (2012) further argued that the; "fork-tongued discourse, anchored in a technicist approach, constitutes one of the key factors that constrain and stifle teacher educators' meaningful uptake of learner-centred pedagogy in the Namibian teacher education reform" (p.76). In order for learner centred pedagogy to be meaningful, they suggest that there is a need for a comprehensive perspective that will take into account changes in teacher educators' pedagogic skills, structural arrangements such as time-tabling, sequencing, pacing and strict views regarding syllabus coverage.

2.4 Electromagnetism and electromagnetic induction

This section discusses what electromagnetism is all about, highlighting the role it plays in the modern world, misconceptions often associated with it as well as challenges and possible interventions associated with it.

2.4.1 Magnetic effects of electric current

An electrical charge in a conductor experiences an electric force. When the charge moves, it creates a magnetic field surrounding the charge. This magnetic field can be magnified by increasing the charges. The effect is a magnetic field in the region surrounding a wire carrying a current of moving electrons. The magnetic field can be witnessed using iron fillings spread over the region of the wire or with the use of plotting compasses. The strength of the magnetic field is defined in terms of the force it exerts on a current-carrying conductor placed in the field. Two current-carrying wires placed side by side exert forces on each other. This effect is used in the definition of the ampere, the unit of current (Grounds & Kirby, 1990).

The larger the current, the larger the force exerted by the magnetic field around the conductor. The strength of the magnetic field is measured in terms of a vector quantity, B, called the magnetic flux density. If a wire carrying current is placed in a magnetic field, then the wire experiences a force which depends on the magnetic flux density at the wire. The value of the magnetic field is defined as the force per unit length per unit current. Thus, if a wire of length L, carrying a current I, is placed at right angle to a uniform field B, the wire experiences a force F, then the flux density will be:

$$B = {}^{F}/_{IL}, \qquad \text{measured in tesla (T)}$$

The direction of the force is perpendicular to both the field B and the current, I, and can be determined by using Fleming's left-hand rule (Grounds & Kirby, 1990).

2.4.2 Electromagnetic induction

If you move a current-carrying conductor through a magnetic field, or move a magnetic field past a current-carrying conductor, or change the strength of the magnetic field linked with the circuit, an e.m.f. generated by changing the flux linked with the circuit is said to be induced. The first law of electromagnetic induction states that the induced e.m.f. is equal to the rate of change of flux linkage, where flux linkage, Φ, is equal to flux, ϕ, multiplied by the number of turns, N.

$$\text{Thus, } \Phi = \phi N, \quad \text{so} \quad V = {}^{d\Phi}/_{dt} = {}^{d}/_{dt}\,(NBA)$$

Note that the flux linked with a circuit has to change to induce an e.m.f., this means, that is an e.m.f. can be induced by changing N, B, or A. This leads to the second law of electromagnetism induction (Lenz's law) which states that the induced e.m.f. is always in such a direction as to oppose the change that causes it. This means that the induced e.m.f. must be in such a direction as to oppose the change which caused it. This law is a consequence of the law of conservation of energy, since if a change induced an e.m.f. in a circuit and this e.m.f. actually assisted the change then, once started the system would self-generate energy (Grounds & Kirby, 1990).

In simple terms, moving a wire through a magnetic field will induce an e.m.f. in the wire, a current will flow if the wire is in a closed circuit. The direction of the current can be determined by using Fleming's right hand rule (Grounds & Kirby, 1990). Fundamentally, many practical applications discussed in the next section depend on the principles of the above concepts. Considering the pace of technological development, it is likely that there are more yet undiscovered applications that will transform the ways in which machines function.

2.4.3 Applications of electromagnetic induction

Electromagnetism is used in a wide variety of devices, for example, in loudspeakers, relays, telephones, door bells, amplifiers, in domestic appliances, in electrical generation, from spacecraft to industrial applications. There is clearly a need for the standard of electromagnetism in the syllabus be elevated to international level with emphasis on effective teaching and learning, and provision for adequate science resources. Misconceptions related to learning electromagnetism are discussed in the following section.

2.4.4 Misconceptions in electromagnetism

Since I could not find literature on high school misconceptions about electromagnetism, views discussed in this section are based on college student-teachers' and practising novice teachers. Albe, Venturini and Lascours (2001) and Saglam (2010) found that student teachers had difficulty in understanding magnetic flux. Erinosho (2013) and Raduta (2005) found that college student teachers were unable to grasp the relationship between electric and magnetic fields. Equally, they found it difficult to understand induced e.m.f. and how it is produced (Raduta, 2005).

According to Raduta (2005) misconceptions often arise as a result of student teachers misunderstanding key electromagnetism concepts, and this often is associated with inaccurate interpretation of symbols. Also, these misconceptions are often due to ambiguous presentations of electromagnetism topic in textbooks, the direction of Lenz's law force and the application of the right-hand-rule as well as the mathematics involved in electromagnetism. Although mathematics is a critical component for understanding electromagnetism, a basic understanding of electromagnetism as required in the grade 10 curriculum requires very basic mathematic skills.

The challenges discussed above are no different to those at school level. As discussed in Section 1.2, learners at high school also find the of electromagnetism topic challenging. According to Examiners' reports, lack of practical activities and the use of real life materials during the teaching of electromagnetism topic is a major contributing factor to challenges in learning this topic. Likewise, a lack of science resources, particularly in electromagnetism is considered a major factor which hinders teachers from including practical activities in their science lessons.

2.5 Challenges associated with mediation of electromagnetism

In my experience, teaching electromagnetism is not stress-free. In Namibia, little is known of the difficulties facing both by science teachers and learners as to why electromagnetism is treated badly. Working with science teachers has shown that doing practical activities in science lessons and electromagnetism in particular, is minimal.

Khoboli and O'Toole (2011) reported that a lack of laboratory equipment such as electromagnetism kits, crowded classrooms and rowdy learners, and a lack of significance of practical activities for most science teachers are issues discouraging them from conducting practical activities in their science lessons. Teachers in Lesotho were unable to implement learner-centred approaches due to non-existence or inadequate equipment, large class population, time constrains, *etcetera*. In schools which did have some laboratory equipment, Khoboli and O'Toole (2011) reported that teachers acknowledged that occasionally they avoided using the equipment due to lack of practical skills and inadequate time for preparation of activities.

Despite the fact that the curriculum advocates a constructivist approach to teaching and learning of science such as LCE, Mukwambo and Zulu (2013) disclosed that inexperienced science teachers, quality of accessible materials, time allocated for practical work and teachers' capacity to initiate learners into the science community by using practical work are further challenges facing the education system.

2.6 Interventions for mediating the topic of electromagnetism

It is a prerequisite to diversify the pedagogical content knowledge of teachers in order to suit learning requirements as put forth by Schulman (1986) as well as Cochran, King and De Ruiter (1991). Zuza, Almudi, Leniz and Guisasola (2014) pointed out that electromagnetism is challenging to teach, in part because key measures in electromagnetism are independent yet closely associated. Likewise, Román (2012) argued that conceptual vastness of concepts and high abstraction are some of the reasons why teaching electromagnetism is a challenge.

To alleviate difficulties confronting learners when learning electromagnetism, Román (2012) recommended that learners' attitudes towards science need to be improved. In his study in Mexico, revealed that a combination of practical activities (historic context, use of animations and video group discussion and everyday applications) can offer constructive results in learning electromagnetic induction (Faraday's law of induction), hence strengthening abstract and empirical understanding.

Bagno and Eylon (1997) reported that most textbooks (particularly in the United States of America) did not stress the idea that an alteration in magnetic field is associated with the production of an electric field. As a result, Raduta (2005) was not surprised that learners found it challenging to associate labels such as 'Lenz's law' or 'induced e.m.f.' with the production of the electric current. The view of this research was that by using easily (locally) accessible materials, teachers could be able to mediate learning of electromagnetism using a more constructive approach that would incorporate practical activities in the teachers' science lessons.

An example of using local materials was when Mukwambo and Zulu (2013) found an innovative way of sourcing distilled water for their laboratory experiments from an air-conditioner and from traditional distillation. Despite the fact that most Namibian schools lack science equipment to enable teachers to carry out practical activities in their science lessons, Erinosho (2013) counselled teachers to advance interest and learning of physics. Teachers ought to make available concrete familiarities in physics so that learners can associate meanings with learning material and in so doing achieve better understanding and retention of information (ibid). As a final point, Saglam (2010) puts forward the use of mind-mapping or concept mapping as tools which may improve assimilation of electromagnetism concepts.

Scholars such as Dori and Belcher (2005) and Chen and Howard (2010) have validated the use of ICT in learning electromagnetism using computer gaming and live simulations software. For instance, Dori and Belcher (2005) propose that teaching should not only be in spoken and printed text, but also through still and moving pictures, visual simulations, 2D and 3D visualizations, graphs, and illustrations. Furthermore, they reverberate that representations are superior to words for learning concepts. Cognitive and psychological benefits of learner centred pedagogy are often alluded to as the primary reasons for teachers, schools, and governments to adopt the use of ICT as teaching approaches (Vavrus, Thomas & Bartlett, 2011).

However, in a country like Namibia, ICT learning tools are out of reach for most schools. For this reason, this research focused on transforming ways of teaching electromagnetism and electromagnetic induction by means of using easily accessible materials such as discarded electronics (speakers, motors, electronics and etcetera).

2.7 Practical Activities in Science Education

In this section the role of practical activities in science classrooms is discussed, emphasizing its strengths and weaknesses.

2.7.1 Practical Activity in Science

Research opinions of practical (hands-on) activities in science instructions are varied. Woodley (2009); Millar (2004) and Oloruntegbe and Ikpe (2011) reasoned that it is indispensable for learners to interact with materials throughout learning. Bowell and Eison (1991) described the role of practical activities as to involve learners in meaningful learning processes other than listening and make them think about what they are learning. The next sections briefly elaborate on the strengths and weaknesses, and the promotion of practical activities as an approach to learning science.

2.7.2 The strengths of practical activities in Science

The prominence of practical work in science is extensively viewed as the utmost effective way of constructing knowledge meaningfully. In Namibia, the curriculum validates scientific literacy (Namibia. MoE, 2009) and the subject policy (Namibia. MoE, 2008) promotes learner-centred education where learners ought to be actively involved in hands-on activities to attain practical skills, attitudes and knowledge. In addition, the syllabus (Namibia. MoE, 2010), makes suggestions for likely hands-on activities in all topics.

In the UK, practical activities are part of teaching and learning science. Most academics agree that only excellent practical activities can involve learners thoughtfully and instil vital scientific concepts and skills, such as inquiry processes (Woodley, 2009). Woodley (2009) asserted that practical activities allow learners to comprehend the significances of experiencing hands-on activities in science. Paiget argued that for learners to construct knowledge accurately, they should be involved in the learning processes (Sigel & Cocking, 1977). According to Von Glasersfeld (1989), learning does not take place when knowledge is received passively, but when learners are actively involved in the learning processes.

Furthermore, research has shown that learners learn best when they are actively involved in the learning process which helps in developing their ability to think (Prince, 2004) as it encourages learner-centeredness (Nyambe, 2008), using scientific processes. Practical activities promote learner-centeredness which the NCBE advocates (Namibia. MoE, 2009).

Likewise, Millar (2004) held that practical (hands-on) activities equip learners with appropriate thoughtful science for them to partake assertively and meritoriously in the contemporary realm. Abrahams and Millar (2008) worked on efficacy of hands-on work in teaching and learning, publicising evidence that most learners appreciate practical activities in science lessons in contrast to instructions without hands-on activities. Practical science activities offer means for learners to attain hands-on skills that are indispensable for the new workforces that require cutting-edge scientific knowledge and specialised expertise (Abrahams & Millar, 2008; Prince, 2004).

Lazarowitz and Tamir (1994); Lunetta (1998) and Hofstein and Lunetta (2004) suggested that practical or laboratory activities enable social interaction among learners. Hence, learners develop essential skills necessary for scientific understanding and cognitive growth. Bell, Urhahne, Schanze and Ploetzner (2010) proposed that learners are more successful when learning in shared surroundings such as group work as opposed to working alone.

Research findings by Maselwa and Ngcoza (2003) on grade 9 learners revealed that most learners enjoyed practical activities in science lessons. The authors further found out that learners felt that practical activities were powerful in promoting conceptual development and understanding of science concepts, and the activities minimised rote learning. Maselwa and Ngcoza's (2003) notions of "hands-on", "minds-on" and "words-on" on practical activities promoted scientific skills of observation, investigation, problem-solving and so forth as learners could visualise phenomena, hence, promote the enhancement of conceptual understanding. Hatting, Aldous and Rogan (2007) agreed that, from their experience, learners are always enthusiastic about carrying out meaningful practical activities. Despite numerous benefits practical activities bring science education, research has also shown that practicals have the potential to impede the very same benefits.

2.7.3 The weaknesses of practical activities in Science

Contrary to widespread acknowledgement of the immense advantages practical activities bring out in the learning of science, Hodson (1990), Roberts (2004) and Millar (2004) cautioned that if not properly planned, practical activities may possibly hamper the very same learning intended to aid. Hodson (1990), Leach and Scott (1995) argued that science practical activities do not always guarantee learning. Hodson (1990), for instance, strongly disputed the educational values of practical work. Based on his experiences, he concluded that most practical activities carried out in schools are 'ill-conceived, confused and unproductive' (p. 33).

According to Hodson (1990), practical activities may not necessary improve learners' motivation, rather some learners may find some practical activities boring. Hodson (1990), warned that there is often no or little learning in practical activities as most high school practical activities follow certain recipes which often lead to unproductive activities and a waste of time. Millar (2004) complemented that arguing that often there is no link between practical activities and the theory behind such activities. Roberts (2004) warned that if not planned and carried out correctly, practical activities in fact have the potential to hinder learning. Agreeing with Hodson (1990), Abrahams and Millar (2008) posited that practical activities in most schools are ill-conceived, disorderly and unproductive. Likewise, Oloruntegbe and Ikpe (2011) asserted that most teachers' anxiety and that the context-based learning may possibly hinder completion of curricula. Moreover, additional hard work is required in planning hands-on activities (ibid).

2.7.4 The promotion of practical skills through practical activities

The significance of science through seeing and experiencing the situation as part of practical (hands-on) activities offer learners multiple understandings of science. The advancement of practical activities is perceived to offer benefits to learners (Schulman, 1986; Driel, Verloop & de Vos, 1998) particularly in Namibia (Namibia, MoE, 2009) provided such activities are conducted in ways that will advantage the beneficiaries (learners). Hence, science practical activities should be well formulated and intended as recommended by the curricula. Hands-on activities should offer learners participation in experimental processes, data gathering and construing from results.

In her attempt to promote the use of easily accessible materials in science practical activities in Namibian schools, Asheela (2017) found that teachers need knowledge and exposure on how to use these easily accessible resources. Through the use of easily accessible resources, she further found out that teachers were motivated, thus acquired practical knowledge to include practical activities in their science lessons.

While it is hard to measure achievements of practical activities, according to Millar (2004), such activities offer additional open-ended, investigative kind of skills which develop learners' tactical knowledge of scientific enquiry. Furthermore, Millar (2001) asserted that if learners are permitted to decide on individual enquiries, it will give them all-out possibilities for own search on an assignment, consequently making it extra motivating. Consequently, Oloruntegbe and Ikpe (2011) counselled teachers to integrate innumerable home-based linked activities as these offer a source of meaning, hence encouraging experiential-based teaching and learning and in-depth understanding of science concepts.

2.8 Theoretical Frameworks

According to Meriam (2009), a conceptual or theoretical framework is the blueprint in which a research is based. Lending support, Imenda (2014) summed it up that conceptual or theoretical framework theory is a set of interrelated propositions, concepts and definitions that present a systematic point of view. The framework has specific relationships between or among concepts; which explains and/or makes expectations about the occurrence of trials based on the identified relationships (ibid).

This study was informed by social constructivism in conjunction with pedagogical content knowledge as the theoretical frameworks.

2.8.1 Social constructivist theory

The concept of social constructivism is attributed to the work of Vygotsky (1978). Social constructivism conceives an active construction of knowledge on the part of the learner and that it unifies and transforms the mind, environmental (socio-cultural) processes into new, embodied forms of knowledge. This study adopted Vygotsky's theory (1978) whose primary focus is in the notion of social construction explaining how the teacher is able to help his/her learners construct new knowledge using easily accessible resources in particular.

According to Moll (2002), social constructivism is a sociocultural theory which advocates that learning occurs as a result of social interaction with a knowledgeable individual. This perspective highlights that knowledge is constructed socially within a society (ibid). Moll (2002) further held that social constructivism places learners at the centre of learning, taking learners' everyday experiences into account. McRobbie and Tobin (1997) posited that the social constructivist perspective places more emphasis on learning environments. Learning can be enhanced if learners can associate what they know to what they are to learn as proposed by constructivists (Moll, 2002). What is more important in all learning environments is that teachers ought to consider learners' empirical realities, prospects to use existing knowledge to make sense of their experiences, and prospects of testing the legitimacy of what is being learned (McRobbie & Tobin, 1997).

Moll (2002) argued that social constructivism being a socio-cultural theory, advocates the mediation of learning which occurs because of social interactions with the knowledgeable individual. The social constructivist perspective learning entails sense making by individual learners through social interactions (Driver, Asoko, Leach, Mortimer, & Scott, 1994; McRobbie & Tobin, 1997). Knowledge construction happens during individuals' engagement in tasks, academically or socially. This perspective highlights that knowledge is socially constructed within a society (Moll, 2002). Learning is actively processed whereby learners construct knowledge, meaning and skills which leads to developing 'new' knowledge (ibid).

According to McRobbie and Tobin (1997), active involvement during the mediating of learning contributes to better understanding of science. In other words, learning involves constructing one's individual knowledge from one's individual experiences. The concept of mediating learning is attributed mainly to Vygotsky (1978). Vygotsky's mediation of learning incorporated in social constructivism is based on a fundamental concept known as the 'zone of proximal development' (ZPD) which is the region between what a learner can do on his own, and what he can do with the help of a "knowledgeable other" such as a teacher. Furthermore, his theory highlights the importance of social interactions during the learning process.

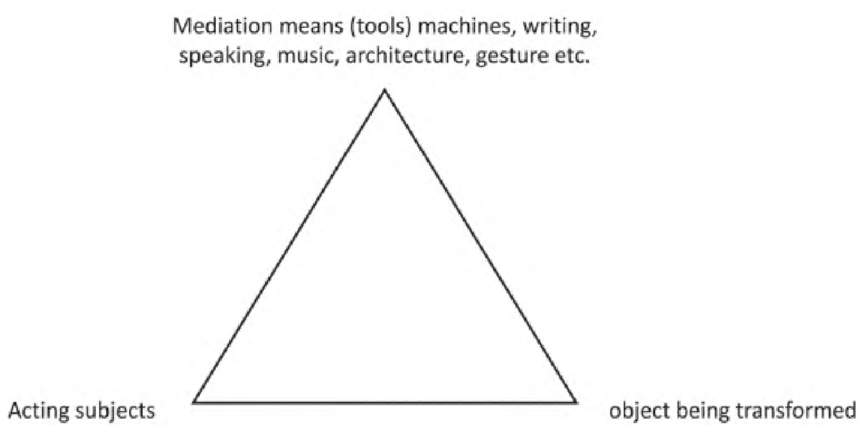


Figure 2.1: Vygotsky mediation model *Source: (Vygotsky, 1978)*

In this study data generation and analysis, relied on Vygotsky's concepts of mediation. His mediation triad linking subjects (teachers), object (the problem space or object of learning) and tools (Figure 2.1) served to unpack the mediation process and the associated challenges that teachers face when teaching electromagnetism. Wells (2002) suggested that "agent-acting-withmediational-means" (p.46) is the basic unit describing human activity (practice). The point is that whereas other species act directly upon the object of interest to them, humans on most occasions interpose a mediating artefact (tool) between themselves and the object of interest, thereby enabling them to act more effectively. Tools can be physical (hummer, car, pen and paper, *etcetera*) or non-physical such as concepts, frameworks, policies, language and so forth.

Using Vygotsky's mediation triad, for instance, the sub-question is unpacked: *How do Grade 10 Physical Science teachers help learners to make sense of concepts on electromagnetism through using easily accessible materials?* In terms of the mediation triad, the absence of practical activities constrains mediation of electromagnetism concepts.

2.8.2 Pedagogical Content Knowledge

According to Shulman (1987), pedagogical content knowledge (PCK) represents a "blending of content and pedagogy into understand of how particular topics, issues are organized, represented, and adapted to the diverse interests and abilities of learners" (p.8). Shulman puts forward a resilient argument that teachers are people who know something not understood by learners, and it is the teachers who help learners unlock the content knowledge which learners do not understand, using well-structured teaching methodologies.

Cochran, King and De Ruiter (1991) broadened that pedagogical content knowledge (PCK) is an integrated understanding that is synthesized from teacher knowledge of pedagogy, subject matter content, student characteristics, and the environmental context of learning, They paraphrased the connotation of PCK as a concept that uses the understanding of subject matter concepts, learning processes and strategies for teaching the specific content of discipline in a way that enables learners to construct their knowledge effectively in a given context.

This knowledge referred to by Shulman (1987) and Cochran *et al.* (1991) guides teachers in their teaching practice, encompasses teachers' knowledge and beliefs with respect to various aspects such as pedagogy, learners, subject matter, and the curriculum and it is also derived from past knowledge and ongoing experiences (Williams, 2012). Shulman (1987) sub-divided PCK into seven components (subject content knowledge, methodological knowledge with reference to subject content deliveries, knowledge of the curriculum, general pedagogical knowledge referring to classroom principles and strategies, knowledge of learners, knowledge of educational contexts referring to school governance and social structure and knowledge of educational ends pointing to educational values and purposes, and school philosophy) of which two are listed and deliberated below:

(a) Methodological knowledge regarding subject content deliveries; and

(b) General pedagogical knowledge referring to classroom principles and strategies.

According Van Driel *et al.* (1998), craft knowledge is diligently associated to PCK as integration of knowledge which embodies teachers' accrued understanding in relation to their teaching practice. Concurring, Williams (2012) articulated that PCK is developed through practice. Teaching knowledge practices (methodology) is the first PCK component for discussion.

For teachers to be effective in their teaching, Shulman (1986) emphasized that they ought to practice worthwhile forms of representation of ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others (learners). Van Driel *et al.* (1998) agreed with Shulman (1986) that teachers must confidently transform subject-matter knowledge, so that it can be used successfully and adaptably in the communication process between teachers and learners during classroom practice.

In order to remain within the perimeters of this study, only two of Schulman's (1987) components are discussed as they help to brighten the study analysis.

While Shulman (1987) conceded that content knowledge develops continuously during practice, Ball, Thames and Phelps (2008) cautioned that teachers must know the subject content they teach and the subject content learners are anticipated to understand. Furthermore, through professional practice, Mann (2005) qualified that knowledge is constructed and developed and this leads to teachers developing a sense of credibility or congruence.

2.9 Concluding remarks

In this chapter, I discussed the relevant literature that supported the research. The social constructivism theory and pedagogical content knowledge were presented as the theoretical frameworks which informed the study. The curriculum requirements were outlined by looking at LCE in the learner-centred education (LCE) in the Namibian context. What electromagnetism entails, was described, also the strengths and weaknesses of practical activities in science education and their promotion were explored.

The next chapter, discusses the methodological framework and research techniques used in the study.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This research explored how Grade 10 Physical Science teachers in under-resourced schools help learners to make sense of concepts on electromagnetism, using easily accessible materials. This chapter describes the methodological frameworks that underpinned the research process in this study. A qualitative method design was adopted that allowed for the collection of qualitative data and analysis of responses of teachers that emerged from the workshop discussions, lesson presentations and interviews. The techniques used to collect data to answer the research questions are described. Various data gathering techniques used are described, namely, questionnaires, workshops, lesson presentations and stimulated-recall interviews. The sampling strategies, data analysis, validity and trustworthiness, and ethical considerations pertaining to the study are considered. The chapter ends with some concluding remarks.

3.2 Research design and orientation

The research design planned the nature of the study as informed by the social constructivist theoretical framework on which the study is grounded. According to Cohen, Manion and Morrison (2011), a research design proposes the overview of purpose, methodology, data gathering techniques, data required and data analysis techniques of the research.

3.3 Interpretive paradigm

This study was underpinned by an interpretive paradigm. According to Hussain, Elyas and Nasseef (2013), an interpretive research seeks to understand values, beliefs and meanings of social phenomena. Concurring, Bertram and Christiansen (2015) explained that within the interpretive paradigm, researchers aim not to predict what people will do, rather understand and describe how people make sense of their worlds and meaning making of their actions. An interpretive paradigm enabled me to understand how teachers mediate the topic of electromagnetism using easily accessible resources (LTSMs).

An interpretive paradigm allowed better interaction with the participants during the data gathering process. It also permitted me to work closely with participants on their views and experiences while developing teaching resources for including practical activities in their lessons.

It was essential to identify elements of knowledge construction because this assessed the effectiveness of the LTSMs through the reactions of the teachers. Methods used to obtain personal reactions included questionnaires, observations and stimulated-recall interviews. The aim of the questionnaire was to gain some insights into teachers' perceptions and experiences in the teaching of electromagnetism. It was hoped that these perceptions and experiences would guide the science teacher participants and me to develop appropriate lessons which would ultimately contribute to improved mediation of electromagnetism. A participatory route was followed which according to Bertram and Christiansen (2015) allows active and direct participation by the participants in finding solutions to problems facing the education community. Hence, I collaborated with the teacher participants in developing LTSMs and model lessons. According to Blanche, Durrhein and Painter (2006), participative methodologies are consistent with the interpretive framework adopted. Within the interpretive paradigm, a qualitative case study approach was employed.

3.4 The case study method

Baxter and Jack (2008) argued that a qualitative case study is an approach to research that enables investigation of an occurrence within its setting using a variation of data sources. This ensures that the issue is not explored through one lens, but rather diverse lenses that reveal multiple aspects of the occurrence are used (ibid). Concurring, Cohen *et al.* (2011) described a case study as a specific circumstance that is regularly designed to illustrate more general principles. Essentially, a case study approach was appropriate in this study because it allowed me to focus on the precise objective rather than looking at an expansive picture that cannot be resolved within the specified time.

According to Gay, Mills and Airasian (2011), a case study research is unique in that it leads to diverse varieties of understanding compared to other types of research. In this case, the focus was on understanding how Grade 10 Physical Science teachers help learners to make sense of concepts of electromagnetic topics using easily (locally) accessible resources in under-resourced schools. Schell (1992) asserted that a case study is the most flexible research design because it allows the researcher to maintain the general distinctive character of everyday actions while investigating experimental events.

Cohen *et al*. (2011) stated that a case study presents research data in a more publicly accessible form than other kinds of research reports and they hence allow researchers to make generalization instances. However, Cohen *et al.* (2011) warned that a case study has possible limitations since it is not simply open to verifying, therefore it may be selective, biased and subjective. Biasness was avoided in this study by verifying and transcribing the workshop discussions, lessons observations and interviews verbatim.

3.5 Phase 2: Collaborative approach to designing and testing the resource

In this research, I teamed up with my research participants to answer my research sub-questions 3 and 4. According to Thomson, Gregg and Niska (2004), a collaborative approach in educational settings involves educators teaming up to create solutions to educational problems. Thomson, Gregg and Niska (2004) believe that collaborative approaches can lead to effective teaching strategies and resources, thus, improving performance of both educators and learners.

Bhana (2006) says that participatory action research is a method which produces knowledge by collaborating between the researcher and participants to improve educational practices. As a result of collaborative participation, members solve educational issues effectively than they would as individuals (Lave & Wenger, 1991). Hence, through workshops, we co-developed resources from easily accessible materials, worksheets and model lessons. After the workshops, the research participants used the resources when implementing their lessons.

3.6 Research goal and questions

This section introduces my research goal, main question and sub-questions.

3.6.1 Research Goal

The main goal of this study was to understand how Grade 10 Physical Science teachers help learners to make sense of concepts on electromagnetism through using easily accessible materials in under-resourced schools.

3.6.2 Main Research Question

How do Grade 10 Physical Science teachers help learners to make sense of concepts on electromagnetism through using easily accessible materials in under-resourced schools?

3.6.3 Research sub-questions

- What are Grade 10 Physical Science teachers' perceptions and experiences of teaching the topic electromagnetism?
- What factors influence Grade 10 Physical Science teachers' perceptions and experiences of teaching the topic electromagnetism?
- What can Grade 10 Physical Science teachers do to improve teaching and learning of electromagnetism in under resourced schools?
- What enables or constrains Grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible resources in under-resourced schools?

3.7 Research sites

The study was largely conducted in the Swakopmund education circuit of the Erongo region, Namibia (see Figure 3.1). Thirty questionnaires were distributed to Grade 10 Physical Science teachers in the Swakopmund education circuit and in the Gobabis education circuit in the Erongo and Omaheke regions respectively. However, the implementation of the LTSMs was carried out at two schools in the Swakopmund education circuit.

Figure 3.1: Namibian map showing the research sites. *Source*: *https://www.google.com.na/search?q=namibian+maps+showing+regions&biw*

Convenience sampling was used to select the schools based on their proximity to each other and to me, thus reducing travelling costs and general organisation. According to Cohen *et al.* (2011), convenience sampling allows researchers to simply choose site(s) from those to whom they have easy access. Brayman (2001) explained that researchers sometimes choose certain samples by virtue of their accessibility. Since I was working with these science teachers in the Erongo and Omaheke regions at the time of this research, it was convenient to select them for participation in the study.

Learner populations of the two participating schools in the Swakopmund education circuit were very diverse in their social background, with Oshiwambo, Damara and Herero as the dominant groups. Some were from other ethnic groups from the north-east, far east-east, east and southern parts of the country. According to the participant teachers, the most common spoken indigenous languages at school are Afrikaans, Oshiwambo and Damara/Nama. According to the Namibia 2011 Population and Housing Census, the most commonly spoken languages at home in the Erongo region are Oshiwambo (39% of households), Afrikaans (20%), Damara/Nama (19%) and Herero (10%), (Namibia Statistic Agency (NSA), 2013). These languages are taught as a 2nd language along with English being the medium of instruction. Both schools (identified as S1 and S2) were 100% public schools supported by the government.

3.8 Research size and sampling techniques

The criteria used to identify participants to respond to the questionnaire survey were that teachers were currently teaching Physical Science at Grade 10 level, and have taught at that level for the past five years or more. Additionally, the two teachers who helped me to co-develop and implement the LTSMs were to be Garde 10 Physical Science teachers, having taught for at least five or more years at Grade 10 level.

These two teachers were identified using purposive and convenience sampling methods. There were several justifications for choosing these teachers. Firstly, electromagnetism is first introduced in Grade 10. Secondly, these teachers had good working relations with me. According to Cohen *et al*. (2011), purposive sampling is used for a specific purpose, for example, it allows researchers to access the knowledge for a specific purpose. As indicated above convenience sampling also allows researchers to simply choose a site which they have easy access to.

3.9 Research participants

The primary focus of my research was to develop resources which would hopefully alleviate the difficulties Physical Science teachers are facing in teaching the science subject. Hence, two Grade 10 Physical Science teachers in the Swakopmund circuit participated in this study. Data gathered from working with the two teachers helped me to answer my research sub-questions 3 and 4. Likewise, ten (10) Grade 10 Physical Science teachers returned the questionnaires. These questionnaires helped me to answer my research sub-questions 1 and 2.

3.10 Role of the Researcher

My role as a researcher during the research was to enable the research process to take place. I distributed questionnaires to teachers in Swakopmund and Gobabis circuits. Permission was sought from the two teacher participants before they agreed to participate in this research. I also asked for permission from the principals at the schools where the two teachers come from. I also asked permission from the Directorate of Education in the Erongo region to allow me to conduct my research in their schools.

The two teachers were made clear as to the steps of the research processes (workshops, lesson presentations and observations, and interviews). During the stimulated recall-interviews, I probed for more information from the participants to supplement the data from the questionnaires and observations.

Finally, I transcribed the observation video lessons and stimulated recall-interviews. The data were then interpreted, analysed and discussed and the research written up and the findings presented. Data from the workshops were also interpreted, analysed and discussed along with data from the lessons and stimulated recall-interviews.

3.11 Data gathering techniques

For triangulation purposes, data were gathered using several strategies. According to Cohen *et al.* (2011), triangulation encompasses using more than one technique to gather data with the aim of improving its validity. The following four data gathering techniques were used:

- Questionnaires;
- Workshops;
- Lesson observations; and
- Stimulated-recall-interviews.

Table 3.1: Summary of data collection methods and instruments used

Stages	Methods used to gather data	Document from which data was gathered	Purpose of the data
Stage 1	Piloting of questionnaires and interview questions	Piloting was done with three Physical Science teachers teaching grade 10	To find out how accurate the questions were in addressing my sub-research questions.
Stage 2	Distribution of questionnaires to grade 10 Physical Science teachers	Perceptions and experiences of grade 10 Physical Science teachers on the teaching of electromagnetism and the use of easily accessible materials	To collect data for research sub-questions and 1 and 2.
Stage 3	Conduct workshops	To develop the resources (easily accessible materials) and worksheets	Prepare the resources for the lesson implementation Respond to research question 3.
Stage 3	Lesson presentations	Observations sheets and video-taped lessons	Respond to sub-research question 4.
Stage 4	Recall-interviews	To find out teachers' experiences using the resource and probe further on the effectiveness of the resource	Respond to sub-research question 4.

3.11.1 Document analysis

According to Cohen *et al.* (2011), document analysis allows researchers to reach out to otherwise inaccessible information in a particular subject where the sources of information may be obstructive or non-reactive. Document analysis refers to techniques of making references from identified characteristics of messages in documents objectively and systematically (Brayman, 2001). To Cohen *et al.* (2011), qualitative data analysis comprises classifying, accounting for and clarifying the data in order to make sense of the data in terms of participant's explanations of the situations and opinions, taking into account patterns, themes and classifications.

Government documents analysed included curricula documents, Examiners' reports and past examination papers. Government documents offered insights into requirements and policies regarding teaching and learning of Physical Science in the Namibian context. Examiners' reports provided data on past learners' performances in the electromagnetism topic in particular. Lastly, past examination papers were analysed to provide insight on how the topic of electromagnetism is assessed.

3.11.2 Questionnaires

According to Cohen *et al.* (2011), a questionnaire is a convenient instrument commonly used for gathering survey data, providing structured data which can be administered without the presence of the researcher, and often being reasonably straightforward to analyse. Gay *et al.* (2011) explained that a questionnaire is a printed collection of self-report questions to be answered by a selected set of research participants. In this research the selected participants were Grade 10 Physical Science teachers. This technique was chosen because it enabled me to collect data from a large number of participants within a short available time. The questionnaire was designed by me with the assistance of my supervisor and co-supersivor. The questionnaire asked teachers' views and experinecs of teaching the topic of electromagnetism in grade 10 and whether they make use of easily accessible materials during in teaching the topic or not. Teachers were also asked as what they thought could be the benefits of using easily accessible materials in teaching the topic of electromagnetism. A copy of the questionnaire is attached in Appendix 4.

Rule and John (2011) noted that questionnaires are less expensive to administer than other forms of data collection. According to them, another advantage of a questionnaire is that it provides an efficient method of concurrent data collection from a large number of participants. However, questionnaires also have many disadvantages. Respondents may answer the questions according to the way they understand as the researcher is not always present to clarify the question. Likewise, questionnaires can only be administered to literate respondents and (as happened in this study) may have a low return rate and may take too long to return (Bertram & Christiansen, 2015)

Open-ended questions ensured that they did not limit respondents' expression of their views. The reason for distributing to many teachers in different regions was to obtain a broader view of teachers' perceptions and experiences in teaching about electromagnetism. The data from questionnaires were used to answer research sub-questions 1 and 2:

3.11.3 Model Lesson Plans (Intervention)

To answer my research sub-question 3, the two teachers in the Swakopmund circuit collaborated with me to develop learning and teaching support materials (LTSMs) using easily accessible materials and worksheets on electromagnetism. According to Jonassen and Rohrer-Murphy (1999), a substantial and meaningful activity cannot only be accomplished individually seeing that "the human individual's activity is a system of social relations" (p. 67). So, the reasons for collaborating with the teachers were to strengthen the LTSMs and to have the teachers accustomed so that they were comfortable to use the resources in their lessons. See Figures 4.2 and 4.3, and Table 4.4 for the LTSMs and Appendix 6 for a copy of the worksheets.

3.11.4 Lesson observations

Chitiyo, Taunekeni and Chitiyo (2015) posit that observational techniques allow the researcher to use multiple senses in order to understand participants' actions, roles, and behaviours. Observations are also used to understand a situation from the perspective of the participants (Hatch, 2002). Agreeing, Cohen *et al*. (2007) described using observation as data generating tool where the researcher has the opportunity to look directly at the actions rather than relying on second-hand information.

Four lessons were observed that is, two lessons per teacher (identified using codes T1 and T2 respectively) making use of the resources which we developed together. The teachers were identified by code to conceal their identities as promised when they were requested to participate in this research.

Lessons were observed and video-recorded. Lesson observations enabled me to gather first-hand information of the action that took place during the lessons. The observations were guided by an observation schedule shown in Appendix 8. McKerman (1991) noted that video-recording the lessons allows the researcher to replay the tapes to fully explore the events of the lessons and check the truthfulness of text records, especially if there were unclear interpretations needing verifying from observation scripts.

Transcripts of the lessons were then made which were used to formulate questions for the stimulated-recall interviews. The transcripts were later given to the two teachers to authenticate them.

3.11.5 Stimulated recall interviews

To Lyle (2003), stimulated recall interviews are processes in which video recordings are played back to participants to recall their thinking of events and so stimulate them to thinking about them. Lyle (2003) added that stimulated recall interviews allow researchers to analyse cognitive reasoning of participants.

One stimulated-recall interview took place with each teacher, which combined the two lessons given by that teacher. Since the teachers indicated that they were busy with the examinations, learners' continuous assessment progress and general administrations preparations which was a few days before end of year examinations, the interviews took place days after the lessons.

Bertram and Christiansen (2015) warned researchers to be careful when conducting interviews so that power relations do not influence the interviewee's responses. In this case, my position as an interviewer did not play any role in influencing teachers' responses because participants saw me as a critical friend given the way we worked with each other. Lambert and Loiselle's (2008) advice was followed to audio record and transcribe the interviews and note wherever an interviewee is sending out any mixed feelings.

The interviews were conducted in a conducive environment where the teachers were able to express themselves. They were done after school when there would be no interruptions from fellow teachers and learners. Each interview (see Appendix 9) lasted for about 25 minutes. During the interviews, both teachers were relaxed and expressed their feelings freely. This was possible because the two teachers and I have known one another for the last 5 years and we have been working together.

3.12 Data Analysis

A mixed methods approach was used with the focus on qualitative research and less emphasis on quantitative research, when analysing the results from questionnaires, lesson observation. According to Walker and Myrick (2006), data analysis seeks to organise and reduce the data gathered into themes which in turn can be fed into descriptions, models or theories. Data from lesson questionnaires, workshop discussions, lesson observations and interviews, were collected and grouped by coding based on the themes and questions answered.

Walker and Myrick (2006) posit that coding in qualitative research is one way of exploring bits of information in the data, and looking for similarities and differences within these bits to categorize them. To code, data are broken down, compared, and then placed in categories. Cohen *et al.* (2011) explained that qualitative data analysis comprises organizing, accounting for and clarifying the data in order to make sense of it in terms of contributors' descriptions of the situation, noting patterns, themes, groupings and regularities. This literally means unpacking the acquired research data in order to make sense of whether they are within the interpretive framework of the study and answer the research questions. In qualitative research, findings are typically expressed by quoting interviews from experiences the researcher has had during data gathering (Jackson, 1995).

Data from the questionnaires, workshop discussions, lesson observations and interviews were analysed using qualitative methods which allowed me to gather teachers' responses regarding their views and experiences with the use of the easily accessible materials in their lessons. Furthermore, the qualitative method allowed me to gather data on teachers' actions during the workshops, lesson presentations and interviews. Also, qualitative data were collected from questions 2 and 9 of the questionnaire.

Data generated from questionnaires, workshop discussions, lesson observation and interviews were also analysed by transcribing the video-recorded and audio-recorded interactions with teachers, with a view to establishing analytic statements regarding teachers' pedagogical practice when using LTSMs.

Quantitative analysis was done by tabulating certain frequencies of responses regarding views and experiences of teachers on their difficulties of teaching the topic of electromagnetism and their use of easily accessible materials.

The data analysis process used in the mediation of learning used social constructivism and pedagogical content knowledge (PCK) as theoretical frameworks. Mediation of learning emphasized teacher-learner interactions as was well evident during the data analysis from the transcribed sheets where in many instances were highlighted where the teachers were in conversations with the learners during the practical activities. It was proved necessary to include social constructivism because of its interrelationship with mediation of learning.

3.13 Piloting the study

I piloted my questionnaire with five (5) teachers teaching Grade 10 Physical Science in the Walvisbay circuits to check whether the questions I had asked addressed my research questions 1 and 2. This was possible with the help of the Ministry of Education, Erongo Regional Education Directorate' Senior Education Officer for sciences at Swakopmund. Furthermore, with the help of my MEd collegues and my supervisors, changes were made to the questionnaire in order to respond to my research questions 1 and 2.

The worksheets were also piloted with a Grade 10 Physical Science teacher in the Gobabis education circuit of the Omaheke region. That is, the Grade 10 Physical Science teacher taught using these resources. This helped me make necessary changes whereby procedures in the worksheets where unclear. Additionally, the LTSMs were tested and adjusted accordingly so that the resources worked as per the procedures in the worksheets.

3.14 Validity and trustworthiness

Bless and Higson-Smith (1988) explained that measurement techniques are assessed in terms of the principles of reliability and validity. Reliability is the trustworthiness of data. On the other hand, validity is concerned with the accuracy of the empirical measures as a representative of the concept in question.

According to Cohen *et al.* (2011), for the data to speak to the content and for construal and be valid, the data selected must be representative of the sample data set. Triangulation is referred to as "the use of two or more methods of data collection in the study of some form of human behaviour" (ibid, p. 195). Triangulation thus helps researchers to detect analysis errors from the data and strengthens the validity of the findings.

The questionnaire was designed to answer my research sub-questions 1 and 2. The questionnaire was validated with four Grade 10 Physical Science teachers in the Walvisbay circuit of the Erongo region to check whether it addressed the research sub-questions. Additionally, the questionnaire was further revised several times with the help of my MEd colleagues and supervisors. This enabled me to modify questions that were ambiguous. The revised questionnaire was then distributed to teachers in the two circuits, Swakopmund circuit in the Erongo region and Gobabis circuit in the Omaheke region. This was possible since at the time of this study my work involved working with Grade 10 Physical Science teachers in these circuits.

The two participating teachers and I collaboratively developed two worksheets during the workshops and these were utilised along with the lesson presentations. The worksheets were validated with inputs from two senior secondary Physical Science teachers with more than 20 years of experience in Swakopmund. Further validation was acquired from my supervisors. The worksheets were further validated by piloting them in one of the schools in the Gobabis circuit of the Omaheke region. The reason for piloting the resources was to see how learners were going to respond to the resources and the worksheets. Adjustments were therefore made before the worksheets were ready for the lesson presentations.

As highlighted by Bless and Higson-Smith (1988) and expanded by Cohen *et al.* (2011) trustworthiness in qualitative research can be regarded as the fit between what the researcher records as data and what occurs in the natural setting being researched. Prolonged discussions with the teachers and exposure of the resources to the teachers and learners helps to build trust. In order to further enhance the trustworthiness of the data, it was considered in parallel with the available literature.

3.15 Ethical Considerations

Ethical issues were addressed through confidentiality, anonymity and voluntary participation of participants. Bless and Higson-Smith (1988) advised researchers that research participants should not be involved without their consent. It is therefore important to take utmost care with research participants so as not to invade their privacy.

In light of the above and prior to conducting the research, I negotiated with the teacher participants to inform them about ethical issues. The purpose of the negotiations was to introduce the research and clarify with participants. After that, formal written requests for permission were sought from the relevant authorities, namely, the Ministry of Education and Culture Regional Directorate (Education Director) as well as the research sites' head of institutions (school principals) (see Appendices 1, 2a and 2b). Approval was given by the Ministry of Education Regional Directorate, the school head and parents of Grade 10 Physical Science learners.

Cohen *et al.* (2011) indicated that informed consent is a practise in which individuals indicate whether to partake in an investigation after being cognisant of specifics that might influence their decision. The agreement forms signed by participant teachers were assurance that their names would be protected using pseudonyms (see Appendices 3a and b). Therefore, the participant teachers were identified as T1 and T2 and their schools as S1 and S2 respectively.

3.16 Concluding remarks

This chapter described the methodological framework used to gather data for the research. The interpretive paradigm which informed the research was presented followed by a discussion of the qualitative method approach used. The chapter further outlined in more detail the sampling strategies used to choose participants for interviews. The issue of validity and trustworthiness was discussed and ethical issues were managed by obtaining informed consents and permissions and using coding for the identities of participating teachers. In the next chapter, I present, analyse and discuss data generated using questionnaires.

CHAPTER FOUR: DATA PRESENTATION, ANALYSIS AND DISCUSSION (PHASE 1)

4.1 Introduction

The previous chapter discussed the methodology used and described how data were generated to answer the research questions in this study. To develop an understanding of how Grade 10 Physical Science teachers help learners to make sense of concepts of electromagnetism through the use of easily accessible materials in under-developed schools, the following sub-questions were asked:

1) What are Grade 10 Physical Science teachers' perceptions and experiences of teaching the topic electromagnetism?
2) What factors influence Grade 10 Physical Science teachers' perceptions and experiences of teaching the topic electromagnetism?
3) What can Grade 10 Physical Science teachers do to improve teaching and learning of electromagnetism in under resourced schools?
4) What enables or constrains grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible resources in under-resourced schools?

This chapter presents the data generated from questionnaires given to Grade 10 Physical Science teachers. That is followed by presentation of data generated from workshops conducted with two Grade 10 Physical Science teachers in Swakopmund education circuit of the Erongo region. Then I present data from lesson observations and stimulated-recall interviews conducted with the two teachers. Data generated from the workshops, lesson observations and interviews with the two teacher participants are analysed and discussed in the next chapter.

The teachers' profiles, is presented first that is, their gender, age groups, qualifications and teaching experiences of grade 10 Physical Science. In line with the ethical principles of confidentiality and anonymity, respondents were not required to provide any identification. The ten (10) returned questionnaires were numbered from 1-10 thus teacher 1, question 1, male (T1Q), T2Q, T3Q and so on. With regard to the two teachers with whom the LTSMs were co-developed, their identities and schools were also coded (see Section 3.15). Teacher one from school 1 was coded as T1 while Teacher two from S2 was coded as T2.

4.2 Quantitative data presentation

Ten teachers answered the questionnaire and each teacher was given a code that was used throughout the study. Questions 1 to 4 in Part A provided demographic information of participants. In Part B participants were required to provide mostly qualitative responses with only questions 2 and 9 being quantitative. Question 2 required the participants to indicate a ‘Yes’ or ‘No’ answer based on their experiences on the difficulties of teaching the electromagnetism topic. Following up on question 2, question 3 required participants to explain their choices in question 2 and hence this produced some qualitative data. Likewise, question 9 required participants to indicate ‘Yes’ or ‘No’ as to whether they make use of easily (readily) accessible materials in their teaching of electromagnetism topic and follow-up question 10 provide an explanation of the extent they made use of such materials.

T1, offered Physical Science to grades 9 and 10. He holds the Basic Education Teachers Diploma (BETD) and an Honours degree in Education. T1 had been teaching grade 10 Physical Science for the past 5 years and is a National marker. In 2016, he was selected as a Team Leader for Physical Science National marking. He was also part of the team that set-up the grade 10 Physical Science end of year exam for 2017.

T2 taught Physical Science to grades 9 and 10 and had been teaching at grade 10 Physical Science for the past 6 years. T2 held a further diploma in education and she has been a National marker for grade 10 National Examinations for the past 3 years.

S1 was a junior secondary school with grades 1 to 10 and S2 was a senior secondary school with grades 8 to 12. Both S1 and S2 were multi-cultural diverse schools with a mixed-race learner population. Both S1 and S2 were 100% government schools, located in the coastal tourist town of Swakopmund in the Erongo Region of Namibia.

4.2.1 Biographical information of the participants

This research was conducted in Swakopmund circuit, one of the three circuits of the Erongo region. Each circuit is headed by an Inspector of Education. However, to obtain a wider view of teachers' perceptions and experiences of teaching the topic of electromagnetism, a questionnaire (See Appendix 4) was sent to 30 teachers from 30 different schools in two regions, namely, Erongo and Omaheke regions. The questionnaire was distributed through the Science Advisory staff members of the two (Erongo and Omaheke) education directorates in their respective regions. Of the 30 questionnaires sent, 10 were returned.

Bertram and Christiansen (2015) report that questionnaires have a low return rate, more especially ones that are posted by mail. The biographical information of the participants is presented in the table below.

Table 4.1 Teachers' demographic information

Demographic information	Codes for teachers	Frequency
Male	T1Q, T2Q, T3Q, T4Q, T5Q, T6Q	6
Female	T7Q, T8Q, T9Q, T10Q	4
ECP	None	0
BETD	T6Q, F10Q	2
ACE/FDE/MASTEP	T1Q, T2Q, T4Q, T8Q, T9	4
HONS	T3Q, T5Q, T7Q	4
MEd	None	0
PhD	None	0
Others	None	0
Less than 1 year	None	0
1 to 2 years	None	0
Between 2 and 5 years	T2Q, T4Q, T5Q, T8Q	4
Between 5 and 10 years	T1Q, T3Q, T9Q, T10Q	4
Above 10 years	T6Q, T7Q	2
20-25	None	0
26-30	T3Q, T4Q	2
31-35	T8Q, T9Q, T5Q	3
36-40	T1Q, T2Q, T6Q, T10Q	4
41-45	T7Q	1
46-50	None	0
Above 50	None	0

Of the ten participating teachers, six were males. All had the minimum qualification of a Basic Teaching Diploma required to teach up to grade 10 level. That is, two teachers had BETD, four had ACE/FDE and four had a Bachelor of Honours as their highest qualification. Their experience in teaching Physical Science at grade 10 level ranged from 2 to 10 years, with T7Q having the highest teaching experience of grade 10 Physical Science. The ages of participants ranged between 26 to 45 years of age with the modal age being between 31 to 40 years old (see Table 4.1) above.

4.3 Qualitative data presentation and discussion from questionnaires

The qualitative data presented here were generated from the questionnaires (open-ended questions) and semi-structured interviews. Ten teachers took part in answering the questionnaires and two teachers were casually interviewed. All the qualitative data from the 10 questionnaires were collated and triangulated with data from the interviews and these were analysed to extract emergent themes. In this section, some quantitative data is also discussed.

4.3.1 Teachers' views and experiences in teaching electromagnetism topic

In exploring teachers' views and experiences in teaching the topic of electromagnetism, they were asked to provide accounts of their own experiences as teachers. They were also asked to provide their views and experiences of their learners' participation during their science lessons of electromagnetism. This was to respond to research sub-questions 1 and 2 which investigated grade 10 Physical Science teachers' perceptions and experiences and factors which influence their perceptions and experiences of teaching the topic of electromagnetism.

Teachers' views on the topic of electromagnetism were wide-ranging. Five teachers indicated that the topic was appropriate to grade 10 as it gave learners good background to subsequent grades. In exploring whether teachers experienced difficulties when teaching the topic of electromagnetism, Table 4.2 shows that six teachers reported having encountered some difficulties during their teaching the electromagnetic topic.

Table 4.2: Number of teachers experiencing problems when teaching the topic of electromagnetism

Do you experience difficulties when teaching the topic of electromagnetism	Yes	no
	6	4

Six teachers indicated that they had difficulties in teaching the topic of electromagnetism. When asked to elaborate on the difficulties, teachers agreed that lack of electromagnetism materials was a major contributing factor to the difficulties. Three teachers left out question 3 which asked them to elaborate on their responses in question 2. T1Q responded by saying; *"I have never experienced any problems apart from those of material scarcity"* In subsequent responses 9 teachers acknowledged that the topic is challenging to teach. This contradicted the four responses in Table 4.2 when asked to highlight difficulties they encountered when teaching this topic. All the teachers viewed that the topic was challenging to teach, especially in the absence of practical activities.

From the teachers' responses in this section, it was clear that the teachers under-stated their challenges. For instance, T9Q said *"I view electromagnetism as a very interesting and at the same time challenging topic to teach"*. Meanwhile T10Q responded; *"It can be very challenging, most especially if you are not equipped (not have enough teaching aids), and it will be very difficult to persuade the learners"*. While T7Q indicated that it is easy to teach electromagnetism topic, a scarcity of science resources to incorporate practical activities in her lessons made it difficult to teach this topic. T8Q's views of teaching electromagnetism was that concepts of electromagnetism are difficult to understand when not well emphasized. This concurs with the claims by Raduta (2005), Venturini and Lascours (2001), Saglam (2010) and Erinosho (2013) that learners develop misconceptions in learning electromagnetism when the topic is not well explained.

One may broaden this to say that teachers identified the absence of practical activities as a contributing factor to challenges in the teaching of electromagnetism as discussed in the next section.

Nine teachers indicated that their learners participated well in lessons which incorporated practical activities. However, T5Q indicated that learners' participation was limited and they prefer to memorise the content without understanding. This view contradicted the rest of the respondents and the lessons presented by T1 and T2 which clearly showed that learners participated in activities throughout the lessons.

However, T5Q's experience in teaching the topic of electromagnetism was supported by T3Q who said; *"Learners will participate in this topic at the beginning of the topic because the beginning is known to them, but as you move to the two motor/generators, participation gets lesser."* T4Q supported the above statement and his own response was that learners' participation in science lessons of electromagnetism is moderate during his lessons. Meanwhile, T4Q remarked that; "*while there is a lot to learn in electromagnetism topic, I have observed that little is assessed at the end of the year*". According to T4Q, this has resulted in learners loosing interest in learning the entire topic. T1 and T2 expressed similar sentiments when asked for their views on this response.

These teachers' views corroborate with the analysis of past end of year exam papers (2012, 2015 and 2016). Exam papers revealed that only a small part of electromagnetism topic is assessed every year with least changes to the question. For instance, the electromagnetism questions of 2012, 2015 and 2016 were precisely alike (see Figures 1.2, 1.3 and 1.4 for comparison). The questions revealed that as per the syllabus, only the first 4 basic competencies are often assessed.

Nonetheless, nine teachers who indicated that their learners participate well in practicals further emphasized that these learners only participate actively when there are enough resources for all the learners. Also, even though most teachers claimed that their learners participated in the lessons, their responses suggested otherwise. What was regarded as learners' participation happened during teacher-demonstrations not necessarily during practical activities by learners. For instance, T2Q responded that; *"learners are more involved when all materials are available to carry out investigations, but less involved when there are no materials to carry out investigations."* Similarly, T7Q responded that; *"they participate very well, but I think, they will participate more when you are doing practicals"*.

4.3.2 Teachers' views on challenges in teaching electromagnetism topic

Teachers were asked to share the difficulties/challenges they faced when teaching the topic of electromagnetism. In a typical response T10Q revealed that she found it difficult to motivate learners to make them understand the real meaning of an electromagnet using concrete examples. T5Q echoed that sentiment by saying: *"getting learners to understand how electromagnets work, since I cannot show any concrete evidence.*" Likewise, T4Q said: "n*o teaching aid available at school and some improvising sometimes is difficult".*

Two respondents (T3Q, T8Q) indicated that they have difficulties in explaining motors and generators. T3Q responded that; *"explaining motors and generators well in detail is more difficult for me. To explain well in detail the two forces in a motor and the formation of the a.c. [alternating current] graph in generators"* This difficulty in understanding how motors and generators work was the result of not understanding the basic principles of electromagnetism and was addressed during the LTSM implementation phase of the research.

Teachers were further requested to elaborate on the difficulties their learners encountered in the topic of electromagnetism. Nine teachers acknowledged that their learners indeed faced difficulties. Two teachers (T2Q and T7Q) left the question (question 4) unanswered. Nonetheless, T4Q said his learners found it difficult to understand the electromagnetism content itself. According to him, learners learn very little even when he carried out demonstrations in his science lessons.

T9Q revealed that her learners find it difficult to identify the poles of an electromagnet. This resonated with the examiners' report for 2012 which states that "the labelling of the poles seemed to be a guessing game by a number of candidates, as one could find the labels anywhere all over the circuit. This somehow gave an indication that the 'right-hand rule has not been mastered by the candidates in determining the poles on the electromagnet" (Namibia. MoE, 2012, p. 240). Similarly T10Q indicated that her learners find it difficult to understand how current can lead to the induction of a force around an insulated wire and how induction can be used to make an electromagnet.

Exploration of the challenges faced by learners when learning the concepts of electromagnetism, helped explain the challenges faced by teachers when teaching electromagnetism and to answer research question 2 which explored the factors that influenced Grade 10 Physical Science teachers' perceptions and experiences of teaching electromagnetism.

4.3.3 Factors affecting teachers' perceptions and experiences

In this section of the questionnaire, teachers were asked to mention factors which they thought influenced their perceptions and experiences when teaching the topic of electromagnetism. According to teachers' responses, the factors affecting their perceptions and experiences in teaching the topic of electromagnetism were mixed. While at least two claimed to have acquired good understanding of the topic of electromagnetism through their teaching experiences, the same teachers claimed that learners find it very difficult to understand the topic.

Throughout the responses, teachers underlined the importance of practical activities in sense making of electromagnetism. For instance, T2Q responded that; *"electromagnetism topic is based on practicals or investigations"*. According to T2Q, the electromagnetism topic requires sufficient time to teach as concepts are easily forgotten when taught theoretically. T5Q, T6Q and T8Q highlighted that learners were not able to build electromagnets. T8Q revealed that, her learners found it difficult to identify the poles and the direction of the current flow. T4Q and T10Q maintained that it simply makes no sense to teach the topic in the absence of resources.

To sum up teachers' responses, they claimed that learners struggle to understand the magnetic field of a solenoid, to identify the poles and directions of the current flow and to produce electrical current by moving a magnet in and out of the coil. Furthermore, teachers' indicated that learners are unable to build electromagnets and struggle to understand how generators and motors work. It can be summed up that lack of practical activities in teaching electromagnetism was a major contributing factor science teachers experienced.

The importance of practical activities was evident during the lesson demonstrations by T1 and T2. Observations during those lessons revealed that learners enjoyed science lessons which involved practical activities.

4.3.4 Teachers views on use of easily accessible materials in teaching electromagnetism

Teachers were asked in question 9 whether they made use of easily (local) accessible materials when teaching the topic of electromagnetism and then to elaborate in questions 10 and 11. Seven teachers responded that they did use easily accessible materials when teaching the topic of electromagnetism and only three teachers (T3Q, T4Q and T6Q) said they had not used such resources at all. Table 7 show the responses of the teachers.

Table 4.3: Number of teachers using/not using easily accessible (locally sourced) materials problems when teaching the topic of electromagnetism.

	Yes	no
Have you ever used easily (local) accessible materials?	7	3

Of the seven teachers who responded to have used easily accessible materials in table 4.3, there were eight teachers who elaborated to the kinds of materials they made use in their science lessons in response to question 10. Most teachers indicated that they used magnets, while 3 teachers indicated that they made use of materials such as nails, motors, generators salvaged from electronic equipment such as speakers, electronic toys and radios.

Two of the responses to question 10 were striking. T5Q explained; *"I tried using magnets and show the field lines."* T7Q elaborated; *"I let them (learners) write a worksheet after each such topic"* These responses clearly indicated that these two teachers did not actually make use of easily accessible materials, contrary to their responses in question 9.

Teachers who responded as not using easily accessible materials in question 9 were also asked to elaborate in question 11. Four of the ten teachers (40%) responded that they only used what was available. For instance, T3Q expressed; *"it is one thing I never thought of doing"*. T5Q confessed; "*I do not know substitutions that can be used.*" T4Q responded that, as a teacher she did not always have the materials available, but usually made use of what was available.

Responses from teachers showed that most were conversant with the concept of easily accessible materials. However, the level at which these resources were utilized in the teaching of electromagnetism was questionable as indicated by seven teachers. For instance, T3Q responded that he tried using a magnet to try and show the field lines of a magnet and T8Q responded; *"using materials from the local environment which learners can get themselves e. g. magnets from old radios, metals, etc."*

The syllabus encourages teachers to, where applicable, use local everyday prototypes to illuminate scientific issues, conceptions and progressions. Textbooks can be a source of such examples. In addition, the 2013 Examiners' report proposed the use of easily accessible materials, stating that; "one would also recommend that the use of everyday practical examples in teaching gives some relevance of the subject to the learners, which in turn makes the subject interesting and better understood" (Namibia. MoE, DNEA, 2013, p. 249).

A point often overlooked with easily accessible materials is the benefits these resources may bring in science education. Strangely, three teachers (T2Q, T9Q and T9Q) indicated that they were not familiar with such materials. Although T3Q and T4Q indicated in question 9 that they used these easily accessible materials, they left question 10 blank which required them to elaborate the extent they made use of such materials. The seven teachers who said they did use easily accessible materials may not necessary have meant that they used such resources in their science lessons. The extent these resources were being utilized by these teachers may not necessary have meant the resource was helping the teachers to mediate learning of electromagnetism concepts.

4.3.5 Benefits of using easily (local) accessible materials

Even though three teachers responded that they did not know what easily accessible resources were, all ten teachers indicated that they were familiar with the benefits of easily accessible materials. It was evident that teachers concurred that easily accessible resources had the potential to enable teachers to help their learners to make sense of concepts of electromagnetism. T1Q and T6Q responded that easily accessible resources can help bridge the gap of materials scarcity with T1Q emphasising that the problem was worse in rural schools than urban schools. Comparatively, scarcity of resources is not only worse in rural schools, but is a common challenge in most government schools.

Three teachers responded that since learners are familiar with easily accessible materials, they believe that such materials can help enhance the understanding of electromagnetism concepts by arousing learner's interest in science. Important to this study as echoed by T6Q and T9Q was that easily accessible resources are cheap and easily acquired. T9Q added that, by using easily accessible materials, learners practice recycling principles and what is learned in class is meaningful to real life situations.

4.3.6 Teachers' views and experiences on practical activities

In this section, teachers were asked to give their views about the use of practical activities in mediating the concepts of electromagnetism. This section aimed at responding to research questions 1 and 2, investigating grade 10 Physical Science teachers' perceptions and experiences, and factors influencing the teaching of electromagnetism topic.

All ten teachers strongly agreed that practical activities were indispensable in the teaching the topic of electromagnetic and science in general. The teachers agreed that using practical activities as opposed to theoretical approaches, helped learners to grasp the topic of electromagnetism very well T9Q affirmed that; *"through practical activities learners develop the power of observation, thinking, problem solving and making conclusions based on observations and results".*

All the teachers believed that learners' involvement in practical activities promoted active learning. Thus T9Q concluded in her response that; "*active learning follows the edge of - 'hear and forget', see and remember', do and understand'*. Furthermore, T10Q responded; *"a practical activity helps and enhances learners' understanding as it (practical activities) bring reality into learners' minds, thus it activates their thoughts"*. All ten teachers believed that the inclusion of practical activities is essential when teaching the topic of electromagnetism.

Teachers' responses above illuminate the importance of practical activities in science education as viewed by various scholars. Millar (2004) believed that practical activities often offer learners appropriate thoughtful means to take part in science endeavours. Practical activities offer learners hands-on skills (Abrahams & Millar, 2008) which enable them to learn new practical skills required in a workplace (Abrahams & Millar, 2008; Prince, 2004).

According to Von Glasersfeld (1989), constructive learning only takes place when learners are actively involved in the learning processes. Concurring, Bowell and Eison (1991) asserted that practical activities help learners think about what they are learning, hence, making meaning from the learned materials. T10Q agreed with Von Glasersfeld (1989) and Bowell and Eison (1991) that practical activities help and enhance learners' understanding as according to her, it brings reality into learners' mind, thus activating their thoughts.

Furthermore, all the teachers argued that electromagnetism cannot be taught theoretically as it will not make any sense to the learners. Practical work, teachers believe, will enable learners to grasp new complex concepts associated with electromagnetism through visualisations of materials used in the activities. It is primarily for this reason that the Namibian curriculum (Namibia. MoE, 2009) promotes LCE approaches. Likewise, Nyambe (2008) advocated that through LCE, learners are able to make meaning of the science being learned. With this in mind, 3 of the 10 teachers hoped that this study would lead to the development of more easily accessible materials in other topics and make them available to schools.

Practical activities also promote the notion that learning is best when learners interact with one another, the teacher and the LTSM resource. Lazarowitz and Tamir (1994); Lunetta (1998) and Hofstein and Lunetta (2004) suggested that laboratory or practical activities have the potential to enable social interaction among learners which enable them to develop necessary skills for scientific understanding and cognitive growth. Learning is more successful in shared interactive surroundings (Bell *et al.*, 2010). This conforms to the theory of Social construction which was the main theoretical framework underpinning this study.

Although teachers used strong expressions to show that they recognised and acknowledge the role of practical activities in science, they showed little evidence that they actually carried out practicals in their mediation of the concepts of electromagnetism. This reverberates with one of the key comments often highlighted in the examiners' reports that there are barely any practical activities in teaching and learning of science in most Namibian government schools. However, all the teachers maintained that lack of science resources in their schools was a major factor constraining them from carrying out such vital tasks.

4.3.7 Improving mediating the topic of electromagnetism

Given the challenges shown above, this section requested teachers to allude as to what they did to ensure that learning took place when teaching electromagnetism despite the scarcity of resources. In earlier responses four teachers said they did not experience difficulties when teaching the topic of electromagnetism. However, when asked during to elaborate, only one teacherindicated to have never experienced difficulties apart from material scarcity. Two teachers left the question open and the rest provided divergent challenges. Some challenges highlighted were explaining motors and generators and how they work and explaining the right-hand rule. T10Q expounded; *"sometimes it is difficult to persuade learners and how to make them (learners) understand the real meaning of electromagnet using concrete examples'.* However, T10Q did not elaborate on what kind of concrete examples she used.

When I followed up with two teachers to elaborate more on what was meant by 'concrete examples', they simply mentioned objects like magnets, wires and discarded electronic parts. T10Q highlighted that she struggled to make learners understand how electromagnets work when she was unable to show her learners any visuals to reinforce the explanations. It is clear from the teachers' responses that practical activities were one option to alleviate their challenges.

When asked what they did to ensure that learning takes place despite the difficulties and challenges; most teachers had difficulties clarifying what they do to alleviate the situation. Although most teachers said they improvised, they equally complained about the lack of resources such as electromagnetic kits. T2Q responded; *"availability of electromagnetic material is lacking. If there is any, then they are few compared to the number of learners and some learners won't be able to participate*." T2Q here highlighted that even if there were some resources, these were often not sufficient to enable all the learners to take part in an activity.

According to T5Q, he always tried to explain how a practical should be done, despite the absence of resources. He further said he always tried to get learners to use their imagination. Teacher T8Q said she sent learners to search for information from the internet. T10Q claimed that there is inevitably no time to set-up practical work. She further claimed that some teachers are too indolent to explore further and to improvise or set-up practical work for their learners. On a strong note, T4Q declared that teaching aids should be made available for proper learning to take place.

T10Q's claim that teachers often did not have adequate time to prepare practical activities is supported by Khoboli and O'Toole's (2011) study in Lesotho, where they found that time-constraint was one of the factors which hindered teachers from incorporating practical activities in their science lessons. Educational constrains highlighted by Khoboli and O'Toole (2011) are evident in most government schools in Namibia. Most science teachers tend to shy away from conducting practical activities in their science lessons due to crowded classes and undisciplined learners which defeat the notion of LCE. T3Q reported downloading videos from YouTube and using them to reinforce his teaching of electromagnetism.

Likewise, during one of the workshops, T2 reflected that she was unable to prepare activities because she had many classes to attend to. Both T1 and T2 revealed that teachers have many responsibilities in addition to teaching, for example, preparing lessons and activities for those lessons and administration, to mention but a few.

My personnal experience has been that some teachers simply do not carry out practical activities in their science lessons despite availability of resources in their school laboratories. Three schools I visited in the Omaheke region with the Rössing Foundation Outreach Programme had brand new electromagnetic kits which had not been used since these schools acquired them from the Millennium Challenge Account (MCA) programme in 2015.

From this evidence, one can conclude that a lack of science resources constrains teachers' abilities to effectively mediate the topic of electromagnetism.

4.4 Presentation and discussion of qualitative data from workshop discussions, lesson presentations and interviews

The qualitative data presented here were generated from the workshops, lessons presented by research participant teachers and stimulated-recall interviews with the teachers. Two teachers took part in the workshops and lesson presentations. All the qualitative data from the workshops, lessons and interviews were collated and triangulated with two interview transcripts and these were analysed to reveal emergent themes. The data in this section sought to answer research sub-questions 3 and 4:

- What can teachers do to improve teaching and learning of electromagnetism in under resourced schools?
- What enables or constrains grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible resources in under-resourced schools?

4.4.1 Workshops

Two workshops were conducted with the teacher research participants, which served to introduce the easily (local) accessible materials in a way similar to Asheela's (2017) Namibian study. However, unlike with Asheela (2017), my research worked with only two Grade 10 Physical Science teachers in developing and implementing the resource. The objectives of the workshops were to further clarify what was expected of the two teachers as participants in the study, introduce the resource materials, collaboratively design model lessons and worksheets aiming to use easily (local) accessible materials. Furthermore, to decide on a time-table for implementing the resources (lesson presentations and interviews).

a) First workshop

The first workshop discussed what would be expected of the research teachers and was an opportunity to show and share the easily accessible resource with the teachers. The workshop lasted 3 for hours. Two draft worksheets were introduced based on the objectives as stated in the syllabus. These needed to be collaboratively developed further to being them into line with the competencies in the syllabus.

During this workshop, T1 attended, but T2 was unable to attend due to personal matters. After this workshop, I visited T2 at her school and briefed her on what transpired during the workshop. The teachers were informed that they would be required to teach two lessons each, which would be video-recorded, and they would hereafter participate in stimulated-recall interviews.

During the workshop, we discussed how the prior-knowledge on magnetism would be carried out. We agreed that, the lesson would begin with a revision of magnetism using an OHP, a transparency, a magnet, iron fillings and some plotting compasses. An advantage of screening the visuals is that the whole class is able to clearly see the process and actions, unlike drawing sketches which are often misinterpreted and led to misconceptions.

The workshop continued with a discussion of the main lesson. The lessons' main theme was the magnetic effect of an electrical current. Under this theme, there were two learning objectives which were sub-divided into four basic competencies (see Figure 7 below) set in the syllabus.

• know the magnetic effect of an electrical current in a straight conductor and a solenoid	• investigate the magnetic effect of an electrical current in a straight conductor • investigate, sketch and compare the magnetic field around a bar magnet and a current carrying solenoid (both shape and direction of magnetic field lines are required)
• know how to build electromagnets in loudspeakers and electric motors	• describe how to build an electromagnet and outline its uses • investigate and explain the difference between the electromagnetic properties of iron and steel and predict the difference between a temporary and a permanent magnet

Figure 4.1: An extract of the syllabus showing basic competencies on electromagnetism topic

The lessons were guided by these basic competencies as listed in the syllabus. Teachers are required to plan their lessons based on the syllabus and each lesson plan was based on the stipulated learning objectives in Figure 4.1.

The resources were presented and we discussed how they would be used. We carefully studied each piece of the resource and how it would fit in the activities of the lessons. We also discussed the sources of each item so that teachers knew how they were obtained. A copy of the transcript of the first workshop can be viewed in Appendix 5a.

b) Second workshop

In the first workshop, teachers were introduced to the resources and the worksheets that accompanied them. The second workshop was used to further review the worksheets and carry out the practical activities using the easily (locally sourced) accessible material. Both teacher participants attended this workshop.

We discussed further changes to the worksheets and agreed that I would circulate them to two experienced teachers for validation purposes. These validators were well experienced, with more than 20 years of teaching Physical Science in Swakopmund and Walvisbay. Further validation was sought from my principal supervisor during the contact session of August 2016.

We continued the workshop by practising the actual practical activities while following the procedures in the worksheets. This exercise was a collaborative effort, as we rotated responsibilities. For instance, one of us read the instructions, while the other two assisted each other in performing the actions. After several procedures we exchanged roles and continued the workshop. During the workshop, T1 felt relieved as he revealed that he had tried a similar activity previously but the materials did not work out as expected.

During the workshop, T2 raised a concern that most of her learners are unable to read and follow instructions in an activity. However, she admitted that there were a few learners (referred in the workshop as clever learners) who were able to read and carry out activity procedures by themselves with minimum assistance. The concern was that even if learners could read and carry out the procedures by themselves, the normal 40 minutes' period may not be long enough to complete each activity. It was then agreed that the teachers should read the instructions while learners carried them out. Equally, learners would each receive the worksheets which they would be able to refer to during the lessons. At the end of the activities, we agreed on possible dates for which the lessons are to be implemented. Appendix 5b gives a transcript of the second workshop.

During this workshop, the teachers showed that they were familiar with the resources presented to them. However, the use of such materials in their teaching was limited, although T2 said she had tried to use such materials. In T1's laboratory (also used as teaching classroom) display cabinets, some easily accessible materials (e.g. old generators) were displayed. Contrary to T1, T2 explained that she had always wanted to use such resources, but had always drawn back due to uncertainty.

Both T1 and T2 appreciated the opportunity offered to experiment with the resources and looked forward to teaching the lessons. To the contrary, T2, whose school was fairly resourced compared to S1, reflected that she hardly did practical activities due to the workload. T1 and T2 remarked that lack of laboratory resources and their full teaching schedule hindered their ability to assimilate practical work in the teaching.

4.5 A description of the type of easily accessible resource used in this study

A brief description of the easily accessible materials (LTSMs) which were utilised by the teachers is given here. These materials were devised to respond to research sub-question 4: *What enables or constrains grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible resources in under-resourced schools?* Recognising the scarcity of resources in most government schools, this study intended to transform science learning in electromagnetism by utilising inexpensive but effective LTSMs locally sourced. So, the main aim of the study was to encourage teachers incorporate practical activities in the teaching of science. Figure 4.2 shows the electromagnetic kit and its parts are shown in Table 8. Figure 9 shows the electromagnetic kit for one group.

Figure 4.2: An electromagnetic kit made from easily accessible materials

Figure 4.3: An electromagnetic kit made from easily accessible materials for a group of about 4 learners

Table 4.4: *Parts of the easily accessible materials*

Number	Item
1.	3 cells (size AAA), (two cells would also be sufficient)
2.	About 1. 2 metre thin insulated wire
3.	2 to 4 plotting compass clear (more will be useful)
4.	2 nails (a soft iron and steel, about 100mm in length)
5.	About 20 to 30 paperclips of the same size (pins work as well)

All parts (cells, paperclips, iron and steel nails) were sourced from local retailers and the insulated wire and plotting compass were sourced from a retailer specialising in school laboratory equipment. Each set (group kit) consisted of 3 cells, 2 compasses, two round nails (iron and steel each) of about ±100mm length and about 1 metre insulated wire, and about 20-30 paperclips. The cost of one kit was approximately N$ 560-00, which contained sufficient materials for seven (7) groups of four (4) learners per group. This is far below the cost of a standard electromagnetic kit approximately N$ 3500-00.

4.6 Concluding remarks

This chapter, presented, analysed and discussed the data collected from questionnaires and the preparation work for developing and presenting a locally sourced electromagnetic kit. The data from the questionnaires answered the research sub-questions 1 and 2. They revealed that responding teachers' perceptions and experiences of teaching the topic of electromagnetism were diverse. Respondents considered the topic of electromagnetism relevant and challenging. Most teachers were familiar with and to a lesser degree made use of easily accessible materials (LTSMs) during their teaching.

In the next chapter, I present, analyse and discuss data generated from the lesson presentations, observations and stimulated-recall interviews.

CHAPTER FIVE: DATA PRESENTATION, ANALYSIS AND DISCUSSION (PHASE 2)

5.1 Introduction

The previous chapter, presented, analysed and discussed the data collected from questionnaires. The data generated from questionnaires enabled me to answer research sub-questions 1 and 2. This chapter presents the analysis, and discussion from data generated from the workshops, lesson observations and stimulated-recall interviews conducted with the two participating teachers.

To develop an understanding of how grade 10 Physical Science teachers help learners to make sense of concepts of electromagnetism through the use of easily accessible materials in under-developed schools, the following sub-questions were asked:

3) What can teachers do to improve teaching and learning of electromagnetism in under resourced schools?
4) What enables or constrains grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible resources in under-resourced schools?

The lessons observations are first presented as reflections of events of the classroom.

5.2 Data presentation from lessons

This section presents, discusses and analyses the lessons as presented by the two participating teachers, highlighting salient indicators as they emerged. After the observations, the teachers were interviewed using stimulated recall-interviews. This helped in understanding teachers' views and experiences, and to probe further on what had transpired during the lessons. In this section, as explained earlier the two teachers are referred as T1 (teacher 1 from school 1) and T2 (teacher 2 from school 2) respectively.

5.2.1 T1 lesson observations (see transcript in Appendix 8a)

(a) Lesson 1

T1 began the lesson by revising magnetism.

> *"Now what you are going to see what you have already learned in the theory. Around a magnet, you find a magnetic field. An object only experiences a force if it is within this magnetic field. And the end of a magnet, you find that the magnet is stronger at its ends compared to the sides."*

The teacher demonstrated the magnetic field on the screen using an OHP while learners observed and T1 explained that:

> *"You can see that around the magnet, we can see the magnetic field. At the end of the magnet, it is where there are a lot of iron fillings. Plus magnets are stronger at the end of the magnet compared to the sides. So, that's how it is."*

T1 continued with the main lesson by reading the heading on the worksheet and mentioned that learners may be wondering what electromagnetism has to do with an electrical current. This was probably just to prompt learners' thinking about the lesson and T1 continued by reading the objectives of the lesson.

Thereafter, T1 informed learners that he would be reading the instructions and they would be required to carry out the actual activity. At the same time, they should discuss their results (observations and conclusions), recording them on the worksheets. Throughout the lesson, T1 moved around and made sure that every group was busy with the task. Occasionally, I assisted the teacher through a participatory observation by also moving around assisting some groups while T1 helped other groups. In some cases, the teacher probed further by rephrasing some questions from the worksheets to make them think. At one point T1 asked the learners, *"What do you think makes the compass needle to deflect every time you connect the wire to the cells or the circuit is closed?"* During the lesson, the teacher continued reminding learners that the activity was a group work and they should discuss their observations and conclusions before writing them on the worksheet. T1 concluded this section of the activity by summarising that, as the number of cells was increased, the deflection on the compass needle increased, signifying that there was an increase in the force around the wire.

The teacher continued by reading objective 2 and said; *"Electromagnetism is a way of producing?... (*T1 *paused for learners to provide the answer)..., what do you think we are producing now? (*T1 *turns statement into a question, using gestures to express the question as well). Electro-means- electricity is involved, magnetism-we are producing magnets, using current, that's what we are going to do now. So, because it is electromagnet, so you are now producing magnets by using current. That's what we are going to do now."* In the end, T1 answered his own questions because the learners were all quiet.

T1 summarised the lesson by comparing the magnetic fields of permanent magnets with magnetic fields of a current-carrying wire as well as what to do to increase the strength of the magnetic field.

(b) Lesson 2 (see transcript in Appendix 8b)

T1 started the second lesson by revising the previous work. During this review, he emphasised the aspects which appeared to be of importance to the next lesson. T1 explained that:

> *"We found out that a wire experience a force when current flows, a force similar to that of permanent magnets and force can be increased by either increasing the current or coiling the insulated wire."*

Starting with the main lesson, T1 explained that the lesson was building on the previous work. He continued to read the instructions on the worksheet as learners engaged in the activity. Meanwhile, the teacher moved around helping some groups. I noticed that T1 spent more time assisting two groups at the back of the classroom. At one time, he intervened in a group by demonstrating what the group was expected to do. He then reminded the learners to discuss and record their findings.

As observed in the first lesson, at times T1 asked questions of the class, to which at least two groups appeared not to pay attention but rather continued with their activity. T1 was mindful of slow groups, giving them more time, sometimes intervening to help them. Also, T1 continued reminding learners of the need to complete the activity before the end of the period.

Due to shortage of time, the conclusion was completed in a hurry. The lesson lasted 40 minutes, which was the time allocated in the school time-table.

5.2.2 T2's lesson presentations and observations

(a) Lesson 1 (see transcript in Appendix 8c)

T2 started the first lesson with a brief explanation of my presence and particularly the reason for video-recording the lesson. She asked learners to be open and free to participate. To an extent, we co-taught the lesson as I helped to distribute the materials and walked around helping the groups. As an introduction, T2 started by revising some concepts on magnetism.

Thereafter, T2 asked learners to look at their worksheet and she begun by reading the heading and objectives from the worksheet. T2 proceeded to read procedure 1 and instructed learners to carry out the activity. After 3 minutes, she asked learners if they were done with procedure. She then continued reading the procedures while walking around the classroom, observing whether the groups were busy with the task. I observed that she visited two groups more than the others.

Throughout the lesson, T2 repeated and rephrased the procedures. At times when she realised that learners were taking too long to complete a procedure, she used the chalkboard to clarify the instruction with the help of sketches (see Figure 5.1). The use of the chalkboard seemed to be effective as learners were then able to provide answers to the questions posed which they were initially unable to do.

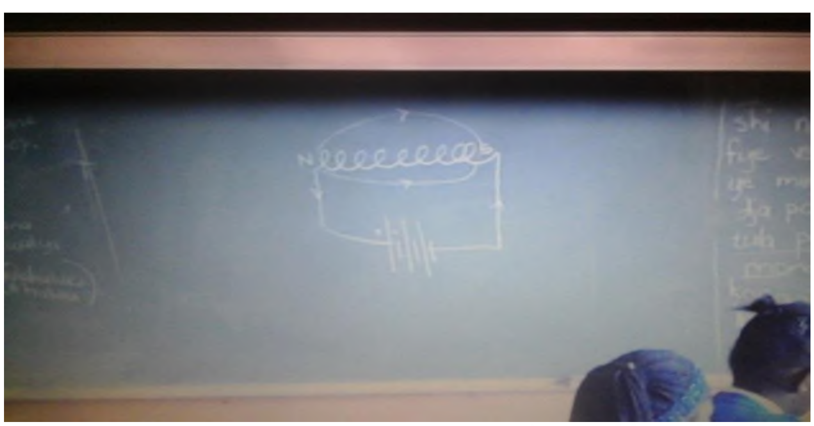


Figure 5.1: The drawing T2 used during lesson 1 in order to demonstrate magnetic field in a solenoid

T2 concluded the lesson by asking learners to list the similarities and differences between magnetic fields of a permanent magnet and a solenoid which she had drawn on the board. Throughout the lesson, learners were busy with the activity.

(b) Lesson 2 (see transcript in Appendix 8d)

The lesson started by revising key concepts from the previous lesson. T2 followed a teaching method of posing a statement and asked learners to complete. For instance she said; *"The poles of the electromagnet are similar to those of a ………..?"* The class then responded; *"permanent magnets"*. She then concluded the introduction but saying;

> *"The very last thing I said in yesterday's lesson was, if you know the flow of current in the circuit, this can help you identify the poles of the solenoid (electromagnet)."*

T2 started the main lesson as follows;

> *"And today's lesson is a continuation of what we did yesterday, looking at the electromagnet, the building of electromagnets and its uses, where we are going to look at the differences between the properties of iron and steel. We will be able to make differences between a temporary and permanent magnet, hoping that you still have the idea in mind."*

She then summarised and explained the lesson's objectives and distributed the worksheets while I helped with the distribution of the resources. She further reminded learners that she would be reading the procedures while they would be required to carry out the practical activities.

As the lesson progressed, she walked around and probed some groups to see if they were following the instructions or not. She mainly helped groups seated at the front of the room. Throughout the lesson, learners were occupied with the activity and appeared to be enjoying the lesson. The lesson ended with the teacher summarizing and consolidating the key concepts that emerged from the practical activity.

5.3 Analysis of the lessons observations

It emerged from the lessons that both teachers had positive views on how the electromagnetic kits enabled them mediate the concepts of electromagnetism. Participants revealed that the utilisation of the electromagnetic kit allowed them to incorporate a learner-centred approach in their science lessons and their learners fully participated and contributed to their own learning. Both teachers (T1 and T2) disclosed that most of their previous science lessons had used a teacher-centred approach with a focus on demonstrations. The most compelling evidence that the utilisation of this resource helped improve their teaching of electromagnetism came out during the stimulated recall interviews with the teachers as discussed in the next Section 5.4. A noteworthy comment by T1 after his second lesson was:

> *"There is a need for all science teachers to come together so that we can develop our own resources such as the ones I just used, rather than waiting for the government to provide us with the resources".*

While his learners were leaving the class, after his second lesson, he pointed to me and said; *"look at how happy my learners feel because they carried out practical activities themselves, which I was not able to do without your assistance".* Similar comments were made by T2 during our informal conversations after one of the lessons. She remarked that such resources could greatly help all teachers teaching different grades, if these teachers were willing to sacrifice their own time to come together in order to develop such resources. She was hinting at the long time spent on developing the worksheets and testing and validating the resources during the workshops.

I concur with this as my observations revealed that teachers made use of the resource with little difficulty. As alluded to in the lesson discussions, teachers made use of analogues to complement and reinforce the practical activities. For instance T1 and T2 used chalkboard sketches to help their learners to interpret and draw conclusions. Throughout the lessons, T1 and T2 continued paraphrasing the procedures whenever learners appeared to be grappling with an activity.

5.4. Recall-interview with T1 and T2 (see Appendices 9a and b)

Stimulated-recall interviews took place after two weeks as the video-taped lessons had first to be watched and arrangement made for the time to conduct the interviews. Because the teachers had limited time, two interviews were conducted each looking at both lessons. These interviews further helped in formulating responses to research sub-questions 3 and 4.

The overall response by both T1 and T2 regarding the electromagnetic kit was constructive. Both were enthusiastic about the impact the resource made to his learners. For instance, T1 remarked that after the lessons, his learners informed their school mates in other grade 10 classes of their experiences. This encouraged those learners to request that they too be offered those lessons which involved those practical activities. T2 agreed with these sentiments. She revealed that several learners from other grade 10 classes approached her asking to given the exposure to such activities. However, because these lessons took place near the end of year exanimations, only T1 managed to conduct the same practical activities with the rest of his grade 10 learners. T2 admitted that the logistics of preparing for the end of year examinations impeded her from fulfilling that task. Both T1 and T2 articulated that the use of easily accessible materials helped them improve their teaching of electromagnetism.

The teachers' assertions that the resources helped them improve the teaching of electromagnetism was visible in learners' written work. An analysis of learners' written worksheets from the lessons showed that the use of easily accessible materials helped the teachers improve their mediation of electromagnetic concepts. Learners' written responses from observations and conclusions during the practical activities were seen to be responding to factual scientific principles of electromagnetism. As an illustration, Figure 5.2 below shows learners' responses from both schools during the practical activities.

School 1		School 2	
Quest.	**Learners' responses**	**Quest.**	**Learners' responses**
		Part 1	
1 (a)	It deflects slow/a little/compass will deflect	1 (a)	It goes/points/moves to north/lies in N-S direction
(b)	Deflects slow/moves a little/moves towards north/deflect fast	(b)	It moves from east to west *(needle deflects*
2. (a)	It deflect fast/slow/no specific direction	2. (a)	action
(b)		(b)	More movement than with 1 cell/ moves faster with 3 cells compared to 1 cell. Moves much more faster as there is more voltage
3.	Flow of current increases movement of compass/plotting compass moves when current flows	(c)	A process of electromagnetic induction/magnetic field is disturbed by electric current
4.	Current flow from one direction (+ve to – ve)/compass detects flow of current.		
5.	Increase number of cells	3.	Add more cells/increase number of cells

Figure 5.2: An extract of learners' responses during the practical activity in lesson 1

The above evidence validates other data that emerged from this study that easily accessible materials has the potential to replace standard science laboratory equipment in under-resourced schools. In particular, this data corroborates the two teachers' call for the formation of a 'science teachers' group' comprising of science teachers teaching the same grade in order for them to develop own science resources. This would satisfy the calls often made in Examiners' reports such as:

> The doing of practicals will always be to the benefit of the learners and this area in teaching and learning should not be neglected. One would also recommend that the use of everyday practical examples in teaching gives some relevance of the subject to the learners, which in turn makes the subject interesting and better understood (Namibia. MoE, DNEA, 2013, p. 249)

When asked what their most captivating moments were during the lessons, T1 cited the involvement of learners and how these learners responded to the resources. According to T1, learners' participation during the lessons was remarkable. T1's insights were parallel to calls made by the Namibian curriculum and education advocates (Nyambe, 2008) for the inclusion of practical activities in the teaching and learning of science in schools.

The data demonstrated that practical activities help promote interactions between 'teacher-learner' and 'learner-learner', as conceived by social constructivists (Vygotsky, 1978). Vygotsky's theory suggests that we learn first through person-person interactions and then as individuals through an internalization process that leads to deep understanding (Blake & Pope, 2008). The presence of the resource during the lessons helped learners in this internalization process.

Observations during the lessons confirmed that teachers were in constant communication with their learners throughout the lessons. Teachers continuously were reading the procedures on the worksheets while they carried out the activities, they probed further where necessary and learners constantly engaged themselves in discussions during the tasks. Both T1 and T2 reflected that their previous teaching approach was mostly teacher-centred due to lack of science resources. T1 and T2's accounts above are clear indication that easily accessible materials have the potential to help science teachers in under-resourced schools improve their teaching of electromagnetism.

During the lesson observation, both teachers appeared to pay attention to certain groups by making frequent visits and assisting where needed. When asked to elaborate on the above observation, both T1 and T2 admitted that these groups comprised of what they referred to as 'slow learners'; hence, the need to give them additional assistance. Teachers were further asked why throughout the lessons, they paraphrased the procedures (this was most evident with T2). According to them, their learners were not used to read and follow instructions since they were rarely involved in practical activities on their own. Hence, they saw the need to help their learners by reading the instructions. When asked if they were not under-estimating their learners' potential or not, T1 and T2 strongly dismissed such perception. T1 went further to clarify that he knew his learners very well as he had taught them from grade 9 to 10.

Teachers were asked to suggest what improvements needed to be made in the reources. T1 suggested that before using the resource, there was a need to test each cell and the plotting compass. T2 made similar points. Overall, T1 was impressed with the resources, stressing that *"There is a need for Physical Science teachers in the region to come together and further develops similar resources in other topics in order to reduce the dependence on the Ministry of Education, Arts and Culture"*. Equally, during the stimulated-recall interview, T2 reflected that the easily accessible materials provided her with the platform to help her learners understand the concepts of electromagnetism through interactive activities.

According to T2, the use of easily accessible materials, which are already familiar to learners helped increase their motivation throughout the practical activities. This was substantiated when T2 reported that learners who were not part of the lessons (learners from other classes) approached her requesting to take part in those lessons. These learners had been informed by those who had attended the lessons.

In conclusion, data presented and analysed in this section revealed that the resources used in this study were appropriate for that grade and topic. Teachers revealed that easily accessible materials helped them improve their teaching of the topic of electromagnetism. They hinted the need to develop additional resources in other topics.

5.5 Analysis and discussion of analytical statements

To generate data for this section questionnaires, workshop discussions, lesson presentations and interviews were collated and analysed together with interview transcripts. These data were scrutinized for commonalities, contradictions and emergent categories developed, some of which were merged to form themes while others did not. The formulation of analytic statements was guided by the characteristics of social constructivism theory. After this process, sub-themes were devised that were translated into five analytical statements. These analytical statements were aimed at answering the research questions and are set out in Table 5.1 in the subsequent page.

Table 5.1: Analytical statements presented in relation to the research sub-questions

Data source	Theme	analytical statements	RQA
Document analysis and questionnaires	Views and experiences when teaching electromagnetism	Teachers exhibit varied views and experiences when mediating learning of electromagnetism concepts	1 & 2
Document analysis, questionnaires and observations	Challenges in mediating the topic of electromagnetism and possible solutions	Challenges when mediating the concepts of electromagnetism and what has been done to overcome the challenges.	2
Document analysis, workshop, observations and semi-structured interviews.	Developing LTSM to help improve teaching and learning approaches	Mediating tools are fundamental in providing a scaffolding for learners to make sense of electromagnetism concepts (LCE)	3 & 4
Document analysis, lesson presentation, semi-structured interviews and observations	Mediating electromagnetism concepts	The effectiveness of developed LTSM in helping teachers mediates and provides scaffolding for learning and how to improve them.	4

These analytical statements are discussed below.

5.5.1 Analytical Statement 1:

Teachers exhibit varied views and experiences when mediating learning of electromagnetism concepts

This statement emerged from discussions and analysis of grade 10 Physical Science teachers' views and experiences when teaching the topic of electromagnetism and from an analysis of factors which influenced their experiences when teaching the topic of electromagnetism.

The views and experiences of teachers discussed in this section emerged from the participants' responses. These were considered meaningful because the participants embodied extensive teaching background. Furthermore, teachers' views on the importance and relevance of the electromagnetism topic gave credence to the study. This analytical statement responded to research question 1.

As suggested by Zuza, Almudí, Leniz and Guisasola (2014), electromagnetism is central part of physics instructions at several different levels of science. In their questionnaires teachers highlighted the role electromagnetism plays in physics and their views and experiences on the teaching of electromagnetism were diverse. Teachers were divided as to whether their experiences showed that it was easy or difficult to teach electromagnetism. Teachers' claims that it was easy to teach the topic was contrary to their teaching experiences and to the Examiners' reports. It is possible that the teaching methods of these teachers were not effective

For this reason, Shulman (1986) warned that for teachers to be successful in their teaching, they ought to practice worthwhile forms of teaching methods, use appropriate analogies, illustrations, examples, explanations and demonstrations in ways the learning is comprehensible to learners. Unless the topic of electromagnetism is taught effectively as suggested by Shulman, the potential for learners to continue performing poorly will remain a problem.

However, nine teachers agreed that, it becomes difficult to teach the topic in the absence of practical activities. According to these teachers, most of their learners found it difficult to understand electromagnetism concepts. This could be attributed to the fact that most teachers taught this topic in the absence of practical activities due to lack of electromagnetism kits. Various studies have revealed that college students face various difficulties when learning the topic of electromagnetism (Erinosho, 2013; Raduta, 2005). In his case study of students' conceptions of electromagnetic induction while viewing a series of videos, animations and interactive simulations, Richards (2010) claimed that from his 18 years of experience of teaching introductory college physics courses to have found plenty of evidence that students experienced the topic of electromagnetism as very challenging. This supported the views of teachers who believed that electromagnetism was a difficult and challenging topic to teach.

Teachers revealed that factors affecting their views and perceptions were that learners often did not understand what they were taught. Teachers assumed that because of teaching Physical Science for many years, the experience made them better teachers. However, their responses to the rest of the questions, indicated otherwise. For instance, the same teachers who claimed to have acquired good understanding of the topic after teaching for several years complained that their learners found it difficult to understand that topic.

The Examiners' reports have continued to point out failure by learners in the national exams in this topic. For instance, the Examiners' report of 2012 revealed that learners simply guessed the answers when they were asked to label the poles of the electromagnet. Likewise, in his study on student misconceptions in high school grade 12 Physics Examination, Van Niekerk (2011) revealed numerous misconceptions related to electromagnetism and many other physics topics which he believed contributed to poor performances in science in general. According to Van Niekerk (2011), misconceptions were as a result of learners' naïve, superficial and fragmented understanding of scientific phenomena. This may be possible because teachers may be teaching the topic of electromagnetism inappropriately.

Lastly, according to the teachers involved in this study, lack of practical activities was a major contributing factor to poor learner performance. Lack of practical activities in learning of science is discussed in subsequent sections. Thus, this study underscores the importance of practical activities in science education.

5.5.2 Analytical Statement 2:

Teachers' challenges when mediating the concepts of electromagnetism and what has been done to overcome the challenges

In order to respond to research question 2, a survey was administered to ten teachers. The questionnaires were intended to respond to the research question: *What factors influenced grade 10 Physical Science teachers' perceptions and experiences of teaching the topic electromagnetism*? To understand these factors required discussing and analysing the challenges faced by teachers in teaching electromagnetism. Analysis of literature was used to strengthen the arguments.

Challenges faced in teaching electromagnetism

According to Zuza *et al.* (2014), the topic on electromagnetism is challenging to teach, in part due to key quantities which are independent but closely linked. Likewise, within the framework of Maxwell's theory, electromagnetic induction is a phenomenon associated with two different events; the time variation of a magnetic field, and the movement of a conductor in a magnetic field, or a combination of the two (Zuza *et al*., 2014).

Additionally, in their study to identify difficulties in teaching electromagnetism to first year college students in France, Roussel and Hélier (2012) reported that students felt that electromagnetics was a difficult and demanding subject. They found that most students rather opted for courses like digital systems design, which students believed to be easier to grasp and more rewarding. To emphasize, in most countries teaching electromagnetism it is combined with teaching mathematics, such as linear algebra, vector calculus, integral calculus and the study of complex variable functions, thus making it less attractive due to the mathematics involved. Despite that, in some countries, particularly in Asia, electromagnetics studies are still appealing to students (Roussel & Hélier, 2012).

To put it differently, teaching electromagnetism is certainly not a stress-free exercise. Although research findings in this field commonly point to challenges facing college students taking electromagnetism courses, the challenges are not limited to college only. It is worth pointing out that the success of students at college level is fundamentally dependent on learners' readiness from their high school activities.

In Namibia on the other hand, little is known of the difficulties facing both science teachers and learners as to why the topic of electromagnetism is a menace. However, according to teachers surveyed and Examiners' reports for grade 10 Physical Science subject, learners face various challenges which hinder them from understanding electromagnetism. In Namibia, learners are first introduced to electromagnetism concepts only in grade 10.

According to the responses, teachers struggle to teach electromagnetism as they find it difficult to make learners understand the real meaning of electromagnetism. Teachers pointed out those learners find it difficult to understand how current can lead to the induction of a force around the wire and how it results into a magnet. Teachers further reported that learners find it difficult to determine the poles of an electromagnet and to distinguish between a motor and a generator.

To emphasize, these teachers' views resonate with the 2012 Examiner's report which stated that; "*the labelling of the poles seemed to be a guessing game by a number of candidates, as one could find the labels anywhere all over the circuit. This somehow gave an indication that the 'right-hand rule has not been mastered by the candidates in determining the poles on the electromagnet" (Namibia. MoE, 2012, p. 240).* Similarly, the 2014 Examiner's report pointed out that only 0.25% of all learners who sat for the Physical Science final examination correctly answered the question on electromagnetism. According to the report, the majority of learners failed to incorporate the involvement of the coil and the magnet in their answer when describing the generation of electricity.

With the admissions revealed in the Examiners' reports in mind, teachers asserted that they struggled to explain motors and generators and how they work, or to explain the right-hand rule. Identically, another teacher admitted that she sometimes finds it difficult to make learners understand how electromagnets work when she cannot show learners any illustrations to strengthen her explanations during her teaching, although she is a trained and qualified teacher.

All ten teachers identified the lack of practical activities as a major contributing factor to poor performances of their learners in science particularly, in electromagnetism. In this case teachers recounted that, they were unable to carry out practical activities during their lessons because their schools are not equipped with science equipment and apparatus to enable them to carry out such activities.

In addition to lack of laboratory equipment such as electromagnetism kits as hinted by teachers, Khoboli and O'Toole (2011) emphasized that crowded classrooms, rowdiness of learners and lack of significance seen in practical activities by most science teachers were concerns discouraging teachers from conducting practical activities in their teaching. This was confirmed by the two collaborating teachers who presented the lessons. However, during the stimulated-recall interviews, T2 asserted that work-load was a contributing factor which hindered her from carrying out practical activities in her lessons. T2's sentiments reverberated well with Khoboli and O'Toole's (2011) findings that teachers in Lesotho were unable to implement learner-centred approaches due to non-existence of or inadequate equipment, large class population, time constrains, *etcetera*. This is indeed true for most Namibian government schools.

Bizarre as it may appear, according to one of the responses in the questionnaire, as a way of alleviating the challenge of lack of learning resources in electromagnetism, one teacher revealed that sometimes she attempted to make learners use their imagination to understand what was being taught. Practical activities will be discussed in subsequent sections in this chapter.

Lack of practical activities in science lessons

This phenomenon is a significant factor for why most learners performed poorly in science, particularly in the topic of electromagnetism. Mukwambo and Zulu (2013) disclosed that in-experienced science teachers, quality of accessible materials, time allocated for practical work and teachers' capacities to initiate learners into the science community using practical work are further challenges facing the Namibian education system. During my visits to schools as part of the Rössing Foundation Outreach Education Programme, I found out that most schools do not have the necessary science equipment to enable teachers to conduct practical activities during their lessons.

Although it may be true that most schools lack science equipment, the researcher has also found that some schools visited in Omaheke region did have sufficient science equipment including recently purchased electromagnetic kits. When teachers were asked why such resources were not utilised, most revealed that they were not familiar with such equipment and had not used them while doing their teacher training at college.

Parallel evidence was reported by Khoboli and O'Toole (2011) that in schools which had some laboratory equipment in Lesotho, teachers acknowledged that occasionally they did not use this equipment due to lack of practical skills and inadequate time for preparation of activities. Meanwhile, Raduta (2005) disclosed that learners failed to comprehend key concepts in electromagnetism, leading to misconceptions associated to inaccurate interpretation of symbols. Raduta (2005) further pointed out that the misconceptions were often due to ambiguous presentations of electromagnetism in textbooks, the direction of Lenz's law force, the application of the right-hand-rule as well as the mathematics involved in electromagnetism. The following is an extract from the examiners' report highlighting misconceptions in learners' answers.

> "Induced magnetism' was the answer that commonly appeared as opposed to 'electromagnetic induction' which was the required answer. The labelling of the poles seemed to a guessing game by a number of the learners of the candidates, as one could find the labels anywhere all over the circuit. This somehow gave an indication that the 'right-hand rule has not been mastered by the candidates in determining the poles on the electromagnet" (Namibia. MoE, 2012, p. 240*)*.

5.5.3 Analytical Statement 3:

Mediating tools are fundamental in providing scaffolding for learners to make sense of electromagnetic concepts

Analytical statement 3 aimed at answering research sub-questions 3 and 4:

- What can teachers do to improve teaching and learning of electromagnetism in under resourced schools?
- What enabled or constrained grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible resources in under-resourced schools?

Vygotsky (1978) stressed that mediation of learning is accomplished using physical materials and/or psychological such as LTSMs and language. As postulated by Vygotsky (1978), it was found that tools were fundamental in the mediation of learning of the topic of electromagnetism. To this end, this study developed and implemented a resource from local accessible materials which two teachers showed they could use as mediating tools to provide scaffolding for learners. This resonates very well with the Namibian curriculum (Namibia. MoE, 2009) which promotes the LCE approach as a meaningful and preferred teaching and learning method. The developed LTSMs using locally sourced materials, are at the centre of the analyses in this section.

Promotion of prior knowledge

Engaging what learners already know when mediating learning of science is a way of assimilating learners' prior knowledge (PK) and new knowledge (what is being learned). Several authors have argued that it is crucial to integrate prior knowledge during the mediation of science (Oloruntegbe & Ikpe, 2011; Roschelle, 1995; Stears et al., 2003). Roschelle (1995) claimed that learners construct new knowledge meaningfully when they integrate their PK during learning. Oloruntegbe and Ikpe (2011) took a parallel view that the inclusion of learners' PK during teaching and learning enhances learners' conceptual understanding of science concepts.

T1 and T2 were both familiar with the importance of prior knowledge. They introduced their lessons with what learners already knew (prior knowledge) and built on that. For instance, in the first lesson, both teachers began their lessons by revising magnetism, including concepts such as magnets, magnetic poles, magnetic fields, magnetic forces and induction.

When T1 and T2 were asked why they always started their lessons with learners' prior knowledge, their responses were that, it is the only you will get learners to understand new work. In fact, according to these teachers, the educational policy required that lessons be started with what they already know.

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Teacher: The poles of the electromagnet are similar to those of a?

Learners: permanent magnets (the whole class provided the answer)

Teacher: Same apply if you have to draw the magnetic field lines, the forces are moving from North-pole into??to

Learners: The South-pole (the whole class provide the answer)

Teacher: The very last thing I said yesterday was, since you know the flow of current in the circuit, this will help you identify the solenoid (electromagnet), hence the positive side of the battery is on the same side with the North-pole of the solenoid (electromagnet).

Throughout the revision, the teacher used a diagram to help explain the concepts learned in the previous lesson.

Figure 5.3: An extract of lesson 2 transcript of T2

Figure 5.3 shows that T2 began the lesson with what had been taught in the previous lesson. Prior knowledge is often referred to as the subject knowledge learned in previous learning. This seems to resonate with Svinicki (1994) who argued that lessons should begin with reviewing what has been done as that helps activate learners' prior knowledge. Oloruntegbe and Ikpe (2011) expressed similar views, equally asserting that the inclusion of learners' prior everyday knowledge enhances conceptual understanding.

With both T1 and T2 drawing on their learners' prior knowledge, learners were able to follow the lessons as reflected in the their responses during the lessons (Figure 5.3). Svinicki (1993,1994) complemented that learners' learning is conditioned by what they already know. That is, presenting new information in relation to the old information helps strengthen old knowledge. Roschelle (1995) proposed that teachers ought to use real everyday examples in linking resources to be learned. His proposal was implemented by the teachers when they used everyday examples as tools to help their learners make sense of concepts of electromagnetism.

Despite the advantages that prior knowledge contributes in learning, Campbell and Campbell (2008) cautioned that it can also lead to failure in the classroom. Meyer (2004) had the same view that unless correct approaches are used, prior knowledge can hamper new learning something which is dependent upon how closely learners' prior knowledge harmonises with the learning expectations of the teacher. Meyer (2004) investigated novice teachers' and expert teachers' conceptions of learners' prior knowledge. He found that expert teachers were more likely to ask learners to use previous knowledge to explain real life situations before going to new knowledge. Otero and Nathan (2004), in their investigation into pre-service teachers' conceptions of learners' prior knowledge admitted that their pre-service teachers were not sure how to effectively build on their learners' prior knowledge during their teaching practices.

Hence, Campbell and Campbell (2008) proposed the alignment of the curriculum with prior knowledge. Furthermore, Meyer (2004) recommended the designing of pre-service courses for teachers so as to emphasise and engage learners in meta-cognitive activities through which they become aware of how to apply prior knowledge to make meaningful choices in their teaching. In addition to prior knowledge, the role of practical work which is discussed in the next sub-segment, enlightens any mediation of science.

Practical Activities and teaching and learning approaches

As outlined in the literature review, it is assumed that sense construction does not certainly yield good results when teaching omits visual activities. The role of practical activities has been described as being to involve learners in meaningful learning processes (Bowell & Eison, 1991). According to Millar (2004), practical activities help learners to understand concepts better. As learners visualise phenomena through practical activities, their understanding of scientific concepts is enhanced and alternative concepts are confronted and replaced. Woodley (2009) asserted that practical activities allow learners to comprehend the significances of experiencing hands-on activities in science. Learner-centred education is thought to place learners in the centre of learning for them to attain practical skills, attitudes and knowledge. For that reason, Von Glasersfeld (1989) reasoned that learning does not take place when knowledge is received passively, but when learners are actively involved in the learning processes.

The ten teachers who participated in the survey strongly supported the inclusion of practical work in science education. They believed that practical work was vital to teaching science as it helps learners develop scientific skills, promote active learning and enhance understanding of concepts. They further agreed that practical work brings reality into learners' minds and activates their thoughts. As one teacher reiterated, *"involving learners in practical activities promotes active* *learning which follow the power of; 'hear and forget', see and remember', do and understand'"*. The teachers felt that the topic of electromagnetism is confusing if no practical work is used in its teaching. Hence, according to the teachers, teaching electromagnetism requires practical work. Hatting, Aldous and Rogan (2007) agreed that, from their experience, learners are always enthusiastic about carrying out meaningful practical activities. They blamed lack of practical activities as a main reason for the learners to fail the topic of electromagnetism

Throughout the lessons, teachers were reading and elaborating on procedures, probing what learners were busy with and moving around helping individual groups. Social constructivism was essential in that the teachers continuously encouraged discussions during the lessons. Also, learners' responses during the lessons showed that they continuously discussed the activities as they carried them out.

The easily accessible materials provided scaffolding opprotunities for social interaction between the teachers and learners and among learners themselves. Lazarowitz and Tamir (1994); Lunetta (1998); Hofstein and Lunetta (2004) supported that practical or laboratory activities have the potential to enable social interactions among learners, hence learners develop essential skills necessary for scientific understand and cognitive growth. Bell *et al.* (2010) proposed that learners are more successful when learning in shared surroundings such as group work as opposed to working alone. Oloruntegbe and Ikpe (2011) counselled teachers to integrate innumerable home-based linked activities in their lessons. Such resources offer a source of meaning and promote experiential-based teaching and learning, so facilitating understanding of science concepts (ibid).

The study further revealed that easily accessibly materials can be ideal resources as substitutes in in the absence of standard laboratory electromagnetic kits. The use of easily accessible materials has the potential to improve teaching and learning, particularly by novice teachers. Novice teachers will be able to use easily accessible materials as they are less complicated to understand than are standard science laboratory equipment. Furthermore, electromagnetic kits sourced from easily accessible materials use everyday materials which both the teachers and learners are familiar with, resulting in more confident use by teachers. Because of using such resources, prior knowledge (what teachers already know about the resource) was incorporated in the teaching and learning process.

Research has shown that learners learn best when they are actively involved in the learning process as that helps to develop their ability to think (Prince, 2004; Schwigtzer, 2007) using scientific processes which encourages learner-centeredness (Nyambe, 2008). Practical activities promote learner-centeredness which the Namibian Curriculum advocates (Namibia. MoE, 2009). Likewise, Miller (2004) advised that hands-on activities offer learners appropriate thoughtful means to participate in science activities. Abrahams and Miller (2008) publicised proof that most learners appreciate hands-on activities in science lessons in contrast to instructions which provided for little hands-on activity. These findings motivate a belief that easily accessible materials can be effective in promoting practical work in science classrooms.

Notwithstanding, the science teachers in this study did encounter some problems when they were using the easily accessible materials. During one lesson, it was observed that some learners needed more attention and some groups recorded unexpected findings. As discussed in Chapter 4, some cells and plotting compasses gave unexpected results. However, on replacement of those items, the kits worked well. During the stimulated-recall interviews, teachers revealed that it was important to pre-test the cells and the plotting compasses. The weakness of practical work exposed by Hodson (1990) and Roberts (2004) was that if teachers put little effort into preparing the activities the results may be confusing. There is a need to revisit the education system as one teacher in the questionnaire indicated that teachers have little time to prepare practical activities because their schedule is tight with many periods of teaching and few pauses in between.

Innovations to improve teaching and learning of electromagnetism topic

When teachers were asked how they ensured that learning takes place despite the challenges that they experienced in their science classroom, they provided different solutions. According to seven teachers they relied on improvisation. However, when probed further most teachers mentioned everyday materials such as discarded electronics parts such as magnets, wires and electric motors. Although these teachers had some idea of what easily accessible materials were and showed evidence that they used these resources, the extent and effectiveness of their use were questionable.

In closing, though most teachers showed awareness and cited some benefits from using easily accessible materials, teachers equally showed that they under-estimated these benefits. In a small way, this study sought to help science teachers to be able to teach electromagnetism through practical activities.

5.5.4 Analytical Statement 4:

Easily accessible materials (LTSMs) help teachers mediate and provide scaffolding for learning

This section analysis the usefulness of the easily accessible materials as a response to research question 4. The research question was; *what enables or constrains grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible resources in under-resourced schools?* Past Examiners' reports have frequently pointed to the scarcity of practical activities in science as a major contributing factor to learners' poor performances.

As discussed in Chapter 1 (see Sections 1.2-1.4) and Chapter 2 (Section 2.9), a number of researchers have suggested that science tasks play a distinctive and crucial part in science education (Maselwa & Ngcoza 2003; Millar, 2004; Woodley, 2009). These authors enlightened that successful science education systems are ones where practical activities are an integral part of teaching and learning. Understanding science key concepts, particularly in electromagnetism (Raduta, 2005; Saglam, 2010) promotes social construction in science education (McRobbie & Tobin, 1997; Moll, 2002) whereby learners construct knowledge best through social interactions with peers and the teachers. O'Donoghue *et al.* (2007) attested that when learners learn through social interactions, sense making of science concepts is enhanced.

5.7. Concluding remarks

This chapter presented, analysed and discussed the data from the workshops, lesson observations, and reflections during the stimulated recall-interviews with the two participating teachers. The results revealed that the easily accessible materials (electromagnetism kit) were effective in achieving the syllabus' objectives of helping learners to make sense of the concepts of electromagnetism. The data in this study revealed that grade 10 Physical Science teachers could develop their own electromagnetic kits using easily accessible materials and so improve teaching and learning in the electromagnetism topic. The study further revealed that easily accessible materials have the potential to help grade 10 Physical Science teachers.

Nonetheless, the research also revealed that during the mediation process, there were some challenges regarding the materials. However, these challenges could be avoided by checking the resources before the lesson.

The next chapter, summarizes the research findings, and provides recommendations and conclusion.

CHAPTER SIX: SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

The main aim of this study was to investigate how Grade 10 Physical Science teachers help learners to make sense of science concepts in electromagnetism using easily accessible materials in under-resourced schools. The study was prompted by the need to integrate practical activities in science lessons. Research has shown that integrating practical activities in science lessons helps learners to make sense of concepts of electromagnetism and to make connections to everyday activities related to the topic (Bowell & Eison, 2004; Miller, 2004; Woodley, 2009). Furthermore, Examiners' reports encourage teachers to integrate practical activities using everyday practical examples in their teaching, because this shows the relevance of the subject to the learners and that in turn makes the subject more interesting and better understood (Namibia. MoE, 2013).

Data were generated using questionnaires to elicit teachers' views, workshops to develop the resource, lesson presentations and stimulated-recall interviews. Vygotsky's (1978) socio-cultural theory provided the theoretical framework and this was used as a lens to analyse the data. Qualitative data were analysed inductively and sub-themes and then themes were formed.

6.2 Summary of findings

The data generated were analysed to answer four research questions. A summary of findings for each is presented.

6.2.1 Research Question 1

What are grade 10 Physical Science teachers' perceptions and experiences of teaching the topic of electromagnetism?

The study found that, with the exception of one teacher, all the teachers who were surveyed considered the teaching of electromagnetism topic difficult to teach, particularly in the absence of practical activities. While teachers felt that having prior experience in the teaching of electromagnetism made it simpler to teach, their experiences and Examiners' reports revealed that teachers generally struggle to teach this topic.

Most of the teachers complained that their learners often find it difficult to understand concepts of electromagnetism. This affirms Richards's (2010) and Roussel and Hélier's (2012) claims that college students find the topic of electromagnetism very challenging. Teachers felt that their learners often did not understand what they were taught during the lessons. Although some teachers believed that the experience they gained by teaching the subject for several years, gave them the ability to teach science effectively, their responses indicated that such experiences had not at all make them good teachers of electromagnetism. Despite efforts teachers put in their lessons preparations, they complained that learners were unable to comprehend the topic well.

These difficulties were revealed in Examiners' reports which repeatedly pointed out that questions on electromagnetism were poorly answered by learners during end of year examinations. The teachers' perceptions corroborated Miller's (2004) and Woodley's (2009) findings that practical activities help learners understand science concepts better as the activities allows them to visualise phenomena.

6.2.2 Research Question 2

What factors influence grade 10 Physical Science teachers' perceptions and experiences of teaching the topic of electromagnetism?

Several factors were highlighted by the Grade 10 Physical Science teachers about teaching the topic of electromagnetism. Although they appeared to have knowledge of the topic of electromagnetism, they revealed that they struggled to teach electromagnetism as they found it difficult to make learners understand its real meaning. For example, they pointed out that their learners failed to understand how current can lead to the induction of a force around a wire and how it results into a temporary magnet.

Major factors influencing teachers' perceptions on the topic of electromagnetism were found to be teachers' attitudes towards their learners and lack of practical activities in science lessons. Teachers felt that they were putting great effort into the teaching despite their learners not perfuming as expected. Furthermore, teachers felt that the lack of practical activities in their teaching was a major contributing factor towards poor learner performances. Some teachers blamed the absence of science resources in their schools, particularly lack of electromagnetism kits. This is despite some science teachers sitting with adequate unutilised resources in their schools.

Teachers further revealed that there was just no time for them to develop their own resources as their teaching schedules were tight, they had many learners to attend to during normal school times. One the teachers (T2) who participated in the resource development and lesson presentations. Also complained that her workload was a contributing factor hampering her efforts to carry out practical activities in her lessons. This echoes with Khoboli and O'Toole's (2011) findings in Lesotho that teachers were unable to implement LCE approaches due to non-existence or lack of science resources, large class population, and time constrains, *etcetera*. For this reason, some teachers blamed government for not providing them with sufficient resources to enable them to conduct their science lessons effectively.

Contrary to claims by some teachers that lack of resources was one of the contributing factor which hindered them from including practical activities, I found out that some of these schools whose science teachers had completed the questionnaires had acquired many science resources which were not utilised at the time of my visit.

6.2.3 Research Question 3

What can teachers do to improve teaching and learning of electromagnetism in under-resourced schools?

In response to this question, the research found that the use of everyday materials as substitute in the absence of standard science equipment in most Namibian schools could help alleviate the lack of practical activities at least in electromagnetism. Teachers strongly supported the idea of using easily accessible materials to enhance learning of science education. For instance, T9Q commented that; "*involving learners in practical activities promote active learning which follow the power of; 'hear and forget', see and remember', 'do and understand*'". The findings corroborate studies by Miller (2004); Prince (2004) and Hatting, Aldous and Rogan (2007) that the inclusion of practical work in science lessons helps learners construct knowledge accurately and understand the learned materials well.

This finding is in line with the notion of 'hands-on', 'minds-on' and 'words-on' on practical activities as advocated by Maselwa and Ngcoza (2003) that practical work promotes scientific skills such as observation, investigation, problem-solving and so on. Through practical activities, learners are able to visualise phenomena which in turn promotes conceptual understanding of science concepts (ibid). This further promotes LCE approaches which are a requirement in teaching as outlined in the Namibian curriculum.

Likewise, this finding resonates well with Vygotsky's (1978) social constructivism which conceives that learners construct knowledge best through active participation in the lessons. Interactions between the teacher and their learners help learners construct new knowledge effectively. This construction was visibly clear during the lesson presentations by T1 and T2. Throughout the lessons, T1 and T2 were in constant conversation with their learners, clarifying procedures, probing what learners were doing and making sure learners were focused on the task. That is, they encouraged conversations between the teacher and learners as well among learners themselves.

6.2.4 Research Question 4

What enables or constrains grade 10 Physical Science teachers when helping learners to make sense of concepts of electromagnetism using easily accessible materials in under-resourced schools?

The two collaborating teachers who presented the lessons using easily accessible materials indicated that using these materials had led to learners having a positive image of science. They emphasized that everyday materials help learners understand what they are learning. Moreover, learners are being exposed to materials which they are familiar with, hence, nurturing positive attitude towards learning of science and a sense of belonging. The findings further revealed that the two teachers who presented the lessons appreciated the use of the developed resource.

Most of the teachers who completed the questionnaires also indicated that easily accessible materials have the potential to help learners construct new knowledge. Overall, easily accessible materials have the potential to enable teachers to incorporate practical activities in their science lessons. This is in line with Hofstein and Mamlok-Naaman (2007) who asserted that science practical work plays a distinctive and crucial role in science education.

Findings in this study revealed that the use of easily accessible materials enabled grade 10 Physical Science teachers to help their learners make sense of electromagnetism. According to the two collaborating teachers, these easily accessible materials truly enabled them to effectively mediate the electromagnetism topic. The research also revealed that easily accessible materials enable teachers to create classroom environments which promote social interactions among learners and the teacher. Through social interactions with peers and the teachers learners are best able to construct knowledge (McRobbie & Tobin, 1997; Moll, 2002).

While the developed resource helped teachers achieve their goals of effective teaching of the topic of electromagnetism, it was also found that if the resources are not well developed and tested, they have the potential to hinder learning. This can happen when parts of the materials to be used (developed LTSMs) are not tested before the lessons.

The research also found that teachers do not have sufficient time to develop their own resources, hence, find themselves left with no option but to teach science lessons in the absence of practical work. Throughout the observed lessons, teachers kept on reminding learners to hurry up with a particular procedure (practical instruction) due to time. At times, the teacher simply forced learners to move to the next procedure in order to complete the task. The research also revealed that some teachers are constrained from developing their own resources from easily accessible materials because they themselves are not familiar with such resources.

6.3 Recommendations

Several recommendations emerge from the research findings and discussion above. The objective of these recommendations is to alleviate some problems encountered when mediating the concepts of electromagnetism. These recommendations are grouped under resources development, pedagogy and science teachers' collaboration.

6.3.1 Resources development

As it emerged from the research, the participating teachers recommended that science teachers should come together and collaboratively develop teaching and learning resources in order to reduce their dependence on their schools and government. This may ensure that science teachers are equipped and able to incorporate practical activities in their science lessons with the developed resources. Through Senior Education Officer (SOE) (formerly advisory teachers), programs can be developed which can encourage both teachers and advisory teachers to develop learning and teaching support materials (LTSMs) in various science topics and grades.

6.3.2 Pedagogy

Science teachers are encouraged to come together in order to share best practices so that all teachers within a geographical area can be equipped with the best practices which would enable them to effectively present science lessons in which learners are to greatly benefit.

6.3.3 Science teachers' collaboration

I recommend that science teachers should share their experiences of using easily accessible materials and the teaching of electromagnetism in order to tap into each other's expertise. This could ensure that their learners are exposed to similar materials which make it easy to evaluate the effectiveness of such resources during collaborative meetings. Teachers can exchange ideas on how best to approach various aspects of different topic of electromagnetism and other science topics. Herein lies the importance of a community of practice as proposed by Lave and Wenger (1991).

6.4 Areas for future research

With the exception of Asheela's (2017) study, I could not find any study in the use of easily accessible materials in science teaching in Namibia. Thus, this research could serve as a stepping stone for future research to promote practical activities in grades 10. Hence, there is a need for further research in the following areas:

- Further research in order to develop further the electromagnetic kit developed in this study so that it is able to cover the whole topic of electromagnetism in Grade 10 Physical Science and beyond;
- A broader study on the teachers' perceptions and experiences on the use of easily accessible materials in grade 10 Physical Science and other grades;
- A study on use of easily accessible materials in other science topics of the Grade 10 Physical Science and in other grades;
- A study on the effectiveness of these easily accessible materials in other topics of Grade 10 Physical Science and other grades; and
- A study focusing on the learners' perceptions and experiences of learning practical activities using easily accessible resources.

6.5 Limitations of the study

The findings of this study were limited to Grade 10 Physical Science teachers in the Erongo and Omaheke regions. Ten teachers from the Erongo and Omaheke regions participated in the survey and another two teachers from the Swakopmund Circuit of the Erongo region collaborated in development and use of easily accessible materials in their teaching of electromagnetism topic in their schools. As only 10 questionnaires were returned by the sample this affected the representativeness of the findings.

Likewise, as only two teachers participated in the development and implementation of the easily accessible materials (LTSMs) in one teaching circuit, this affected how representative the findings are of all the teachers in the Swakopmund circuit or of the Erongo region. Therefore, this research cannot be generalized to the whole region or country. However, the study has revealed some useful insights on the professional development of science teachers in relation to the use of easily accessible resources in teaching science.

6.6 Reflections

My MEd course journey was full of learning along every step. This research journey started when I visited various schools as part of my work at the Rössing Foundation (RF) Outreach programmes. The RF carries out the social-corporate responsibilities of its mother company Rio Tinto's Rössing Uranium Mine. The Education Outreach Programmes provide professional support mainly to subjects such as English, Mathematics and Sciences as mandated by the RF Board of Trustees. The Outreach Programme helps develop teachers' Pedagogical Content Knowledge in their respective subjects, promotes and facilitates the inclusion of practical activities in science lessons by making available science materials to schools which lack such resources.

This idea for the research started when I found that most schools I visited lacked science resources to enable science teachers to incorporate practical activities in their lessons. Because of seeing most teachers teaching science theoretically due to their lack of science resources, I decided to develop science resources from easily accessible materials which are inexpensive and easy to obtain. As a result, I decided to carry out a research which could help science teachers teach science in a more learner centred way, thus, my research goal was expressed in the title: an investigation into how Grade 10 Physical Science teachers help learners to make sense of science concepts in electromagnetism through the use of easily accessible materials in under-developed schools: A Namibian Case Study.

Guided by a team of committed and dedicated supervisors and supported by cooperative MEd colleagues, what could have been insurmountable tuned out to be an exciting journey of new discoveries. As a teacher, I began to comprehend the value of easily accessible materials in enhancing practical activities for mediating the electromagnetic topic. I began to appreciate the concepts of Pedagogical Content Knowledge (PCK) and socio-constructivism approaches to learning. As I reflected on the teaching practices of other teachers, I perceived how I could improve my own practice too. This course opened my eyes to research and new ideas generated by research undertakings.

There were moments when I found myself struggling to collect the questionnaires and arrange for the teachers to present the lessons. I learned that, in life, one needs to be flexible if you want to achieve set goals, more especially when other individuals are involved. Likewise, I had moments of frustration when I was unable to organise the presentations of the lessons using the developed resources due to teachers' other commitments. Nevertheless, at the end of journey, this undertaking was worth giving time as I came out with much more knowledgeable than I had before embarking on it.

Lastly, if I were to carry out the research again, I would involve more teachers in the implementation of the resources and extend the materials to cover the entire topic of electromagnetism so that teachers can have a complete kit of the whole topic. This will ensure that teachers will not have to teach this topic theoretically, but a learner centred approach can be used as encouraged by the Namibian curriculum.

6.7 Conclusion

This chapter discussed the conclusions of each research question briefly and highlighted the main findings, recommendations, limitation of the study, areas for further research and reflections on my research journey. The study revealed that most of the teachers in the Erongo and Omaheke regions understood the importance of using easily accessible materials in teaching of the topic of electromagnetism in the absence of standard scientific resources in under-developed schools. Hence, some teachers included such resources in their grade 10 Physical Science teaching. Teachers also pointed out the benefits and challenges faced when sourcing and using easily accessible materials in their teachings.

This study showed that easily accessible materials have the potential to replace expensive standard scientific resources in most schools which are under-resourced. Furthermore, it showed that lack of practical activities in the teaching of electromagnetism topic can be a thing of the past if teachers develop their own resources from easily accessible materials.

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APPENDICES

Appendix 1

Permission from the Directorate of Education, Ministry of Education, Arts and Culture-Erongo region

ERONGO REGIONAL COUNCIL

DIRECTORATE OF EDUCATION

OFFICE OF THE DIRECTOR

Telephone : 064-410[redacted]
Fax : 064-410[redacted]
E-mail: [redacted]@moe.org.na

Private Bag [redacted]
SWAKOPMUND

Enquiries : Mr. [redacted]
Date : 15 April 2016

Paulo Samuel
Science Education Officer
Rössing Foundation
SWAKOPMUND

RE: PERMISSION TO CONDUCT STUDY FOR A MASTERS DEGRE IN SCIENCE EDUCATION

Your request on the above mentioned subject has been approved with the following conditions:

1. The activity should not interfere with the normal school program.

2. All activities and details of the research should be discussed with the school management and prior approval must be obtained from the principal.

3. Participation of teachers and learners should be voluntary as mentioned in your letter.

Kind regards.

....

[redacted]
REGIONAL DIRECTOR

Appendix 2(a)

Permission from the principal of school 1 (S1)

P O Box 6294
Vineta
Swakopmund
Namibia
Cell: +264 81 268 4977

04 April 2016

The Principal
[redacted] School
[redacted]
Swakopmund

Dear Principal

RE: PERMISSION TO CONDUCT STUDY FOR A MASTERS DEGREE IN SCIENCE EDUCATION

I am a registered student for the Masters of Education (Science Education) with Rhodes University. As part of the fulfilment of the Masters programme, I am required to conduct a research.

Against this background, I am requesting for permission to conduct a study at your school. The aim of this study is to understand how teachers help learners make sense of concepts on electromagnetism through using easily accessible materials. This study will take place at two schools, [redacted] School being the other school.

It is envisaged that the study will apply ethical procedures as no personal information regarding those who participate will be publicised. Furthermore, participation will be voluntary, school academic programmes will in no way be disrupted and the researcher undertakes to share the outcome of the study with your school on request.

I am looking forward to a favourable response in this regard.

Yours sincerely

Paulo Samuel
Rhodes University
Med in Science Education Student

Permission granted
[redacted] (principal)

MINISTRY OF EDUCATION
[redacted]
SCHOOL
20 JUL 2016
P. O. BOX [redacted], SWAKOPMUND
TEL: 064 - [redacted] / 31 FAX: 064 - [redacted]
EMAIL: [redacted]y.na
ERONGO REGION

Appendix 2(b)

Permission from the principal of school 2 (S2)

P O Box 6294
Vineta
Swakopmund
Namibia
Cell: +264 81 268 4977

04 April 2016

The Principal
[redacted] School
P O Box 906
Swakopmund

Dear Principal

RE: PERMISSION TO CONDUCT STUDY FOR A MASTERS DEGREE IN SCIENCE EDUCATION

I am a registered student for the Masters of Education (Science Education) with Rhodes University. As part of the fulfilment of the Masters programme, I am required to conduct a research.

Against this background, I am requesting for permission to conduct a study at your school. The aim of this study is to understand how teachers help learners make sense of concepts on electromagnetism through using easily accessible materials. This study will take place at two schools, [redacted] School being the other school.

It is envisaged that the study will apply ethical procedures as no personal information regarding those who participate will be publicised. Furthermore, participation will be voluntary, school academic programmes will in no way be disrupted and the researcher undertakes to share the outcome of the study with your school on request.

I am looking forward to a favourable response in this regard.

Yours sincerely

Paulo Samuel
Rhodes University
MEd in Science Education Student

MINISTRY OF EDUCATION
[redacted] SEC SCHOOL
01 -07- 2016
TEL: 064 [redacted]
P.O. BOX [redacted] SWAKOPMUND
REPUBLIC OF NAMIBIA

Permission granted.
E. [redacted]
Principal

Appendix 3(a)

Permission from teacher 1 (T1) of school 1

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

EDUCATION DEPARTMENT
Tel: +27 (0) 46 603 8383
Fax: +27 (0) 46 622 8028
PO Box 94, Grahamstown, 6140
E-mail: education@ru.ac.za

04 April 2016

Dear Research Participant

RE: PARTICIPATION IN RESEARCH ON THE USE OF EASILY ACCESSIBLE RESOURCES IN THE TOPIC ELECTROMAGNETISM IN PHYSICAL SCIENCE GRADE 10.

Thank you for agreeing to be a research participant in my study. As per our discussion, my research study is' How do grade 10 Physical Science teachers help learners make sense of concepts on electromagnetism through using easily accessible materials?'

This study will be conducted in **two phases.** The **first** phase requires participants to complete a questionnaire. The **second** phase of the study involves an intervention in the form of a workshop /group work /training with participants on developing and the use of easily accessible resources in science classrooms. Participants will then be required to implement the easily accessible resources in their classroom science teaching.

Additionally, I will video-tape the lessons and conduct stimulated recall interviews (SRI) after each lessons to provide clarity on how, you the teacher helped learners make sense of concepts on electromagnetism through using these easily accessible materials.

Your participation in this research study is completely voluntary and you can withdraw at any time. The data collected in this study will be published as a Rhodes University half thesis. The identity of each participant and their views or contributions will be treated with a high degree of confidentiality and anonymity.

Sincerely

Paulo Samuel
Rhodes University
MEd in Science Education Student

Dr K. Ngcoza (Supervisor)
Rhodes University

I agree to participate in the research on condition that I can withdraw at any time.

Name: G. P. [redacted]

Signature:

Contact number: 081 87[redacted]

Appendix 3(b)

Permission from teacher 2 (T2) of school 2

RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

EDUCATION DEPARTMENT
Tel: +27 (0) 46 603 8383
Fax: +27 (0) 46 622 8028
PO Box 94, Grahamstown, 6140
E-mail: education@ru.ac.za

04 April 2016

Dear Research Participant

RE: PARTICIPATION IN RESEARCH ON THE USE OF EASILY ACCESSIBLE RESOURCES IN THE TOPIC ELECTROMAGNETISM IN PHYSICAL SCIENCE GRADE 10.

Thank you for agreeing to be a research participant in my study. As per our discussion, my research study is' How do grade 10 Physical Science teachers help learners make sense of concepts on electromagnetism through using easily accessible materials?'

This study will be conducted in **two phases.** The **first** phase requires participants to complete a questionnaire. The **second** phase of the study involves an intervention in the form of a workshop /group work /training with participants on developing and the use of easily accessible resources in science classrooms. Participants will then be required to implement the easily accessible resources in their classroom science teaching.

Additionally, I will video-tape the lessons and conduct stimulated recall interviews (SRI) after each lessons to provide clarity on how, you the teacher helped learners make sense of concepts on electromagnetism through using these easily accessible materials.

Your participation in this research study is completely voluntary and you can withdraw at any time. The data collected in this study will be published as a Rhodes University half thesis. The identity of each participant and their views or contributions will be treated with a high degree of confidentiality and anonymity.

Sincerely

Paulo Samuel
Rhodes University
MEd in Science Education Student

Dr K. Ngcoza (Supervisor)
Rhodes University

I agree to participate in the research on condition that I can withdraw at any time.

Name: [redacted]..

Signature: ....

Contact number: [redacted]..

APPENDIX 4

A blank copy of the questionnaire

I, **Paulo Samuel**, student no **611s7301** doing a **Master in Science Education** with Rhodes University. I would like to request all Physical Science teachers in Erongo region teaching grade 10 to take part in my research project by completing the following questionnaire. The focus of my study is *to explore grade 10 Physical Science teachers' perceptions and experiences on the use of easily accessible (available) materials to make sense of science concepts in electromagnetism topic.*

The information obtained in this questionnaire will be anonymous and your name will not be used. Please do not write your name and answer all the questions as free as you wish.

Part A: Professional Profiling of the teacher

Please tick (√) the appropriate box:

1. Gender

Male	Female

2. Qualifications (qualifications you have)

ECP	BETD	ACE/FDE	BEd-Hons	MEd	PHD	Non-Education Qualifications

3. Teaching experience in Physical Science and total teaching experience.

Grade 10	Total

4. Age group (tick one box)

20-25 years	26-30 years	31 – 35 years	36 – 40 years	41 – 45 years	46 – 50 years	Above 50 years

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>

Part B

Teachers' views and Experiences

1. **(a)** What are your views of teaching the topic of electromagnetic in grade 10?

(b) What are your experiences of teaching the topic of electromagnetic in grade 10?

2. Do you as a Physical Science teacher experience difficulties when you teach the topic of electromagnetic?

Yes	No

3. Please elaborate more on the difficulties.

4. What kind of difficulties, if any, do your learners encounter in the topic of electromagnetic?

5. What are your views and experiences about your learners' participation during the lessons in the topic of electromagnetic?

6. What kind of difficulties, if any, do your learners encounter during the lessons in the topic of electromagnetic?

7. Given the challenges (if any) you and possible other science teachers face, what do you do to ensure that learning takes place when teaching the topic of electromagnetic?

8. What are your views about the use of practical activities in the teaching the topic of electromagnetic?

9. Have you ever used easily accessible materials (for example, discarded radio parts, etc.) in your teaching of the topic of electromagnetic? Tick one box

Yes	No

10. If yes, please elaborate on these easily accessible materials.

11. If not, please elaborate why you do not use easily accessible materials.

12. What do you think could be the benefits of using easily accessible materials in teaching the topic of electromagnetic?

13. What else would you like to share with me in teaching the topic of electromagnetic?

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Thank you for participating in this study. If you have any queries, feel free to contact me at:
paulosamuel248@gmail.com / +264 81 268 4977 or +264 81 324 7866

APPENDIX 5(a)

Transcript of 1st workshop

This workshop started with school teacher 1 (T1), school 2 teacher 2 (T2) joined later during the workshop as she indicated telephonically that she will be delayed.

Researcher: Good morning Mr Udjombala, thank you for accepting my invitation, and I should also acknowledge that I am very thankful for you to agree to become a research participant.

Teachers: Thank very much and welcome Mr Paulo

Researcher: The aim of this small workshop which I would like to introduce my resource to you which I would like you to implement in your lessons. So what we are going to do is going through the equipment that I have organised/developed as per the syllabus' objectives. I think the objectives which we are going to look at is under electromagnetic effects and electromagnets, electrical current, which is basically falls under electromagnetism.

These objectives here (pointing at a page in the syllabus which contained the lesson's objectives) will require you to present at least two lessons and those lessons will be video-taped.

Teachers: Okay, and these two lessons should I present them to all the classes of just one class?

Researcher: Just one class. But you may repeat the lessons with other classes but I am only interested and video-tape one class. And the aim of the research as you may have seen in the letter of consent which you signed, that the focus is more on how the teacher is going to deliver or teach the lessons using those resources in order to make concepts of electromagnetism well understood by learners.

Teachers: Alright

Researcher: I will prepare two practical worksheets and you will prepare two lessons which will go hand in hand with the practical worksheets. I think before we go to the objectives, I think, as per the lesson objectives, before the first lesson, you need to revise magnetism. I am not sure how to revise with the class, but when I discussed with Ms Ashaanda (teacher from school 2) and advised her to make use of an overhead projector (OHP).

Teachers: But the problem will only be the light in my class, the windows need to be covered. The last time I used it was in the school hall, my classroom was too bright, so the images were not clear. However, I can make use of another classroom which is better than my classroom.

Researcher: In this case, we need to something because even the other lessons may likely require the use of the OHP in order to project images on the screen.

At this moment, the two of us continued discussing on how to reduce the brightness in the classroom to enable the teacher to use the OHP. Possible solutions were to cover the windows with black refuge bags.

Teachers: That will work too.

Researcher: Can we quickly go through how you are going to revise magnetism? Three things which need to be revised; the magnetic field and strength as well as directions of the fields. And I think, that should not take much of the lesson's time, at least two to three minutes.

Teachers: That will be very simply.

Researcher: At this moment, I stood up and was demonstrating the revision using the OHP. A magnet is placed on the OHP and covered with a transparency for visibility. The image of the magnet is displayed on the screen which the whole class can see clearly. Then iron fillings is spread over the magnet to determine magnetic field area and strength. Plotting compasses are placed around the magnet to determine the directions of the magnetic field lines. We therefore discussed how the revision on magnetism will take place.

Researcher: Now, coming to the actual lesson on electrical current, which is the first lesson, the effect of current in a straight conductor and in a solenoid (see copy of syllabus), learners will require to have at least three (3) cells, a solenoid of about 1 metre and at least two (2) plotting compasses and about 25 paper-clips of the same sizes. The idea of the lesson is to show learners that when current flow in a closed circuit, an electrical force is experienced around that wire. For the second lesson, learners will require to have two nails in addition to the material provided in lesson 1.

Teachers: The teacher (school 1) confirmed that he tried to demonstrate the electrical field around a conductor carrying electricity the previous year but it did not work out properly. Hence, this activity will solve that problem.

Researcher: At this moment, I was demonstrating to the teacher how the resource works.

After this workshop, I developed the worksheets and delivered them to T1 and T2 for their input. They were then required to bring along their revised sheets along during the 2nd workshop for further refining of the worksheets.

The workshop took at least 1 hour to complete.

APPENDIX 5(b)

Transcript of 2nd workshop

Researcher: Okay, thank you Mr Udjombala for making time to go through the practical lesson worksheets before implementation of the lessons. Today we are going to go through the worksheet, at the same time carrying out the actual practical activity or experiment. This is to make sure that the worksheet will work out as planned.

At this moment, I read the two objectives for lesson 1 as well placed the resource for the lesson on the table.

I also indicated to Mr Udjombala that Ms Ashaanda will join us a bit later as she is slightly delayed.

At this moment, we agreed that, I will be reading the instructions from the worksheets and the participants will carry out the practical activities.

This workshop also served to review and refine the instructions in the worksheets.

Nine (9) minutes into the workshop, participant 2 (Ms Ashaanda) joined us.

Researcher: I raised a concern on grade 10 learners' ability to read and follow instructions in an experiment, because there are hardly any practical activities carried by learners in state schools. This may require sufficient time to allow learners to complete the activities. Most normal school lessons last for 40 to 45 minutes long.

Both participants indicated that there are some grade 10 learners who are active during lessons and always want to discover things for themselves. However, participant 2 further indicated that most the learners are slow and a 40 to 45 minute lessons will not allow to complete the activity.

Participant 2: "I have a problem with my grade 10 classes. The problem that I am facing is that these four grade 10 classes have not done electricity from grade 8." She indicated that the responsible teachers in previous grades did not complete the previous grade syllabus. Some teachers were on maternity leave.

After the conversation, we continued to carry out the practical activities and refining the instructions in the worksheets.

During the discussion, we agreed that the objectives of the each lesson need to be read at the beginning of each lesson so that learners know what is expected during the lessons.

The workshop took about 50 minutes to complete.

Appendix 6

Worksheets for lesson 1 and 2.

LESSON 1

Practical Investigation on the magnetic effect of an electrical current (electromagnetism)

Name of School: ______________________________ **Date:** __________

Name of learner: ______________________________ **Grade 10** ____

In this experiment:

(a) you are going to investigate the electrical force (magnetic effect) of an electrical current in a straight and coiled (solenoid) conductors and possible ways of increasing the strength of the electrical force (magnetic effect) around the wire.

(b) you are going to investigate, sketch and compare the magnetic field around a bar magnet and a current carrying solenoid (both shape and direction of magnetic field lines are required).

Carry out the following experiment by following the instructions. Write all your observations and answers to any question on the spaces provided.

The Physical Science teacher will briefly revise magnetism before you commence with this activity.

Part 1:

Materials: You are provided with 3 cells; an insulated wire; 2 plotting compasses; 1 iron nail

What to do:

1. Place 1 plotting compasses on top of the insulated wire and connect the two ends of the wire to the terminals of one cell. Observe and write what happens to the plotting compass.

____

____

2. Repeat number 1 with two and three cells. Write your observations below.

____

____

3. Why do you think the plotting compass deflects every time the current flow through the insulated wire?

____

____

4. Why do you think the plotting compass needle always pointed to the same direction? Every time the current was flowing?

____

____

Part 2:

1. What do you think should be done in order to increase the strength (force) which is deflecting the plotting compass needle?

____

____

2. Make a solenoid of 20 windings by using the nail.

3. Place a plotting compass on each end of the solenoid. Draw the solenoid and directions of the plotting compass below.

4. Now connect the ends of the solenoid to the 3 cells and observe how the plotting compasses react to the current through the solenoid. Draw the solenoid in a complete circuit with the new directions of the plotting compasses below.

5. Why are the plotting compasses pointing in the same directions as you have drawn above?

____

____

6. Redraw the complete circuit in number 4 below. Add the magnetic (electrical) field around the solenoid and directions of the field.

7. What can you say about the magnetic field you have drawn in number 6 and the magnetic field of a permanent magnet.

____

____

____

LESSON 2

Practical Investigation on the magnetic effect of an electrical current (electromagnetism)

Name of School: ______________________________ **Date:** _________

Name of learner: ________________________________ **Grade 10** ____

In this experiment:

(a) you are going to investigate how to build an electromagnet and change the strength.
(b) you are going to investigate and explain the difference between the electromagnetic properties of iron and steel and predict the difference between a temporary and a permanent magnet.

Carry out the following experiment by following the instructions. Write all your observations and answers to any question on the spaces provided.

Part 1:

Materials: You are provided with 3 cells; an insulated wire (solenoid); soft and hard iron nails (1 each); paper clips (about 20).

What to do:

1. Revise the experiment you carried out in the last lesson. The teacher will summarize.

2. Prepare a solenoid with 20 windings and place the soft nail inside it.

3. While the nail is inside the solenoid, try to pick up paper clips. Number of paperclips picked by the nail: _________________

4. Now connect the ends of the solenoid to 1 cell and try to pick up any paper clips. Number of paperclips picked by the nail: _________________

5. Repeat number 4 but with two cells. Try to pick up any paper clips. Number of paperclips picked by the nail: _________________

6. Repeat number 4 but with three cells. Try to pick up any paper clips. Number of paperclips picked by the nail: _________________

7. Comment on the number of paperclips picked (attracted) by the nail (electromagnet) every time you increased the number of cells.

____

____

____

---

8. Increase the number of coiling to 40 and connect the solenoid to 3 cells. Try to pick any paper clips. Number of paperclips picked by the nail: _______________

9. Repeat number 8 but increase the coiling to about 60 windings. Number of paperclips picked by the nail: _________________

10. While the paper clips are hanging on the nail (electromagnet), disconnect the current. What happens to the paper clips?

____

11. What is the reason to your answer in number 9?

____

____

12. Comment on the number of paperclips picked (attracted) by the nail (electromagnet) every time you increased the number of coiling.

____

____

____

13. Based on the experiment, state how you increased the strength of this electromagnet?

____

____

____

14. What happens to the electromagnetism of the soft and hard nails when the current is disconnected?

____

____

15. What is an electromagnetism?

____

____

APPENDIX 7(a)

Transcript of Teacher 1 (T1), Lesson 1

Teacher 1: The teacher set-up the equipment to begin the lesson (connecting the OHP to electricity, the magnet and a transparency on top of the OHP. I helped the teacher too).

The first part of the lesson, the teacher revised magnetism as follows:

Introduction of the lesson:

Teacher: Now what you are going to see is what you have already learned in the theory.

Around a magnet, you find a magnetic field. An object only experiences a force if it is within this magnetic field. And the end of a magnet, you find that the magnet is stronger and its ends compared to the sides.

(The teacher now demonstrates magnetic field on the screen while all the learners observe. The teacher continues talking while demonstrating) - You can see that around the magnet, we can see the magnetic field. At the end of the magnet, it is where there is a lot of iron fillings. Plus magnets are stronger at the end of the magnet compared to the sides. So, that's how it is.

You might be asked that, at which side the magnet is more, having more strong force. So you must know. That's the reason why we that...... (Teacher pointing to the image on the screen).

Then, if I am now to indicate ......and then to show ...... so .... A magnet has two poles. That's now only an indication of the magnetic field, the force around it. For us to know the poles of that magnet, then we will be able to determine ....

If I place a plotting compass, then I can put another there (the teacher is demonstrating on the OHP which the image is projected on the screen). It is abit far, you won't be able to see it, so let me put it there.

Then, we can now, now tell ... aaahhhh... the direction.

So, now it is moving away from? ...... towards the? (teacher asks the learners)

Learners: South (majority of learners responded)

Teacher: It is moving away from the North, towards the South. Then you will able to determine which one is the South and which one is the North.

So, that is probably, what you need to know about the magnet and we will have our hand out (practical worksheet) in question .... lesson 1.

Main Lesson

Teacher: Practical investigation on the magnetic effect of an electrical current. (the teacher reads the heading on the practical worksheet.)

Teacher continues: Then, one might wonder again what is electromagnet has to do with the effects of electrical current.

So then ..... aahhh, there you just have to fill up in your name and there is the instruction for letter a, says,,,,,,,, You are going .... (the teacher reads the objectives of the practical from the worksheet) ....

In between the teacher faces the group next to him and say...... I don't think is enough this one (referring to the length of the wire provided to the group) ...... it looks short because we are to turn it, then, probably I can give you another one, because that one looks a bit short.

The teacher continues to read the next objectives of the practical (there were two objectives in the lesson. See practical worksheet, Appendix #

Teacher: So then, you have to ..... start with number one, ... number one, ...so everybody should be able to .... it shouldn't be a one man show.

The teacher continues to read the materials listed in worksheet which each group should have.

Teacher: Find out if everything that is ..... which is there.

Learner: Sir, we don't have plotting compasses. (a group shouted out)

Teacher: You did not get plotting compasses. Okay ..... you get this...

Teacher: Then uhhh, number one it says, ... (the teacher reads instruction number 1 from the worksheet). Then the teacher continues.

Now you have a solenoid which is a coil of wire, this group is just quiet, also that group, what are you doing now? So you must have coil of wire, ... this is a coil of wire (teacher showing a coil of wire to the class).

And then .... please, the work must be done in groups and then you discuss the answer before you start writing anything. You are going to be judged according to the way you present the information in your group and how you discuss it, so you must, ... when you read and don't understand it, you must ask your friend , they could explain much better.

Now, what you need is ahhhh .... you need the plotting compass, you must place one plotting compass on top of the insulated wire and predict what will happen.

Just on there, one plotting compass (teacher talking to one group), do you have a plotting compass? (teacher asked the group).

Okay, you did that part, Now connect the two ends of the wire to the terminals one *cell (teacher read instruction 2).* Now you must use one cell, then you connect it, and you plotting compass must also be on top there. *The teacher walk around the groups to see if the instructions are being carried out correctly.*

Researcher: Mr Udjombala, they must write their prediction, there should one member of the group writing all the time.

Teacher: Okay, , so then, don't forget to write your prediction for number, letter A. When you place it this way, you expect something. Because, we are talking, talking about, electric, ..., carrying wire, you must expect something, knowing the positive and negative terminals, so you must expect something. PROBE FURTHER HERE.

Teacher continue moving around the groups and see something wrong so he correct the group, "Hey, the wire, ... The plotting compass should be on top of the wire, not on the terminal. You must have, ... Someone must hold the wire straight, the plotting compass will on there... (teacher showing the group).

Learners: Busy with the activity.

Teacher: Listen here groups, number one, you must place you plotting compass on top of the insulated wire, on the terminals of the cell. But make sure that your thing settle, neee, it should settle, it should not be moving, (teacher demonstrate with the arm), so that if is moving, you will not see that there is a change, your plotting compass should be quiet.

Teacher (talk to one group): Now you must connect to the terminals and help the group with their activity.

Teacher: The teacher ask one group if they observed something, and that is what I want you to write down what you observe.

Learners: React to their observations.

Teacher walked to another group and asked the same question; did you observe something. ahh…

Teacher: You must write same thing, everybody must not write a different answer, because it is a group work. You must write down what you observe, then you discuss it so that you can come with one point.

Teacher: Did you connect already? (teacher asked 1 group)

Group: Yes, it was the first one.

Teacher: Teacher continue showing (demonstrating) the group how they should handle the resource.

In the background, the teacher is busy moving around the groups to see if their busy with the practical activity.

Researcher pick a group which was very active in discussion and place a voice recorder to capture their discussions.

Teacher: Okay, , Now, you do procedure with letter B. Now connect to two ends of the ends of the wire, I think that is what we did…………, we wrote down that one…..

Teacher Continues reading procedure number two in the practical worksheet for the learners. Now you increase the number of cell and see what will happen again to the….. , with two cells. In the meantime the teacher is approaches a group and tries to guide them in doing the practical correctly.

Teacher: Did you try to increase the number of cells? (asking the groups). Meanwhile the teacher continue to move around the groups. In the background, the teacher asks learners to just write down what they observe from their practical. Number 2 letter B, are you still busy with number 2 letter B, ahhhh……. Learners continue with the activity for the next 3 minutes.

Teacher: Okay, …., should we proceed to number……..

Learners: No sir,, not yet….. (Learners from different groups shout out)

Teacher: You are still at number 2 (teachers asked a group)

Leaners: Yes sir

Teacher: You need to go to number 3…. Learners continue with practical experiment while the teacher and the researcher moves around assisting the groups.

Teacher: Why do you think the plotting compass deflect or move every time the current moves or flow through the insulated wire? (teacher reads a question from the practical worksheet to the learners). Why do you think so?, neee (teacher repeats the question)

Someone interrupt the lesson, but the teacher informs her that the next period is replaced with Physical Science so that the practical activity is completed.

Teacher: Why do you think, …., now is a matter of thinking now, what makes it to deflect,,, to move every time you connect, because you detect that when put in the plot,,,,,, when you in to the battery or to your cells, is when it start moving? Now why do you think it will move? The plotting compass ……. is always moving in response to some, !!!!!!!!..... What is it?

Teacher: Okay, .. you are done with that one, ….., you must discuss your answer neee, to agree upon on one point, just to agree, so, maybe it is moving because of this and this……., or what do you think….

Teacher: Number 4…….. (some learners stop the teacher from continuing, seemingly they are still busy with the previous procedure.)

Teacher: ……..current flows …. electrical current was flowing, okay….

Teacher: Procedure number 5, what do you think should be done in order to increase the strength of the force (teacher reads, a question from the practical worksheet.), which is deflecting the plotting needle? Probably something that you have done already, you have seen how you increased the strength of the …….. Because we need to sum up on that one so that we move to the very interesting part, number 2, electromagnetism.

Teacher concludes the section by providing a summary of the results: As we increase the number of cells, the force around the wire also increases, and that causes……, the one that causes the magnetic, I mean the plotting compass to deflect, so that…. people….I am trying to sum point number 5, nee. Point number 5, it says, why do think, what do you think should be done,….. what do you think should be done to increase the strength of the force? Because, what cause that wire that wire to deflect I mean, what cause the plotting compass to deflect is the force. (here, teacher demonstrate with gestures and his arm), that force is caused by the current flowing in the conductor. Now, that force can be increased by increasing the number of cells, neee. When you increase the number of cells, you also increase the force, which is causing the deflection of the plotting compass. Did you get the point here? (teacher asks the class). The teacher continued to clarify the conclusion.

Part 2

Teacher: Part 2 is very simple as well, this one going to talk about,……, is mentioned there in part 1. Then the teacher reads the objective from the worksheet.

Teacher: Electromagnetism is a way of producing!!!!!, …... (teacher poses for learners to answer) ……., what do you think we are producing now? (teacher turns statement into a question, using gestures to express the question as well). Electro- means- electricity is involved,,,, magnetism- we are producing magnets, using current, that's what we are going to do now. So, because it is electromagnet, so you are now producing magnets by using current. That's what we are going to do now.

Teacher: Now you have a nail, ah, a solenoid, ahhh……., make a coil or winding on a nail (teacher demonstrate with hands how to wind a coil on a nail to make a solenoid to the class). Teacher moves around to see if the groups are doing the right thing.

Teacher: Teacher reads the next procedure to the learners and continue talking…………..If you are done with the 20, place the plotting compass, ….., are you all done with the 20 winding?

Teacher moves around to see if the groups are doing the right thing.

Teacher: As it appears there, nee (teacher pointing to the worksheet), now, there is a space for you to draw, you must draw indicating the direction of the compass where it is pointing, draw it the same way it is there. Those turns, then you indicate. The teacher uses the chalkboard to further clarify what the instruction which learners need to follow.

Teacher: As it is appearing there now you have it, so now, you must draw it there (teacher indicating on the board), then you see how it is appearing. So it will probably point in the same direction or in different direction. So just see how it will point, I am also not sure which direction it will point. At this point, all the groups are busy with the activity while the teacher and the researcher move around assisting the groups.

Teacher: Teacher asks the learners if they are finished with the last procedure before going to the next procedure. Then the teacher reads a question from the worksheet. Teacher and researcher continue moving around from group to group watching whether they are doing the right thing.

Teacher: Okay, lets hurry up because we do not have enough time, you need to hurry up, okay, I think you draw your prediction as what will happen………. At this moment, one learner interrupt and says "No"………. You must draw you prediction, because if you said "Yes" in number 4a, then, you could come up with something in mind, if you said this will deflect when I connect them to the battery, then, what will you predict now, what will you predict, maybe it change, move where, I don't know how from where, then, you tell me. Teacher asks a group if they drew their prediction, At this moment, the teacher and researcher moves around assisting the groups.

Teacher: Okay, should we move to number, I mean letter B. Now connect the solenoid to the battery, you know a battery is more than 1 cell, okay, you must make them three cells. Now you have to observe the changes on that solenoid, why is your solenoid out? In the meantime, both the teacher and researcher are moving around assisting the groups.

10 minutes -16 minutes= Learners are busy in their groups.

Teacher: Now you connected it like this (teacher pointing out to sketches he drew on the board to better explain to the learners), in number 4, letter B, I want to see the direction of this (teacher pointing to the sketches on the board). But that direction should be the same as it appears on your plotting compass. Because some of them might face in different directions, for example, some of them might face down, or face in, or face up, or face in (teacher uses the sketch on the board to illustrate what he means with the directions). At this moment, learners are busy in their groups, while the teacher and researcher move around assisting the groups.

Teacher: Okay, most of you are done with this part, okay, let's go to number 5. Here teacher reads number 5a as it appears on the worksheet. Why is pointing there? Why is pointing in the direction you have drawn? Teacher emphasis the question. You must what you are trying to find out there, because we want to sum up.

Teacher: Okay, number 5b, Okay, (teacher continues and read number 5b as it appear in the worksheet). When you have a permanent magnet, I was demonstrating with a permanent magnet there, what can you say about it? Now, you must check ……………, (teacher demonstrates magnetic directions of a permanent using plotting compasses on an OHP. Okay you are done with number 5b, or you are still arguing on it.

Learners: Yes (One learner answers). At this moment, learners are busy in their groups, while the teacher and researcher move around assisting the groups.

Teacher: Can we move to number 6? Teacher asks the learners but none of them is paying attention because they are busy with the activity. Nonetheless, the teacher continues reading procedure 6 while using the board to illustrate what learners need to do in number 6. Learners busy with the activity.

Teacher: Okay, we have to conclude now. How did you conclude with this one? I have seen one that was pointing like this, the other one that was pointing like this (asking the group to give their results so the teacher indicate it on the sketch on the board. Teacher demonstrate how the plotting compass will appear/point when placed on a solenoid in a closed circuit.

Teacher: The teacher reads number 7 as it appears in the worksheet. A comparison of magnetic fields of a permanent magnet and an electromagnet. The teacher illustrates the direction of magnetic field on the chalkboard.

Teacher: Learners are asked to return all materials back. Meanwhile, learners continued with the activity, they did not want to stop.

APPENDIX 7(b)

Transcript of Teacher 1 (T1), Lesson 2

Introduction

The teacher revises the previous lesson. The teacher begins talking:

By using a plotting compass, we investigated the effect of current which is experienced by the current-carrying wire. And we found out that there is a force which makes these plotting compass (pointing to the sketch drawn on the chalkboard) to change direction. And also, that, we investigated on a solenoid, effect of that.

Then, we also identified force by using a plotting compass. When we connected the current the compasses experienced a force. You also know that this force experienced is like magnetic force of a permanent magnet, and you also increased the strength. I don't know what you used to increase the strength of this one. What did you do? (pointing at the sketch on the chalkboard). What did you do in your previous experiment to increase the strength of the magnetic field?

Learners: Learners randomly answered; increased the number of turns (coiling) and increased the current (voltage). Meanwhile the teacher repeated learners' answers.

Throughout the introduction, the teacher was using sketches to reinforce what was being discussed.

Main Lesson

The teacher continues and uses the introduction to introduce the theme of the main lesson.

Now, we are going to build on this one, to investigate or to experiment about electromagnetic (teacher emphasis). We that material that you have, we don't need to waste time. The teacher then reads the objectives as listed in the worksheet and name out the materials for the activity. The teacher emphasis to learners to follow instructions, write all observations and conclusions. The teacher asks learners to make sure that they have all the necessary materials and start reading the instructions while learners carry out the activity.

At this moment, the teacher begins to move around the classroom checking whether the groups are following the instructions correctly. Throughout the lesson, all the groups were busy with the activity while the teacher was assisting some groups. The teacher appeared to be helping two groups at the centre of the classroom. At time the teacher corrected the group is he saw that they were not the right thing. For instance, one group winded the insulated wire over the nail that one side of the wire was not long enough to connect to the battery.

After every procedure, the teacher asked learners if they finished and discuss answers for any question in the worksheet. Although some learners responded to the teacher's call when asked if they had finished with a procedure, it appeared that most groups did not pay attention to the teacher's questions, rather continued with the activity on their own. PROBE FUTRHER

Throughout the lesson, the teacher remained in the middle of the classroom, moving around from group to group, especially the two groups at the back of the classroom.

IN the end, the teacher quickly rushed through the activity as a way of concluding as there was no more time.

The lesson lasted for about 40 minutes.

APPENDIX 7(c)

Transcript of Teacher 2 (T2), Lesson 1

The teacher and I prepare the resources (OHP, transparent paper, a magnet, 2 plotting compasses and iron filling for demonstration of magnetism.

Introduction

The teacher places a magnet on the OHP and project it on the screen. The teacher then starts the lesson introduction.

If a free suspended magnet is released, it will align itself showing the poles of this magnet. The 2nd thing that we are going to observe is the magnetic field lines around the magnet and this the area where a magnetic force can be experienced using iron fillings. And then thereafter, I will do the reading of the procedures of this activity and you are required to be as fast as you can. Each step should only take at least two minutes to complete. I will read the instructions and yours is to come up with the observations and conclusions.

Then the teacher goes back to revising magnetism. The teacher now places four plotting compasses around a bar magnet projecting the image on the screen. At the same time the teacher asks learners to look at the directions of the plotting compasses and determine the poles of the magnet. Learners seemed to be reluctant to give the answer. Then the teacher reinforced the question by illustrating using drawn compass with arrows indicating the directions of the compasses on the chalkboard. Identify learners could not come to the board, until a boy gave the answer including the reason. The teacher then continued to demonstrate magnetic field using iron fillings which clearly was visible on the screen.

The introduction took about 6 minutes to complete.

Main lesson

Immediately, the teacher goes to the worksheet and start reading the objectives of the lesson as indicated stated on the sheet. The teacher then request learners to make sure that each group has the required materials and procced to read procedure 1.

PROBE: DO YOU THINK ALL THE GROUPS WERE BUSY WITH THE ACTIVITY AT THE BEGINNING OF THE LESSON?

After a while (about 3 minutes), the teacher begins to move around the classroom while helping some groups. At this moment, all the groups were occupied with the activity.

PROBE: WHY DID YOU SEEM TO SPEND MORE TIME WITH THIS PARTICULAR GROUP?

Procedure 2 was then read and learners continued with the activity. At this moment the teacher moved around to the whole class. Throughout the lesson, the teacher continued emphasizing the procedures and providing clues on what to do.

The teacher continue to read the questions under procedure 2 which learners now had to write all observations and some conclusions as to what and why based on the activity.

Then the teacher moves to part b of the lesson by reading the procedures. The teacher continues to re-emphasis the procedures by demonstrating what learners should do.

Some groups seemed not to be knowing exactly what to do. Then the teacher demonstrated on the board by drawing the solenoid.

PROBE: WHY (WATCH FROM 23 MIN) DID YOU CONTINUE TO RE EMPHASING THE PROCEDURES CONTINOUOSLY?)

The teacher then continues to read a question based on the observation of the previous procedure to the learners and ask them to first discuss so that they can write a common answer in their group. Meanwhile the teacher moves and help a group that seems to be slow. The teacher moves to another group and asks their observations, but seemed to help the group to repeat the previous procedure.

The teacher draws a solenoid connected to three cells on the board and asks each group if they concluded with the activity. All the groups responded "Yes", except of 1 group which were still busy.

The teacher asks the class as to why the plotting compasses are showing in the directions as observed, but learners seem not to give the desired response. The teacher then stress further by representing the activity on the chalkboard. After asking learners to give their comparison of the magnetic field in a solenoid and that of the permanent magnet. After a few responses, the teacher reinforced the similarities using the board.

The question about the comparison on the magnetic field of a solenoid and that of a permanent magnet, the teacher asks learners to provide the similarities. Learners give similarities and the teacher reinforces further on the board.

Concluding the lesson

The teacher then concludes by reviewing the similarities as a conclusion of the lessons

APPENDIX 7(d)

Transcript of Teacher 2 (T2), Lesson 2

Introduction

Teacher: The poles of the electromagnet are similar to those of a?

Learners: permanent magnets (the whole class provided the answer)

Teacher: Same apply if you should draw the magnetic field lines, the forces are moving from North-pole into??to

Learners: The South-pole (the whole class provide the answer)

Teacher: The very last thing I said yesterday was, since you know the flow of current in the circuit, this will help you identify the solenoid (electromagnet), hence the positive side of the battery is on the same side with the North-pole of the solenoid (electromagnet).

Throughout the revision, the teacher used a diagram to help explain the concepts learned in the previous lesson.

Main lesson

Teacher: And today's lesson is a continuation of what we did yesterday, looking at the electromagnet, the building of electromagnets and its uses, where we are going to look at the differences between the properties of iron and steel. And thereby in the end we will be able also to make a difference between a temporary and permanent magnet, *hoping that you still have the idea in mind.* PROBE FURTHER WHY IS THE TEACHER SAYING THAT. The above were two objectives of the lesson as indicated in the practical worksheet.

As the teacher explains the lesson's objectives, she is also distributing the lesson worksheets and the resource for the practical activity. The teacher further describes the materials contained in the kit, which materials are required for the practical, demonstrating how learners should wind the solenoid as some groups made winding without leaving a long piece to enable to connect to the battery. So the teacher cleared that so that it is not repeated. The teacher further reminds learners that, she will read the procedures and learners will follow while carrying out the procedures. She warns learners to discuss their answers before they write their answers on the worksheet. WATCH FROM MINUTE 7 AND ASK THE TEACHER WHY SHE WAS DEMONSTRATING THE ACTIVITY AND NOT LETTING LEARNERS DOING THE ACTIVITY.

The teacher then begins reading the procedures of the activity. At the same time, the teacher moves around the groups perhaps to make sure groups are active in the groups.

As the teacher moves around, she continues to probe the groups to see if they are doing as the procedure requires. The teacher assists some groups which she thought may not be carrying the procedures properly.

The lessons end with the answering some questions in part B of the worksheet.

Throughout the lesson, learners seemed to have been occupied with the activity and enjoying the lesson.

The lesson ends with the teacher summarizing the lesson.

Appendix 8(a)

Lesson observation tool: Lesson 1 of T1

The following check list will help me determine how the lesson was implemented using the LTSMs.

What the teacher is doing	Seen/Not seen (√)	Comments
Did the materials and activities keep the learners interested?	√	Lnrs were busy throughout the lesson.
The science content (electromagnetism) was appropriate for the developmental needs of the learners in this grade		
The degree of 'sense-making' of science content (electromagnetism) within this lesson was appropriate for the developmental levels/needs of the learners and the purposes of the lesson	√	Teacher achieved the lesson's objectives
The teacher interactions reflected collaborative working relationships between teacher and learners	√	Teacher kept constant conversation
• The climate of the lesson encouraged learners to generate ideas and questions, (e.g. Learners find the work interesting, challenging and related to learning. • Learners' exhibit interest, enthusiasm and can use positive humor. • Learners exhibit body postures that indicate they are paying attention to the teacher and/or other students. • What could be done if the materials and activities planned did not work?	√ √ √	
What problems, if any, did the teacher encountered during the lesson?	√	Some cells of one group did not work
Is there any signs that the learners appear to have experienced learning?		They were asking questions

Source: Adopted from http://www.edb.org.hk/HKTC/download/eras/11-12/ERAS1112_R02.pdf

Appendix 8(b)

Lesson observation tool: Lesson 2 of T1

The following check list will help me determine how the lesson was implemented using the LTSMs.

What the teacher is doing	**Seen/Not seen (√)**	**Comments**
Did the materials and activities keep the learners interested?	√	Lnrs were busy
The science content (electromagnetism) was appropriate for the developmental needs of the learners in this grade	√	
The degree of 'sense-making' of science content (electromagnetism) within this lesson was appropriate for the developmental levels/needs of the learners and the purposes of the lesson	√	
The teacher interactions reflected collaborative working relationships between teacher and learners	√	
• The climate of the lesson encouraged learners to generate ideas and questions, (e.g. Learners find the work interesting, challenging and related to learning. • Learners' exhibit interest, enthusiasm and can use positive humor. • Learners exhibit body postures that indicate they are paying attention to the teacher and/or other students. • What could be done if the materials and activities planned did not work?	√ √ √	
What problems, if any, did the teacher encountered during the lesson?	√	None
Is there any signs that the learners appear to have experienced learning?	√	Lnrs busy throughout the lesson

Source: Adopted from http://www.edb.org.hk/HKTC/download/eras/11-12/ERAS1112_R02.pdf

Appendix 8(c)

Lesson observation tool: Lesson 1 of T2

The following check list will help me determine how the lesson was implemented using the LTSMs.

What the teacher is doing	**Seen/Not seen (√)**	**Comments**
Did the materials and activities keep the learners interested?	✓	Lnrs busy during the activities
The science content (electromagnetism) was appropriate for the developmental needs of the learners in this grade	✓	
The degree of 'sense-making' of science content (electromagnetism) within this lesson was appropriate for the developmental levels/needs of the learners and the purposes of the lesson	✓	
The teacher interactions reflected collaborative working relationships between teacher and learners	✓	Constant communi-cation btn T and lnrs.
• The climate of the lesson encouraged learners to generate ideas and questions, (e.g. Learners find the work interesting, challenging and related to learning. • Learners' exhibit interest, enthusiasm and can use positive humor. • Learners exhibit body postures that indicate they are paying attention to the teacher and/or other students. • What could be done if the materials and activities planned did not work?	✓ ✓ ✓ ✓	
What problems, if any, did the teacher encountered during the lesson?	✓	Some groups (1 group) was slowly
Is there any signs that the learners appear to have experienced learning?	✓	Lnrs were very busy with the activity

Source: Adopted from http://www.edb.org.hk/HKTC/download/eras/11-12/ERAS1112_R02.pdf

Appendix 8(d)

Lesson observation tool: Lesson 2 of T2

The following check list will help me determine how the lesson was implemented using the LTSMs.

What the teacher is doing	Seen/Not seen (√)	Comments
Did the materials and activities keep the learners interested?	√	Lns were busy throughout the lesson.
The science content (electromagnetism) was appropriate for the developmental needs of the learners in this grade	√	
The degree of 'sense-making' of science content (electromagnetism) within this lesson was appropriate for the developmental levels/needs of the learners and the purposes of the lesson	√	
The teacher interactions reflected collaborative working relationships between teacher and learners	√	Constant communication with lnrs
• The climate of the lesson encouraged learners to generate ideas and questions, (e.g. Learners find the work interesting, challenging and related to learning. • Learners' exhibit interest, enthusiasm and can use positive humor. • Learners exhibit body postures that indicate they are paying attention to the teacher and/or other students. • What could be done if the materials and activities planned did not work?	√ √ √ √	
What problems, if any, did the teacher encountered during the lesson?	√	None
Is there any signs that the learners appear to have experienced learning?	√	

Source: Adopted from http://www.edb.org.hk/HKTC/download/eras/11-12/ERAS1112_R02.pdf

APPENDIX 9(a)

STIMULATED-RECALL INTERVIEW WITH T1S1

Researcher: What is your overall impression of the lesson?

T1S1: The lessons were fruitful, I enjoyed them and I am confident that my learners also enjoyed the lessons. This really gave my learners an opportunity to engage in practical activities as I have always only demonstrated activities due to lack of resources to enable all the learners to participate. Our Ministry of Education also do not provide us with any science equipment. Look, I have been teaching in this school for past 7 years but I have not received any resources despite them asking a list of things we need every beginning of the year.

Researcher: Do you think this resource enabled you to make sense of the concepts of electromagnet to your learners? May you elaborate, please?

T1S1: Yes, you see in the video how my learners were busy throughout the lessons. This a sign that they were learning something. I tell you, these learners were not going to be so busy if the practical activities were not making sense to them. I know my learners very well. If the activity is not interesting, they will just make a lot of noise with being busy with the activity at hand.

Researcher: What evidence makes you say that?

T1S1: Just look at how my learners were busy, them being busy like that is an evidence that they were enjoying the lessons. So based on this, I am convinced that learning took place in these lessons.

Researcher: I noticed that you were paying more attention on the (2) groups at the back of the classroom, why was it so?

T1S1: Yes, this group consisted of slow learners. I do not know why most of them decided to sit in one group. But I had to guide them more than the others since I consider them slow otherwise they were going to delay the lessons. You saw yourself that this same group was always last to finish their task.

Researcher: Let's watch the video from here (10 minutes into the lesson), why were the learners seemed to ignore you as you were talking to them? Learners' were just busy with the activity.

T1S1: This is because learners were enjoying the lesson, they don't get to participate in activities themselves. Maybe, they thought, it's the opportunity now, so they decided to keep themselves busy with the practical activity. And maybe they understood the instructions so they did not need me to elaborate further on the procedure, especially this group, this side.

Researcher: I also noticed that, throughout the lessons, you continued to emphasise on the procedures (worksheet instructions). Why did you do so?

T1S1: Yes, I had to do that because my learners are not used to read instruction and carry such instructions themselves, they will just not be able to carry the instructions without the teacher ready and sometime explain the instruction.

Researcher: Maybe you just under-estimate your learners' abilities?

T1S1: I don't think so, maybe some learners can read and carry out the instructions by themselves. But most of them, can't.

Researcher: Is there anything that can be done to the resource in order to improve it?

T1S1: I just want to say that this kind of resource is good for teaching, for teachers and for the learners. Both teachers and learners are familiar with the resource, so it is easy to use and learner from it. We just need to develop more resource in other topics also. I think, there is a need for Physical Science teachers in the region to come together and further develop similar resources in other topics to reduce dependence on the Ministry of Education, arts and Culture. We need to be proactive as teachers.

Researcher: Thanks so much for agreeing to take part in my research and your time too.

T1S1: You are welcome and thank you too.

APPENDIX 9(b)

STIMULATED-RECALL INTERVIEW WITH T2S2

Researcher: What is your overall impression of the lesson?

T2S2: My views of the two lessons is that this resources helped me deliver the objectives of the lessons effectively. I don't remember when I last conducted a demonstration to my learners. This lessons helped me do just that. Thank you for choosing me to be part of your research.

Researcher: Do you think this resource enabled you to make sense of the concepts of electromagnet to your learners?

T2S2: Very much, my learners enjoyed the lessons very much. Remember, when I told that learners from other classes that did not take part in the lessons were demanding that they also should be exposed to the same lessons. This was an indication that the resource was effective in delivering its intended outcomes.

Researcher: What evidence makes you say that?

T2S2: Just look at what I said earlier, learners were demanding to be part of these lessons. Some of the learners in this class came back later thanking me for selecting their class to be part of your research.

Researcher: Do you think while all the groups seemed to be busy, they were actually busy with the practical activities? Maybe they were just doing other things other than the activity.

T1S1: They were busy with the practical activity, I was watching them. That's why I was moving around from group to group, in order to make sure they were busy with the real work of the lesson.

Researcher: I noticed that you were paying more attention on the one group in front of the classroom, next to the entrance, why was it so?

T2S2: Yes, because this group was made of weak learners, therefore I felt that I needed to help them more. Also, we were not going to finish the lessons on time as this group was going to delay the lessons.

Researcher: Are you not under-estimating your learners' abilities?

T2S2: Not at all, I know my learners well. They are like that, sometimes some of them are not serious, and only few who very serious with their studies.

Researcher: I also noticed that, throughout the lessons, you continued to emphasise on the procedures (worksheet instructions). Why did you do so?

T2S2: That's the only way I can make my learners understand the procedures. These learners are not used to carry out activities on their own because teachers, not only me, only teach theoretical lessons. These learners are abit lazy too, you need to do most of the things for them.

Researcher: At grade 10 level also

T2S2: Yeess… this kids are not serious with their studies.

Researcher: Is there anything that can be done to the resource in order to improve it?

T2S2: What I can say last is that, I would like to thank you again for inviting me to take part in your research because this opened my eyes as to kind of things I can use in order to make teaching easy. I did not think that such things can have this impact if used properly. Regarding the resource, I think, one need to test them well before you used it in the lessons so that you are sure it is going to work out the way you expect.

Researcher: Thanks so much for agreeing to take part in my research and your time too.

T1S1: A big thanks from too.