The impact of computer simulations on the teaching and learning of electromagnetism in grade 11: a case study of a school in the Mpumalanga Province

By

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DECLARATION

I declare that

THE IMPACT OF COMPUTER SIMULATIONS ON THE TEACHING AND LEARNING OF ELECTROMAGNETISM IN GRADE 11: A CASE STUDY OF A SCHOOL IN THE MPUMALANGA PROVINCE

is my own work and that all sources that I have used and quoted have been indicated and acknowledged by means of complete references.

__________________________ __________________

SIGNATURE DATE

(Mr. J.K. Kotoka)

ABSTRACT

The study investigated the impact of computer simulations on the teaching and learning of electromagnetism in grade 11. Electromagnetism is a section of the Physical Science curriculum. Two grade 11 classes in the Mgwenya circuit in Mpumalanga province of South Africa were used as a case study. Using a pre-test, post-test non-equivalent control group design, it was found that learners in the experimental group (n = 30) who were taught using the simulations achieved significantly higher scores on the post-test than learners in the control group (n = 35) who were taught using traditional teacher-centred teaching method; (t statistic = 3.582, df = 56, $p<0.05$). Learners were more active during the lessons, predicting, observing, discussing and explaining concepts. The use of simulations also provided support (scaffolding) that the learners need to enhance learning. The Hake's normalized gain for the experimental group $\langle g \rangle = 0.32$ compared to $\langle g \rangle = 0.18$ for the control group confirmed conceptual improvement. Both teachers and learners indicated that they accept the use of computer simulations in teaching and learning of electromagnetism.

KEY WORDS

Computer Simulations, Electromagnetism: magnetic field lines, the right hand grip rule, Flemings left and right hand rules, motors and generators, Grade 11 Physics, Constructivist Theory.

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DEDICATION

This study is dedicated to my dear wife: Mrs. Love Kotoka and our two lovely children, Gladys Yayra Kotoka and Christian Delali Kotoka.

ACRONYMS

ASS	Assessment Standards
CAI	Computer Assisted Instruction
CAPS	Curriculum and Assessment Policy Statement
CBI	Computer-Based Instruction
CD – ROM	Compact Disc - Read-only Memory
DCGEP	Discovery Channel Global Education Partnership
DoE	Department of Education
DOS	Disk Operating System
DVD	Digital Versatile Disc
FET	Further Education and Training
IA	Index of Agreement
IBM	International Business Machine
ICT	Information and Communication Technology
ICTs	Information and Communication Technologies
LO	Learning Outcome
MBL	Microcomputer-Based Lab
NCET	National Council for Educational Technology
NCS	National Curriculum Statement
NEIMS	National Education Infrastructure Management System
PC	Personal Computers
PhET	Physics Education Technology
TV	Television
ZPD	Zone of Proximal Development

DEFINITION OF TERMINOLOGY

The following terminology has been used in this study and is presented alphabetically:

Computer Simulation: The computer-generated virtual reality of a three-dimensional image or environment that can be interacted within a seemingly real or physical way by using special electronic equipment.

Computer: Electronic machine, operated under the control of instructions stored in its own memory that can accept data (input), manipulate data according to specified rules (process), produce results (output) and store the results for future use.

Curriculum Implementer/ subject facilitator: Refers to the South African Department of Education official who supervises in our case the Physical Science programme of study and helps the teachers to understand their common objectives and assists them to plan to achieve the objectives.

Curriculum: A combination of the learning outcomes, pedagogy, and content that students are to address.

Dinaledi Schools: Schools identified by the South African Department of Education countrywide to excel in Mathematics and Science. These schools are supported by the department and the private sector to increase the number of learners passing high-level Mathematics and Science in Grade 12 and to encourage successful matriculants to pursue further studies in technical disciplines like engineering in tertiary institutions.

Experience: Is defined in terms of a teachers' number of years of teaching. That is the number of years the teacher has taught Physical Science in a secondary school.

ICT (Information & Communications Technology): Refers generally to computer technologies which include other technologies used for the collection, storage, manipulation and communication of information.

Physical Science: In the South African system the subject Physical Science is concerned with the study of Physics and Chemistry.

Secondary School: In the South African system, a Secondary School or High School is the school in-between primary school and University. It starts from Grade 8 and ends in Grade 12.

Software: The sets of instructions and data used by computers, sometimes referred to as computer programmes.

Teacher education: This is the formal training and instruction teachers received as students in tertiary institutions through which they acquired knowledge and developed skills. It refers to the preparation phase of the teachers.

Teachers' background: In this study it refers to teachers' qualifications in terms of academic, professional and teaching experience.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Today, more than ever before, employers require workers with higher problem solving skills. This is because the world is changing rapidly and technology is advancing apace. The skills that education provides must therefore keep abreast of these changes and equip the individual with the problem solving skills to enable them to fit into today's global economy.

Physics is a Science that could provide its learners with the problem solving skills that today's employers require. Physics is often considered the most fundamental of all the natural Sciences and its theories attempt to describe the behaviour of the building blocks of matter, light, the universe and everything in the universe (Jirage, 2011). The importance of Physics in society today is underlined by our reliance on technology. Several of the technologies that are transforming the world can be traced directly to vital Physics research. For example, research on the Physics of semiconductors enabled the first transistor to be developed. This device is the main component of all electronic systems, including computers, and it is considered one of the most important inventions in human history (Woodford, 2011). An understanding of Physics can equip learners with excellent analytical, quantitative and problem solving skills, valuable in a range of careers (Ouellette, 1999). It is not surprising, then, that today an increasing number of employers have realised this fact and are hiring Physics graduates (Modini, n.d). Current trends in the job market thus demand that every effort be made to improve the teaching and learning of Physics in order to encourage learners to develop interest in the subject and subsequently increase the number of learners doing Physics.

However, reports reveal that the number of learners in South Africa who are studying Physical Science, which comprises Physics and Chemistry, are few compared to other subjects (DoE 2009b, 2010b). Furthermore, only a small percentage achieves passes at the matriculation examination (DoE, 2004) cited in (Kriek & Grayson, 2009). The reports on the national senior certificate examination results (DoE 2009b, 2010b, & 2011a) indicate that only 53.4%, 47.8%, 38.9% and 54.9% of learners achieved 30% and above in the 2011, 2010, 2009 and 2008 final grade 12 National Certificate Examinations respectively. Table 1.1 below provides details of these results.

Table 1.1: Candidates' performance in Physical Science: 2011, 2010, 2009 and 2008

Year	Total number of learners	Total achieving 30% and above	% achieving 30% and above
2011	180585	96441	53.4
2010	205364	98260	47.8
2009	220882	82356	38.9
2008	218156	119823	54.9

Table 1.1 reveals that Physical Science learners are not performing well in the final matriculation examinations. This is a cause for concern and research is required to find reasons for this poor performance. One of the reasons could be the non-availability of teaching and learning resources such as laboratories and laboratory equipment. Statistics from the National Education Infrastructure Management System (NEIMS), in Table 1.2 below, show that the percentage of ordinary schools[1] in South Africa without laboratories ranges from 60% to 94%. Limpopo Province is worst off with 94% of ordinary schools without laboratories, while Gauteng Province is best equipped although 60% of its ordinary schools are lacking laboratories. In Mpumalanga, where the study was conducted, a staggering 89% of ordinary schools do not have laboratories. There are 1,868 schools in Mpumalanga, but only 213 of these have laboratories. Out of these 213 schools, only 53 have laboratories which are stocked with Physical Science laboratory equipment. This means that 1,655 schools in the Mpumalanga Province are without laboratories, as indicated in the table below.

1 Ordinary school is a school that is not for learners with disabilities.

Table 1.2: Department of Education laboratories summary grid for ordinary schools

Province	Number of schools	With laboratory	% With laboratory	Laboratory Stocked	% Stocked	Without laboratory	% Without laboratory
Eastern Cape	5,676	493	9	110	2	5,183	91
Free State	1,615	337	21	103	6	1,278	79
Gauteng	2,031	813	40	287	14	1,218	60
KwaZulu-Natal	5,931	719	12	221	4	5,212	88
Limpopo	3,923	235	6	59	2	3,688	94
Mpumalanga	1,868	213	11	53	3	1,655	89
North West	1,674	269	16	72	4	1,405	84
Northern Cape	611	180	29	67	11	4,31	71
Western Cape	1,464	513	35	259	18	9,51	65
TOTAL	24,793	3,772	15	1,231	5	21,021	85

Source: National Education Infrastructure Management System (NEIMS), May, 2011

The lack of Physical Science laboratories and equipment is likely to impede learning and discourage interest in Physical Science. However, an alternative in the form of computer simulations could be considered especially in situations where the real laboratory equipment is lacking because researches have shown that computer simulations have increased learner achievements. Cigrik, and Ergul (2009) and Ogbonaya (2010) reported increased learner achievements in their studies when computer simulations were used. Computer simulations can help learners visualise abstract concepts in Science (Rutten, van Joolingen & van der Veen, 2012). This limited study seeks, therefore, to determine if computer simulations could be used to assist in the teaching and learning of Physics concept electromagnetism in a high school in Mpumalanga.

1.2 CONTEXT OF THE STUDY

The Republic of South Africa (RSA) has a land size of about 1 219 090 square kilometres. It shares boarders with Namibia, Botswana, Zimbabwe, Mozambique, Swaziland and Lesotho. It has a population of about 50 586 757. The republic is divided into nine provinces. Gauteng Province, the capital province, is the smallest by land size but the most densely populated with about 22.39% of the total population of the country resident in Gauteng. Mpumalanga, where this study took place, although larger than Gauteng in land size, has only 7.23% of the country's population (Statistics South Africa, 2011).

For the purposes of educational administration, the provinces are further divided into regions, the regions into districts and the districts into clusters. There are four regions in the Mpumalanga Province; this study took place in the Mgwenya districts of the Ehlanzeni Region. The Ehlanzeni region is divided into 14 educational districts, of which Mgwenya district is one (DoE, 2010b). The other regions are Nkangala, Bushbuck Ridge and Gert Sebande.

Education in RSA is facing challenges similar to those experienced in most developing countries around the world. These challenges include inadequate school buildings which lead to overcrowding in classes and inadequate teaching and learning equipment (Onwu, 1999 and Kihumba, 2009). There is also shortage of teachers, especially in Mathematics and Science (Kopolo, 2009). Mpumalanga as a province in RSA is also facing these challenges and even more because of it rural nature. As a result of these challenges, Mpumalanga lagged behind the other provinces in the 2009 and 2010 National Certificate Examinations (DoE, 2010b). The Ehlanzeni Region is the capital region of the province and therefore the conditions in some of the schools are better than in many schools in other regions which are more remote from the capital. The Mgwenya district is close to the capital city, Nelspruit, so the clusters in the district are more likely to get the necessary materials and support from Department of Education officials. For this reason most of the schools in the region are functional.

1.3 RATIONALE FOR THE STUDY

From my experience as a teacher and an examiner (marker) of Physics in the grade 12 final examinations over the past five years, it has become apparent that learners of Science are not able to satisfactorily answer sections in the Physics question paper dealing with electromagnetism. This problem was mentioned in the chief examiner's report on the 2010 National Curriculum Statement (NCS) examinations: "electromagnetism is very poorly understood by most learners because teachers are also not very confident in teaching this section and the subject facilitators must provide teacher development workshops on these sections" (DoE, 2010a: p. 299). The concepts of electricity and magnetism are highly weighted in both National Curriculum Statement (NCS) and Curriculum and Assessment Policy Statement (CAPS). Electricity and magnetism is to be assessed at ± 37% weighting in the grade 12 matriculation examinations (DoE, 2009).

In addition, as a teacher, I have observed that learners find it difficult to visualise many of the concepts in electromagnetism. Concepts such as magnetic field lines, magnetic field lines moving from north to south, the right hand grip rule, Flemings left and right hand rules, the principles of operations of motors and generators, are all difficult to demonstrate, particularly in an environment where there are no laboratories or laboratory equipment. The teaching of these concepts is difficult, for teachers and learners find the concepts difficult to grasp because they are considered to be abstract. Therefore to visualise the concepts in electromagnetism, computer simulations were used.

1.4 AIM OF THE STUDY

The aim of this study was to determine the impact of computer simulations on the teaching and learning of electromagnetism in grade 11 Physics in one school in the Mpumalanga Province.

1.5 RESEARCH PROBLEM AND RESEARCH QUESTIONS

A growing body of research suggests that computer simulations can have a positive impact on Science teaching and learning (Binns, Bell, & Smetana, 2010). For instance, Bozkurt and Ilik (2010), Chang, Chen, Lin and Sung (2008), Farrokhnia and Esmailpour (2010), Trundle and Bell (2010), Basson (2010), Cigrik, and Ergul (2009) and Ogbonaya (2010) reported more learner-centred, teacher-learner interactions during technology-enhanced instruction and increased learner achievements in their studies. Considering the problems of most schools in Mpumalanga not having laboratories, low learner pass rate in Science, and the emphasis placed on electricity and magnetism in the curriculum, this research sought to answer the following questions:

1. Does the use of computer simulations have an impact on the performance of grade 11 learners in electromagnetism?
2. To what extent does the use of computer simulations influence the learning of electromagnetism in grade 11?
3. To what extent does the use of computer simulations influence the teaching of electromagnetism in grade 11?

1.6 RESEARCH HYPOTHESIS

H_0 = the use of computer simulation has no impact on the performance of grade 11 learners in electromagnetism.

1.7 SIGNIFICANCE OF THE STUDY

Science teachers all over the world are looking for ways to motivate their learners and make Science more accessible. A variety of ways of achieving this have been suggested in literature but unless they are tried out in a South African context, teachers may not be able to decide which of these ways will work. The use of computer simulation is one of the approaches that have been recommended to be used by teachers to promote learners' conceptual understanding ("National Research Council", 2011). This study sought to verify this assertion. Although this is a limited study with two classes in one school and findings cannot be generalized, new insight can be presented with regards to teaching and learning of electromagnetism as a subject. The study will contribute to Physics education literature and will also open up new possibilities for improving Physics teaching, especially where there are inadequate well equipped Science laboratories which could bring about an improvement in learners' achievements. Furthermore, the research will provide information that can be used to make recommendations to school administrators and Physics curriculum developers in South Africa on the formulation of policies to enhance Physics teaching by using computer simulations.

1.8 LIMITATIONS OF THE STUDY

Research involving schools can come with some challenges. For instance, the participating school in this research insisted that learners participating in the research be kept in their original classes intact. This does not permit the researcher to select individual participants to form the control and experimental groups randomly. Even though steps were taken to verify that the two classes were comparable in terms of academic ability before the research commenced, this is a limitation.

Although members of the two groups mixed freely during break times and after classes, it was assumed that the level of contamination would be minimal because their varied classroom experiences could not easily be invoked without sitting together in front of a computer to discuss what was being observed.

There were only two schools in the Mgwenya circuit with ICT facilities. One of these schools did not permit the research because they had already taught electromagnetism to their learners. This situation left the researcher with only one school to use for the study and therefore the results of the study cannot be generalized because the sample may not be representative.

The suitability of the simulation software to the South African curriculum is another limiting factor in this research. The simulations used were not designed specifically for the South African curriculum, therefore there was not one software that could be used alone to teach all the concepts in electromagnetism. So, it became necessary to use simulation software from two sources in the teaching of electromagnetism in this study. Simulation software from the Physics Education Technology (PhET) project based at the University of Colorado at Boulder, Colorado, USA, (See section 2.9.1) and simulations from the Plato Learning Centre based in the UK (See section 2.9.2) were used. However, much time was spent by the researcher to train the teacher (Mr. E) to be able to select appropriate software from the two sources for the various concepts in electromagnetism.

1.9 ORGANISATION OF THE STUDY

Chapter one

In this chapter, the background, context, rationale, problem statement, research questions and the hypothesis of the study are presented. The significance of the study is also discussed.

Chapter Two

A literature review that is related to this study is presented and also a discussion of the theoretical framework guiding the study.

Chapter Three

This chapter focuses on the research methodology, research design, pilot study, selection of participants, discussion of the instruments for data collection, and ethical issues considered in the study.

Chapter Four

This chapter presents data and report on the findings from the data analysis. The findings are used to answer the three research questions that guide the study.

Chapter Five

In this final chapter, the findings of the study are summarised, and the limitations of the study as well as recommendations and implications of the study are presented.

1.9 SUMMARY

The study`s orientation was established in this chapter. The background, the rationale, aim of the study and the research questions and hypothesis were presented. In addition, the significance as well as the limitations of the study were discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In order to place the study in perspective, a literature survey was conducted to present current issues on the teaching and learning in general and in grade 11 Electromagnetism specifically. The use of technology is also discussed to unleash the capabilities of technology to create learning systems that differ from traditionally directed instruction, as reported by Jonassen and Reeves (1996). Collins (1991: p. 28) also remarks that "in a society where most work is becoming computer-based, 'school work' cannot resist the change" This limited study was carried out with the purpose of filling a gap to investigate the impact of computer simulations on the teaching and learning of the topic electromagnetism in the grade 11 Physics curriculum of the National Curriculum Statement (NCS). The constructivist learning theory has been adopted as the basis for teaching in this study.

2.2 THE PROCESS OF TEACHING AND LEARNING

The accomplishment of the objectives of education depends on the teaching and learning process. This process is the most influential tool of education to bring about desired transformations in the learners. To attain the objectives of education the process of teaching and learning, the teacher, the learner, the curriculum and other variables are organised in a systematic way by education departments and school administrators (Harrison, Blakemore, & Buck, 2001).

2.2.1 TEACHING

According to (Dijkstra, Van Hout Worlter & Van der Sijde, 1990) teaching is a complex cognitive skill which requires problem solving in a relatively ill-structured, dynamic environment. Teaching has at least two consecutive stages as every other cognitive skill: planning and execution (Anderson, Greens, Kilne & Neves, 1991). In the first stage a plan is made to solve the problem and in the second stage the plan is translated into action to actually solve the problem. Dijstra et al (1990) assumed that there are knowledge systems involved in teaching. These knowledge systems are lesson organisation knowledge (the skill to plan a lesson), instruction knowledge (the skills to explain the material clearly, to pass questions, to give feedback), and classroom management knowledge (the skill to run a lesson smoothly). Knapp & Glenn (1996) compared the old way of teaching (teache-centred teaching) and the new (learner-centred teaching). Teacher-centred teaching involved introducing information and skills, providing exercises to practice skills and memorize skills information and then checking learners' ability to remember these lessons. However, learner-centred teaching now engages learners in activities that require them to think critically, solve problems, and seek answers to their own questions. Teachers serve as model learners, mentors, coaches and resource persons. Teaching therefore can be seen as the persistent direction and management of the learning process. It is also the process of offering opportunities for learners to produce relatively permanent change through the engagement in experiences offered by the teacher (Sharma, 2008).

2.2.2 LEARNING

Learning is looked at today as how learners construct their individual understanding from personal experiences (Niess, Lee, & Kajder, 2007). When educators think about learning, they should think about how learners organise and connect their personal experience and understanding, their knowledge that connects huge amounts of information for recall, application and expansion of their understanding (Niess, Lee, & Kajder, 2007). Educational Psychologists indicate that learning happens "when experience cause a relatively permanent change in an individual's knowledge or behavior" (Woolfolk – Hoy, 2004: p.178). From the definition, knowledge is acquired when a learner is said to have learnt. The knowledge will be exhibited through a change in the learners' capability and when these are transferred to new situations (Sharma, 2008). Therefore, when there is a relatively permanent change in a learner's behavior or capability as a result of experience or practice, then learning can be said to have taken place.

2.2.3 TEACHER – CENTRED TEACHING APPROACH

Teacher-centred teaching places emphasis on the teacher providing information to the learners. Many teachers learned to teach at a time when teachers were expected to decide what should be learned, how it should be learned, and when it should be learned (Wood, 2008). In this paradigm, the lecture method was and is the main teaching method. In this method, the teachers are defining key concepts, giving examples, explaining relationships, and demonstrating skills. Though some discussion may take place, the focus is predominantly on the teacher asking questions and learners answering the questions. Learners were or are expected to be passive and reactive as instructed by the teacher (Wood, 2008). Research consistently finds that, teacher-centred teaching, and rote memorization of abstract material are less effective in terms of promoting learners learning. Effective teaching requires that learners take part actively, and be allowed to exercise and relate their lessons to their own experience (Tatto, 1999). Even though this is the view current researchers are focusing on, Allen, (2004) mentioned the following advantages and disadvantages of the teacher-centred teaching approach.

Advantages: teacher-centred teaching approach:

- Teachers cover topics faster because learners are mostly passive and just listening to the teacher.
- The focus of all learners is on one person, the teacher and this makes the class quiet.
- Teaching is done by the teacher and those who can learn will learn.

Disadvantages of teacher-centred teaching approach:

- Learners could not master the objectives of the topics.
- Core learning objectives such as communication and information literacy skills could not be learnt by learners because they are mostly quiet and only listening.
- The learners are not engaged all the time in their learning.
- Learners are not active in the learning process.
- Learners do not learn through collaboration with each other, and
- Learners do not learn through cooperation with each other.

2.2.4 LEARNER – CENTRED TEACHING APPROACH

A learner-centred teaching approach proposes that the focus should be shifted from teachers teaching to learners learning where the teacher will be a facilitator in the process (Huba & Freed, 2000). According to Lukinbeal, Kennedy, Jones, Finn, Woodward, Nelson, Grant, Antonopolis, Palos, & Atkinson-Palombo, (2007) teachers should not be placed as the active agent and learners as passive vessels, but rather the classroom should be a place of dialogue and a place where new knowledge is shaped through collaboration. Boyd, (2012) and Kahl & Venette, (2010) also reinforce this belief by saying; the goal of learner-centred education is to shift the focus from teachers to learners where learners would be taking the lead in the discussions in the teaching and learning process. Some more positives of the learner-centred teaching was mentioned by Huba and Freed (2000) as follows. In learner-centred teaching:

- Learners construct knowledge through collecting and simplifying information and integrating it with the general skills of inquiry, communication, critical thinking, and problem solving.
- Learners are actively involved.
- Emphasis is on using and communicating knowledge efficiently to address evolving issues and problems in real-life situations.
- The teacher’s role is to coach and facilitate the learning process and teacher and learners evaluate learning together.
- Assessment is used to promote and diagnose learning.
- Emphasis is on coming up with better questions and learning from errors.
- Desired learning is measured directly through papers, projects, presentations, portfolios, and the like.
- The ethos is cooperative, collaborative, and supportive.
- The teacher and learners learn together.

These advantages makes it easier for the learner-centred teaching to make use of computer simulations, games, field study, peer teaching, group projects, stimulating visual aids, and problem-based learning (Kahl & Venette ,2010). To further support the above positives, (Randler, & Hulde, 2007) reported that they found a higher retention rate in the learner-centred, hands-on group in their study on the topic: “Hands-on versus teacher-centred experiments in soil ecology”. They also reported in the same study that the hands-on and learner-centred approaches were rated as more exciting, reflecting the interest of learners in doing experiments on their own. Even though learner-centred teaching is said have these advantages, according to (Alsardary & Blumberg, 2009), learner-centred teaching is time consuming and not suitable for large classes.

2.3 ROLE OF EXPERIMENTS IN PHYSICS

Physics teachers try to provide a picture of Physics theories to their learners through experiments (Koponen & Mäntylä, 2006). Mhlongo (2010) defines experiments as a set of instructions that learners follow to verify a certain concept or law. In order to accomplish this, learners have to set up the laboratory apparatus, follow a procedure to collect data, apply theory, record the results, draw conclusions and then write an experimental report. The role experiments play in Physics education is so central that hardly any textbook fails to mention that Physics is an experimental Science (Koponen & Mäntylä, 2006). Practically testing the theories in experiments is central to acquiring Physics knowledge and understanding it.

According to Etkina, Van Heuvelen, Brookes and Mills (2002: p. 352), experiments benefit learners in three ways. Experiments allow learners to:

- Observe a phenomenon to collect data, find patterns in the observations and devise an explanation.
- Test the explanations that they have devised for their initial observations.
- Apply the concept that they have devised and tested to explain other phenomena or to invent a device.

The South African Department of Education realises these benefits of experiments; hence in formulating the National Curriculum Statement (NCS) for Physical Science grade 10 – 12, Physical Science is described as a subject that focuses on investigating physical and chemical phenomena through scientific enquiry (DoE, 2003). In order to achieve this, the policy document aims to prepare learners for future learning and employment by developing competencies in three focus areas. These areas are:

- *scientific inquiry and problem solving in a variety of scientific, technological, socio-economic and environmental contexts;*
- *the construction and application of scientific and technological knowledge; and*
- *the nature of Science and its relationship to technology, society and the environment* (DoE, 2003, p. 10)

These focus areas were later transformed and referred to as learning outcomes (LOs) to be achieved through Assessment Standards (ASS). The first learning outcome (LO 1), practical scientific inquiry and problem solving skills, has four assessment standards. These require that learners should be able to:

1. Plan and conduct practical investigations
2. Interpret data to draw conclusions
3. Solve problems
4. Communicate and present information and scientific arguments (DoE, 2003).

These four assessments standards are benefits or competencies that the learner derives from conducting a practical experiment and they prepare the learner for future learning or employment. This further strengthens the argument that experiments are very important in Science and Physics education. It is evident from table 1.2 that few schools in the country have laboratories. Hence, the benefits of experiments mentioned above are definitely compromised as it is certainly needed in the teaching and learning of Physics. This is because Physics is said to be an experimental subject. The topic of electromagnetism under focus in this study requires many experiments that, if performed, will help learners to derive the benefits mentioned above.

2.3.1 PRACTICAL INVESTIGATIONS AND EXPERIMENTS IN PHYSICAL SCIENCE

Practical investigations and experiments form an important part of the formal assessment programme in the NCS. The new curriculum to be implemented in 2012; the Curriculum and Assessment Policy Statement (CAPS), also includes experiments as part of its formal assessment programme (DoE, 2011). According to NCS document (DoE, 2006) for Physical Sciences Grades 10 - 12, Learning Outcome 1 (LO1) is on developing practical scientific inquiry and problem solving skills. This outcome is meant to be assessed at a 35-45% weighting in the Grade 12 end of year final matriculation examinations. For this to be achieved, Grades 10 - 12 Physical Science learners must have completed the following tasks as part of their formal assessment (DoE, 2008):

- Practical investigations and experiments (one in Physics in one school term and one in Chemistry in another school term).
- One research project, either in Physics or Chemistry (this task could involve the collection of data or information to solve a problem, also in one school term).

It is evident, therefore, that practical investigations and experiments are crucial in Physical Science, as reflected in the high weighting of 35 - 45% in the national examination.

2.3.2 PROCEDURE FOR PRACTICAL INVESTIGATION AND EXPERIMENTS IN THE NCS

According to the National Senior Certificate Handbook (DoE, 2009a), the Further Education and Training (FET) band, focuses on teaching and assessing an investigative approach. The motivation for teaching and assessing this type of approach is that it has the potential to reflect what life is about (DoE, 2009a). An investigative approach not only teaches skills essential to Science but also those skills essential to living in a modern world (DoE, 2009a). For these reasons the handbook prescribes a guide to how this formal assessment may be weighted according to the various learning outcomes, as reflected in table 2.1 below.

Table 2.1: An example of the Formal Programme of Assessment

SCHOOL BASED ASSESSMENT (25%)			**EXTERNAL ASSESSMENT (75%)**
Practical investigation Physics Focus LO 1: LO 2: LO 3 60-80%: 10-20%: 10-20%	Practical investigation Chemistry Focus LO 1:LO 2:LO 3 60-80%: 10-20%: 10-20%	Research project LO3 focus (e.g. library/ internet research) LO 1: LO 2: LO 3 10-20%: 10-20% :60-80%	Final Examinations
Two Controlled Tests	Mid-year Examinations	Preliminary Examinations	

Source: National Senior Certificate Handbook (DoE, 2009a: p.11)

The following is suggested as a guide of what should be assessed across an investigation (DoE, 2009c: p. 8):

1. *Developing a hypothesis*.
2. *Manipulation of equipment measurement and observations*.
3. *Planning and designing*.
4. *Presentation of data*.
5. *Analysing, concluding and evaluating*.
6. *Communicating and presenting information*.

The NCS presents policies and procedures on the assessment and what should be assessed. On the other hand, most schools do not have laboratories and laboratory equipment as noted earlier in section 1.1. So, following the above prescribed investigative approach to teaching and learning clearly presents several challenges. For this reason, other resources such as computer simulations should be investigated to determine whether they could be useful in achieving this objective of the NCS which are also in line with constructivist learner-centred teaching approach as discussed in the theoretical framework (section 2.10) of this report.

2.4 ELECTROMAGNETISM

Hair clippers, hairdryers, electric fans, blenders, electric bells and transformers are electrical gadgets used these days. These electrical gadgets make use of the principle of electromagnetism. Prescott (2006) defines electromagnetism as the combination of an electrical field and a magnetic field and their interaction to produce a force. High school electromagnetism basically consists of magnets, magnetic field lines, field around a straight wire, the right hand grip rule, field around a circular wire and solenoid, electromagnets, the Flemings left and right hand rules, force on current carrying conductor, the principles of operations of motors and generators, electromagnetic induction, Faradays' law, transformers, power generation and distribution.

Albe, Venturini, and Lascours (2001) researched the ability of learners to apply mathematical ideas when studying electromagnetism. They had two groups, 50 learners in a teacher training programme and 64 Physical Science undergraduates. Those in the teacher training programme were interviewed before a course on electromagnetism and were then asked in pairs to define magnetic flux and explain its physical significance. The data from the interviews were used to develop a multiple-choice test. The test was administered to the Physical Science learners at the beginning of their degree course. Another diagnostic test probed their understanding of magnetic field and its representation in diagrams. Albe et al (2001) found that, while most students were able to state the formula for magnetic flux, many were unable to define it, or to apply the formula to simple problems. They therefore concluded that many learners' understanding was disconnected and applied incoherently.

Planinic (2006) also reported from a study conducted in Croatia and replicated in America that learners exhibit difficulties in most conceptual areas in electricity and magnetism. The two studies made use of the Conceptual Survey of Electricity and Magnetism (CSEM) which covers a large conceptual domain and gives many opportunities for comparing the difficulties of different conceptual areas in electricity and magnetism. The CSEM was administered as a post-test to 84 Croatian learners in a calculus-based General Physics course at the University of

Zagreb. The most difficult area found among both the Croatian and American learners was electromagnetic induction.

Two other studies, in Turkey and England conducted by Saglam and Millar (2006) where a written test, consisting of 16 diagnostic questions was developed and used to survey the understanding of electromagnetism of upper secondary school learners in Turkey (n = 120) and England (n = 152). Similar conclusions have been reached that learners have a poor understanding of the basic ideas of electromagnetism. From all these studies it is evident that electromagnetism is possibly not well understood by learners even in high schools. Electromagnetism is an important component of high school curriculum in many countries and if learners were well equipped in conceptual areas of it, they should not struggle with it in their higher education (Saglam & Millar, 2006).

In addition, Dori and Belcher (2005) also mentioned that, it is a problem understanding magnetism, which has been studied to a much lesser extent than electricity, and this problem seems to be even more pronounced due to the fact that humans are simply not equipped with sensors to gauge magnetism. Although we can indirectly observe electricity as light generated by current flowing through light bulbs, or felt by electric shocks, there is almost no sensual indication of magnetic fields (Dori & Belcher, 2005)

Therefore, it appears teachers will have to come up with effective instructional designs to enable learners to understand the fundamental ideas in electromagnetism (Saglam, 2010). This is because, Saglam (2010) argues that many research in Science education have revealed that learners in Science courses have many alternative ideas of the basic ideas of Science. But, according to Duit (2009) even though we can find many research reports on learners' understanding of the basic mechanics ideas in Physics, research on learners' ideas in electromagnetism is scarce.

In the field of electromagnetism, technology-rich environments such as computer simulations are crucial, as they can enable the presentation of spatial and dynamic images and depict relationships among difficult concepts for learners to understand (Dori & Belcher 2004). Dori and Belcher (2004) involved media-rich software for simulation and visualization in freshman electromagnetism to transform the way it was taught in order to increase students' conceptual and analytical understanding and decrease failure rates in this area of Physics. The approach was designed to help students visualise, develop better insight, and conceptual models of electromagnetic phenomena. The reform is centred on a collaborative learner centred approach, with the use of visualisations. So Dori and Belcher (2005) contented that using visualisations helps learners in understanding electromagnetism because in this way they could make it possible for learners to see magnetic field lines, magnetic field lines moving from north to south on a magnet, the right hand grip rule, and electromagnetic induction which normally were considered unseen. Therefore, the researcher decided to use computer simulation to see if it could help improve performance and conceptual understanding of grade 11 learners in electromagnetism.

2.4.1 ELECTROMAGNETISM IN THE SOUTH AFRICAN CURRICULUM CONTEXT

The work schedule from DoE stipulates that, electromagnetism as a knowledge area should be treated in two weeks of teaching in South Africa. Usually in each week, there are 4 single periods and 1 double period for teaching in most schools for the Physical Science. This means 8 single periods and 2 double periods in the two weeks of teaching for electromagnetism. The teaching time for Physical Sciences is 4 hours per week (DoE, 2011b and DoE, 2009b). So from this DoE policy, one period is about 40 minutes long and the double periods usually meant for practical work and assessments is about 80 minutes long.

This knowledge area is intended to be assessed at ± 37% weighting in the grade 12 matriculation examinations. The knowledge area has also been allowed a mark allocation of ± 55 of 150 marks in the Physics paper in these examinations (DoE, 2009). But according to the chief examiner's report on the 2010 matriculation examinations, learners performed unsatisfactorily in electromagnetism (DoE, 2010a). And this is a course for concern. Therefore, this research seeks to find a solution using computer simulation.

2.5 THE USE OF ICT IN EDUCATION

Historically, man has developed through the Stone Age, the Iron Age, the Industrial Age and now finds himself in the Information and Communication Age. The history of education has been characterised by successive innovations to enhance higher quality. For many years, scholars have pursued more effective, efficient and satisfying teaching and learning practices. Hermans, Tondeur, van Braak and Valcke (2008) reported that the first electronic computer, intended to make Physics calculations easier, was constructed in 1939 by John Vincent Atanosoff of Iowa State University. Since the invention was designed to reduce the laborious demands of Physics calculations, it is important to trace how this computer has been used, is being used at present and will likely be used in Physics education in the future (Mlabo, 2007). In this regard, Murdock (2004) presents a coordinated chronological sequence of the history of technology in the classroom in the United States (US), as follows:

- 1951 - Television is used for the first time in United States primary schools.
- 1958 - The National Defence Education Act of the US brings new technology into vocational education.
- 1960 - More money is put into education which sees some growth in the use of technology in the classroom.
- 1963 - The Vocational Education Act is passed which allows for more money to support the use of technology in schools.
- 1965 - The Elementary and Secondary Education Act brings new money into schools for technology. Mainframes and minicomputers are introduced in some schools, but most are used for administration or for school counseling.
- 1981 - International Business Machines (IBM) is the first mainframe manufacturer to develop a personal computer (PC); drill and practice computer-assisted instruction (CAI) gains acceptance in schools; and the first educational drill and practice programs are now developed for personal computers.

- 1986 - 25 % of high schools use personal computers for college and career guidance, K-8 schools buying mostly Apple II and Macintosh computers, high schools buying mostly DOS-based clones.
- 1990 - Multimedia personal computers are developed; simulations, educational databases and other types of CAI programs are being delivered on CD-ROM disks, many with animation and sound.
- 1992 - Schools start using gopher servers to provide students with on-line information.
- 1994 - Most US classrooms have at least one PC available for instructional delivery.
- 1996 - Many schools are rewiring for Internet access; a few schools install web servers and provide talent with a way to create instructional web pages.
- 1997-2007 - Educational software becomes more useful and interesting to students as graphics and video are incorporated. Larger computer storage capacity and the growing prevalence of CD-ROM and DVD drives in personal computers make it easier for educators to store large graphic and video and sound files for educational applications.

From this chronological sequence of the history of the use of ICT technology in the classroom, it is evident that greater opportunities in teaching and learning have been opened up by the growth in the development of ICT. For instance, personal computers today are much faster than the cumbersome machines used in classrooms in the 1980s. Owing to this improvement, computers are now easier to use than in the past; that is, they are more user friendly. In addition, more peripheral devices such as scanners, printers, projectors and cameras have been developed which makes using ICT even more exciting.

2.5.1 BACKGROUND TO ICT USE IN AFRICA

Literature on the history and development of technology use in the classroom in Africa is a challenge to keep track of (Trucano, 2010). But according to Arowolo (2009), Zietsman's (1984) master's research report which evaluated diagnostic and remedial aspects of a microcomputer program on the topic of speed, in South Africa is an indication that technology and computer simulations have been in use in South African schools since as far back as 1984. Evidence from *eLearning Africa* website "More than Television," (2008) show that television (TV) and video technology was introduced into the South African classroom by the *Discovery Channel Global Education Partnership* (DCGEP). The DCGEP launched the Learning Centre project at Umkhathizwe Primary School in October 1998. The aim was to develop learning content in the Physical Sciences, Cultures, Geography, Health, Biology and many other subjects in close collaboration with the communities in which DCGEP works. This was intended to meet the communities' specific needs and to produce culturally-relevant programming. Besides serving educational purposes, the Learning Centres also provided the communities with access to national and international news, as well as affording them the opportunity to enjoy live sports events.

Farrel and Isaacs (2007), in their survey of ICT and education in Africa, maintain that ICT use in education is at a particularly dynamic stage in Africa, as there are new developments and announcements happening on a daily basis somewhere on the continent. Their survey reported on *Computer Penetration Ratios at schools in Selected African Countries* in 2006. The ratios are shown in table 2.2 below. This table indicates that computer penetration in some African countries in 2006 was very low, as low as 1.1% in Mozambique and 2.5% in Ghana even though Egypt has a 100% penetration.

Table 2.2: Computer Penetration Ratios at Schools in Selected African Countries, 2006

Country	**Number of schools**	**Number of schools with computers**	**Percentage of schools with computers**
Egypt	26000	26000	100%
Ghana	32000	800	2.5%
Mozambique	7000	80	1.1%
Namibia	1519	350	22.1%
South Africa	25582	6651	22.6%

According to this survey, 13 African countries had developed a national ICT policy by the year 2000, policy development was underway in 10 countries while in the remaining 30 countries there was no policy development at that point. The table below (table 2.3) illustrates the development of national ICT policy from 2000 to 2007.

Table 2.3: Development of National ICT Policies 2000–2007

Status of National ICT Policy Development by Country	**2000**	**2005**	**2007**
Policy in place	13	28	36
Policy under development	10	15	12
No development underway	30	10	5
Total	53	53	53

Table 2.3 reveals that there is progress in the status of national ICT policy development in Africa. The point that future socio-economic development will need to embrace the use of ICT appears to be widely recognised by governments throughout Africa and is manifest in the number of countries that have a national policy for ICT in place or under development. The South African government in a white paper on e-education, for example, stated it's believe, that ICT has the potential to improve the quality of education and training (DoE, 2004), and this is what this research seeks to prove.

2.6 ADVANTAGES OF ICT USAGE IN THE TEACHING AND LEARNING OF PHYSICS

People remember visual information more easily than verbal information. Having access to visual materials and explanations may well extend people's ability to learn, particularly in the case of those who have difficulty learning from books and lectures (Collins, 1991).

At present, various ICT applications exist which aim to stimulate learners' active engagement. These create conditions that would be very difficult, expensive or time-consuming in the Physics laboratory and allow learners the experience of working under such conditions in the classroom (Jimoyiannis & Komis, 2001). Among such ICT applications, computer simulations are of particular significance in Physics teaching and learning as these present numerous advantages. Agina (2003) mentions the following advantages of computer simulations:

- *Interactivity:* It allows a mutual action between the learner, the learning system, and the learning material. Learners will learn faster and have a more positive attitude towards learning when using interactive computer simulations, especially if other techniques such as audio and video are used as well.
- *Engagement:* Interactive learning with live-action computer simulations, video, audio, graphics, feedback, expert advice and questions and answers keep learners interested and reinforce skills. Because it is exciting, challenging and fun to use, interactive learning encourages learners to return to the program again and again. Through continued practice, learning will take place and be integrated into daily performance.
- *Safety:* Many experiments cannot be carried out in the classroom because they are dangerous, and yet learners may need these skills in the workplace. Computer simulation programs can represent these dangerous experiments without the hazards.
- *Flexibility:* Computer simulations are able to show the impossible in real-life learning. Learners have more interaction with the content and are thus more likely to assimilate the knowledge, skills and concepts involved.
- *Motivation:* Since computer simulations provide inspiring and interactive opportunities for flexible education and training, learners will be more motivated to learn. Learners will acquire more skills, which is the main reason for motivating them.
- *Frustration eliminated:* Learners will not encounter experiments that do not work as a result of faulty apparatus or techniques.
- *Practicality:* Computer animations allow learners to learn-by-viewing, learn-by-doing or learn-by-coaching. All these are effective methods for developing practical skills and increasing information retention.
- *Consistency:* All learners learn the same principles and skills. Computer simulations typically force instructional designers to organise and structure learning materials more effectively, and this can result in learning advantages.

- *Immediate feedback:* Learners receive immediate feedback from the computer simulations and this enhances their skills and abilities.
- *Isolating specific actions in a complex sequence:* Computer simulations can show motion for part of a complex operation, thus clarifying functions that would otherwise be impossible to isolate and view independently.

These advantages particularly encouraged me to undertake this study because I would like to contribute to the teaching and learning of Physics, especially electromagnetism, by making teaching more practical, more flexible and more motivational for both teachers and learners.

2.7 DISADVANTAGES OF ICT USAGE IN THE TEACHING AND LEARNING OF PHYSICS

Although there are many advantages in the use of computer simulations, the application of the technology still has its limitations and disadvantages. According to Lai and Kritsonis (2006), research findings show that the use of computer technology has a positive effect on the achievement levels of learners but still has its limitations and weaknesses, such as

- *Cost*: the first drawback of a computer and its technologies is that they raise educational expenses and damage the equity of education. This was also observed by Gips, DiMattia and Gips (2004). But in this study one computer with a data projector was used to present the lessons, as discussed in chapter 4 sections 4.2.2 of this report. In my view, this is less costly than establishing a school laboratory and equipping it.
- *Isolation:* Loss of communication and interaction between learner and teacher, and among learners themselves. Here the teacher in this study used leading questions to introduce and to reinforce concepts, as discussed in detail in chapter 4 section 4.2.2 of this report. So learners were involved and they communicated with each other and also with the teacher. Learners were put in groups to discuss concepts among themselves and then give feedback by means of verbal reports to the teacher and the class.
- *Knowledge:* it is essential that both teachers and learners have knowledge of basic computer operations before they can apply computer simulations to assist in teaching and learning. This disadvantage was also addressed in this study by training the teacher.

The teacher was trained by the researcher to use the simulation software, the computer and the data projector in his teaching. This is reported in detail in chapter 3, section 3.6 of this report.

2.8 ACCESS TO ICT IN EDUCATION

Mumtaz (2000) reports that evidence of good practice in the use of ICT is invariably found in those schools that also have high quality ICT resources, and that a lack of computers and software can seriously limit what teachers can do in the classroom. The importance of schools being well resourced in ICT equipment is also highlighted by Becta publication, primary schools – ICT and standards (Becta, 2003). The inability of a teacher to gain access to ICT resources may be the result of a number of factors and not always simply because the hardware or software is not present within the school. In the Becta survey of 170 teachers, for example, when a large number of respondents identified access to resources as a problem (20.8%) they were actually referring to different kinds of access problems. Some respondents were indeed referring to a lack of resources at the school, while others were referring to the poor quality of the resources that were available. A number of respondents in the Becta survey suggested that although there might be an array of software now available for use in the classroom, much of this software was not appropriate or would not actually enhance a lesson in any way. This is supported by Guha (2000) who found that poorly designed software, and a lack of time for teachers to design their own software, often causes teachers to "give up" and choose not to make use of ICT (Becta, 2004). While this is true, in the current study, the simulation software was provided by the researcher and the teacher was also trained to be able to use the software.

2.9 COMPUTER SIMULATION AND MODELLING

Simulation software involves imitating real or imaginary situations by using the computer to represent the situation through mathematical models with which the user interacts. The user responds to situations presented by the program to affect some particular outcome. With practice and experience, the learner is able to determine the factors and variables which the programmer has incorporated into the system and replay their performance to try out possible improvements (Bransford, Brown, & Cocking, 2000). The use of simulation software in technical training has been successful, with training times diminished by as much as 95% (Bransford et al, 2000). Studies have shown significant gains in achievement scores in areas such as Mathematics when simulation and higher order thinking software is used (Schacter, 1999).

The demarcation between simulations and modelling is analogous to that between toy cars and Lego bricks (Bliss & Ogbom, 1989). Simulations can be classified as models with predefined rules of operation and interaction among objects they encompass. They can be used to support exploratory learning activities in which learners explore the simulation by manipulating the variables or the parameters provided, but not the underlying theories and rules of operation (Bliss & Ogbom, 1989).

Modelling software differs from simulation software in that the computer provides the tools to create a model for a real or non-real environment. It provides the students with greater scope for visualising, designing and controlling an environment (Bransford et al, 2000; Riel, 1998). When used in this way, the computer follows the instructions provided by the learner. The learning situation revolves around the task of creating the environment and instructions to investigate that environment. Modelling therefore extends the scope of learning from purely exploratory to encompassing more expressive activities (Ogbom, 1998).

Simulations help learners to visualise the real world, making the understanding of concepts easier. Simulations can be used where phenomena cannot be observed and explored in the real world. Trey and Khan (2008) used simulations in their study to help learners observe a phenomenon which could not be observed in the real world and found that learners achieved better results after the instruction.

In their study, Rotbain, Marbach-Ad and Stavy (2008: p.54) reported four major advantages from the learners' perspective of working with computer simulations:

> The first one is that the activity helped the learners to visualize the abstract concepts and processes of molecular genetics by representing the subject matter in a more concrete manner. Secondly, it enabled them to work individually in their own time, to run the animation over and over as much as they needed, while controlling the pace of the simulation. Also, the individual animation activity freed the teachers to move between the learners and give them direct feedback as they worked. The last of the advantages was the contribution of the activities to the diversification of the lessons and the interactivity and the immediate feedback of the animation.

In the present study, the researcher chose to use simulations rather than modelling because the intention was not that learners explore the concept of electromagnetism but rather to find out whether a group of learners (the experimental group) would perform better than another group (the control group) after an intervention using simulation software from the Physics Education Technology (PhET) project based at the University of Colorado at Boulder, Colorado, USA, and simulations from the Plato Learning Centre based in the UK.

2.9.1 PHYSICS EDUCATION TECHNOLOGY (PhET) PROJECT

The Physics Education Technology (PhET) project creates useful computer simulations for teaching and learning Physics, Chemistry, Biology, Earth Science and Mathematics and makes them freely available from the PhET website (http://phet.colorado.edu) (Perkins, Adams, Dubson, Finkelstein, Reid, Wieman, and LeMaster, 2006). According to Wieman, et al (2007), the goals for these simulations are to increase learners' engagement, improve learning and improve beliefs about and approach towards learning. There is a collection of these simulations free online created for teachers and learners that demonstrate principles in the natural Sciences especially. These interactive simulations can be used in a classroom or in laboratories to enhance teaching and learning. PhET simulations are developed using the results of education research and feedback from teachers, and are tested in learner interviews and classroom studies (McKagan, Perkins, Dubson, Malley, Reid, LeMaster & Wieman, 2008).

2.9.2 PLATO LEARNING CENTRE

The Plato Learning Center also creates useful computer simulations for teaching and learning Physics, Chemistry and Biology. The computer simulations from the Plato Learning Centre based in the UK used in this research was not free like the PhET simulations. It came on a CD - ROM which can be purchased to be installed on a computer. The CD - ROM is titled the Multimedia Science School (MSS) 11–16 Edition, Version 2.0. MSS 11–16 is an exceptional multimedia resource to support the teaching and learning of secondary Science. Developed by experienced teachers, MSS 11–16 is curriculum-focused software that covers topics in Physics, Chemistry and Biology ("Plato Learning Centre", 2005). This Version 2.0, the latest development of the software package as at 2005, has been enhancing Science teaching and learning in schools around the world for over five years ("Plato Learning Centre", 2005). In early 2005, 50% of secondary schools in the UK had a licence to use at least one of the teaching tools that feature in MSS 11–16 ("Plato Learning Centre", 2005). The CD-ROM features 45 highly interactive multimedia teaching tools that can transform the explanation of difficult concepts such as the Electromagnetism, engaging learners and provoking effective thinking and learning. More information can be found from their website (www. http://platolearning.co.uk).

2.10 THEORETICAL FRAMEWORK

Constructivists support learner-centred approach to teaching and suggest that learning is more successful when learners are actively involved in the learning process rather than when learners are made to receive knowledge passively. Constructivists' learner-centred teaching, helps to develop leaners with critical thinking skills, creative thinking skills, and problem solving skills (Friedrich, & Hron, 2011). According to Wieman, Adams and Perkins (2008), research has indicated that learners learn better when they construct their own understanding of scientific ideas within the framework of their existing knowledge. In order to accomplish this process, learners must be motivated to engage actively with the content and they must be able to learn from that engagement. Interactive computer simulations can meet these two needs; the goals for these simulations, according to Wieman, Adams and Perkins (2007), are increased student engagement, improved learning, and improved beliefs about and approach towards learning. It is hoped therefore that the use of interactive computer simulations in the teaching of electromagnetism holds the key to learners' visualisation of the abstract concepts inherent in this aspect of Physics.

This study is framed by a constructivist theory which has its roots in the psychology-based traditions going back to Dewey (1966), Bruner (1966), Piaget (1970) and Vygotsky (1978). The major theoretical perspectives which support Computer-Based Instruction (CBI) as a means of enhancing student learning are based on constructivism, the leading learning theory of the 1990s. Both these theories have captured the interest and attention of teachers and educational technologists because they have important implications for the design and use of CBI. Indications are that advances in computer technology can help to bring about the development of learner-centred learning environments through the use of a range of tools and techniques which draw heavily on constructivist approaches. The use of constructivism as an approach to the design of learning environments has major implications for the design of computer-based instruction.

A critical component of theories of constructivism is the concept of the zone of proximal development (ZPD), based on the work of Vygotsky (1978), which posits that learning takes place through the learner completing tasks for which support (scaffolding) is initially required. This support may include a tutor, a peer or a technology such as the application of computer simulations. This has led to the use the term computer supported learning. Computer supported learning environments are those in which computers are used either to maintain a learning environment or to support the student learner in this Vygotskian sense (DeCorte, 1990; Mevarech & Light, 1992). This technology was used in this study to help create the types of learning environments and the types of support for learning that are known to be best, but have been ignored or not implemented widely in the past (Glickman, 1991).

Constructivism and learner-centred learning paradigms are supported by advancements in technology such as computer simulations. Vygotsky (1978) proposed that learning requires two mediation tools, tangible or technical tools and intangible tools. The role of tangible tools such as computer simulations as a means of mediation in this constructivist theoretical framework is that they will serve as the scaffold that the learners need to construct knowledge. This position is supported by Kennedy and McNaught (2001) who point out that carefully designed computer-based cognitive tools can scaffold learning.

2.11 SUMMARY

The chapter presented literature review that is relevant to the study. The literature reviewed includes; the process of teaching and learning, role of experiments in physics, electromagnetism, the use of ICT in education, advantages and disadvantages of ICT usage in the teaching and learning of physics, access to ICT in education, computer simulation and modelling. The theoretical framework is also presented in this chapter.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In order to determine the impact of computer simulations on the teaching and learning of electromagnetism in grade 11, a case study was done in one school in the Mpumalanga Province. A mixed method research approach was followed by using quantitative research methods to answer the first research question (see section 1.5 and 3.2) and qualitative research methods to answer the second and third research questions (see section 1.5)

3.2 RESEARCH DESIGN

"Sometimes it is just not possible to randomly assign individual participants to groups. For example, to receive permission to use school children in a study a researcher has to agree to keep students in existing classrooms intact" (Gay & Airasian 2003: p. 378). This is the situation the researcher was faced with and this necessitated the choice of quasi-experimental design for the study. The non-equivalent control group design was used where two existing grade 11 Physical Science classes in a high school were the sample. One of the classes was taken as the experimental group(x_1) and the other class as the control group(x_2).

The school insisted that the two classes were formed randomly and therefore constituted two classes of similar academic abilities. Since this can pose validity threats to the research findings, their previous term marks (June Exams) were obtained (Appendix T) by the researcher and a t-test was calculated using statistical analysis tools in Microsoft excel and the results analysed. The mean, the standard deviation, median and the t-test were calculated using this approach; ($t = 0.906$, $df = 101$, $p = 0.3672$) from the excel calculations. The t-critical two tail is 1.984 approximately 2.00 at $P > 0.05$. The interpretation of this analysis is that since the t-critical (2.00) is greater than the t-statistics (0.906) at $P > 0.05$; there is no statistically significant difference in the achievement of the two classes in the June exams. This t-test therefore established that the two classes were of the same academic ability before the treatment. Details of the t-test calculations can be found in table 4.1 in chapter 4.

3.3 PARTICIPANTS

The participants of the study were two intact Physical Science classes and their two usual class teachers in a high school in Mgwenya Circuit of Mpumalanga Province of South Africa. The two grade 11 Physical Science classes consist of 54 learners in grade 11A and 53 learners in grade 11C. Grade 11A was chosen randomly to form the control group while grade 11C became the experimental group. In total the learners' population was 107 in the two groups. The ages of the participants ranges from 15-19 years.

The two teachers' academic qualifications were the same. Mr C teaching grade 11A had a B.Ed. Science degree and four years teaching experience while Mr E teaching grade 11C also had a B.Ed. Science degree and three years teaching experience. Classroom observations were done by the researcher prior and during the intervention to ascertain that the teachers were comparable in their ways of teaching.

The school randomly distributed the learners into the two classes and they are of comparable academic ability (see section 3.2). The school is one of the few well-resourced schools in the province and it is a Dinaledi school. The school has a computer Science laboratory well equipped with computers, as well as data projectors and overhead projectors. The school also has a Science laboratory with some laboratory equipment. This school was easily accessible to the researcher. The above reasons motivated the researcher to select the school for the study.

3.4 INSTRUMENTATION

Data were gathered using three instruments. They are the observation schedule, the pre-test, post-test for learners, and the structured questionnaires for both the learners and the teachers (Appendix A, B, C and D respectively). The two questionnaires were similar in sections B and C but slightly different in sections A.

3.4.1 CLASSROOM OBSERVATION SCHEDULE

The observation schedule was used when the researcher did classroom observation during the intervention period. This was to enable the researcher to collect data on the teaching of the teachers involved in the study to make sure that they are on the same level with regards to their content knowledge of electromagnetism as well as following what was expected from them with regards to either traditional teacher-centred instruction or learner-centred instruction using the computer simulations. The observation schedule sought to collect information on how the teacher introduces the lessons, learner involvement in the lessons, teacher's ability to teach the content (electromagnetism) effectively and whether teacher follows the work plan and the curriculum in the teaching.

3.4.2 PRE-TESTS AND POST-TESTS

The Pre-tests and post-tests were conducted to measure the impact of the simulation software on the performance of the learners in the experimental group after the teaching intervention. The pre-test, post-test were the same, this is to ensure that the level of difficulty of the two tests are maintained, and the test being the same for the two groups. The test consists of twenty multiple choice questions and five short-answered written questions. The questions in the test were adapted and slightly modified from three sources. Details of the slight modifications are given in section 3.5.1. The questions were from:

- South Africans matriculation past Physical Science (Physics) examination papers
- Commonly used South African Physical Science textbooks and
- Modelling teachers question banks CD2 Part 1.

3.4.3 QUESTIONNAIRES

There were three sections in the questionnaire. Section A of the questionnaire sought background information, while sections B and C sought information to enable the researcher answer research questions 2 and 3. The statements in sections B, and C were adapted and modified from the interview transcript of students and teachers by (Arowolo, 2009). Some of the questions in the interview transcripts were modified into a five point Likert scale questionnaire. The Likert scale questionnaire which was a structured, close-ended questionnaire was chosen over the open-ended type of questionnaire for the following reasons;

- To avoid unclear or useless responses that open responses may produce.
- To avoid the difficulty of scoring open-ended questions or what is usually referred to as free response questions (Gay & Airasian, 2003).

3.5 VALIDITY AND RELIABILITY OF THE INSTRUMENTS

3.5.1 VALIDITY OF THE INSTRUMENTS

For validation, the pre-test, post-test and the observation schedule were given to three experts in Physical Science in the Ehlanzeni Region of education in the Mpumalanga province of South Africa to read and make corrections and suggestions. This is to ensure both face validity and content validity. Two of these experts have been teaching Physical Science in the high school for six and eight years respectively. They both hold B.Ed. degrees in Science education. One was the head of Science department and has six years' experience of teaching Physical Science. The second teacher at the time was a principal of a high school and had eight years' experience in teaching Physical Science in a high school as well. The third expert was at the time the Curriculum Implementer (CI) of Physical Science in the Ehlanzeni region of education. These three experts made valuable suggestions on the test as follows:

- Question one of part 1 had its multiple choice answer (b) being; the direction of the switch. It was suggested that this option should change to, the switch. The reason being that a switch has no direction and may mislead or confuse the learners.
- The phrase, "the north pole of" or "the south pole of" was suggested to be inserted in question 4 of part 1. This was to prevent the question from having two of the multiple choice answers from being the right answers. These two options were options (a) and (b).
- Question sixteen of part 1 had a multiple choice option reading "the magnetism is turned off". It was changed to "the magnetism is lost" for the clarity of that multiple choice option.

- Originally, all the questions in part 1 had option (e); none of the above. But this option was removed from the options of all the questions entirely. As stated by Gay & Airasian, (2003: p. 152) “when constructing a test, one must avoid options like none of the above or all of the above”.

The three experts agreed that the test adequately measures all the learning outcomes or objectives of the topic electromagnetism in grade 11 Physical Science. On the observation schedule, there was no correction or suggestion made.

The structured questionnaire was also given to these three experts mentioned above to read and answer. They were also requested to make suggestions regarding omissions, ideas that may be important and that may have been left out and those ideas that should be removed. There was a concern of clarity of one statement on the questionnaire. The statement reads; “ICT usage makes teaching very descent”. It was therefore suggested that the word descent be clarified or the statement removed. Hence the statement was removed for lack of appropriate word or phrase to simplify the statement.

In addition to these views of the three experts, the questionnaire was given to the pilot sample and their teacher for pre-testing. The pilot sample was also encouraged to make suggestions to improve clarity of the statements in the questionnaire. But this time, no comments or suggestions came up even though the researcher was present at the time to pick up problems and suggestions regarding clarity and ambiguity of the statements in the structured questionnaire.

3.5.2 RELIABILITY OF THE INSTRUMENTS

Reliability tells test users about the consistency of the scores produced in a test and Validity tells test users about the appropriateness of a test. Both are therefore important for judging the suitability of a test or measuring instruments (Gay & Airasian, 2003: p. 141). However, (Gay & Airasian, 2003: p. 141) argue that “a valid test is always reliable but a reliable test is not always valid”. For this reason the reliability of the pre-test, post-test was established after the validity considerations, using the Spearman-Brown formula. For this purpose, the test was given to the pilot sample for testing. The pilot sample wrote the test twice within three weeks. The marks obtained (Appendix E) were used to calculate the Spearman correlation coefficient using SPSS. The marks yielded a Spearman correlation coefficient of 0.65. Appendix F shows a detailed table of the SPSS results of the calculation of the Spearman correlation coefficient. This was then used in the Spearman-Brown formula to determine the reliability of the test instrument. The Spearman-Brown formula yielded a reliability coefficient of 0.79. The interpretation of this coefficient of reliability follows from the fact that reliability is the degree to which a test consistently measures whatever it measures. Reliability is usually expressed numerically ranging from 0.0 to 1.0; so that a high coefficient indicates high reliability. Looking at the range 0.0 to 1.0 for estimating the coefficient of reliability, the reliability of 0.79 for the pre-test, post-test used in this research can be said to be established.

It is important that observation is as objective as possible. Therefore, observers must not bring into the observations, their own interests and biases. To measure the reliability of the observation schedule, three observation practice sessions were arranged by the researcher in the school used for piloting. In the three practice sessions, the researcher and a colleague Physical Science teacher, who is also a registered masters student at the Institute for Science and Technology Education (ISTE) at the University of South Africa (UNISA) observed the three lessons together but independently. The results were compared and checked for consistency and agreements at the end of each observation session. There was about 89% agreement on the statements in the schedule for the three practice sessions. After the three practice sessions the researcher used the observation schedule to observe lessons in the main research study. After each observation, field notes were written immediately to ensure that, memories of what was observed during the lesson was intact as much as possible.

3.6 METHODOLOGY

In this study, the researcher used a quasi-experimental design in which the performances of participants in control and experimental groups were used as basis to establish and explain the impact of computer simulations on the teaching and learning of electromagnetism in grade 11

Physics. In this design, the participants in the two groups first wrote a pre-test. The two grade 11 classes which constituted the two groups were 11A and 11C. The 11A class was randomly used as a control group and 11C as the experimental group. The two usual teachers of the two classes were maintained and used as the teachers in the research to maintain continuity in the school's academic programme. For the purposes of anonymity, the teacher for the control group will be called Mr. C and the teacher for the experimental group will be called Mr. E. This design is consistent with many other similar studies, (e.g. Caner & Ogan-Bekiroglu, 2009; Chee, Munirah et al, 2009; and Arowolo 2009).

For the purposes of this research, and for the two teachers to be at the same level for the research, the researcher and the two teachers met for two hours from 1:20pm – 3:20pm after their lessons for the day. At that meeting, topics to be taught under electromagnetism were reviewed and reorganized for the purposes of the research. This took about one hour after which the teacher for the control group left the meeting and the teacher for the experimental group was trained by the researcher to use the PhET simulations and simulations from the Plato learning centre to teach electromagnetism. The training took place for approximately one hour. Details of the descriptions of the lessons are found in chapter 4 sections 4.2.1 and 4.2.2.

The control group was taught electromagnetism using the traditional teacher-centred teaching approach together with real laboratory experiments and demonstrations. The experimental group was also taught electromagnetism using a more learner-centred teaching approach using demonstrations aided by computer simulations of the concepts using PhET simulations and simulations from the Plato learning center. The intervention lasted for two weeks. The breakdowns of the lessons are detailed in section 4.2.1 and 4.2.2. After these lessons, the two groups wrote a post-test which was the same as the pre-test. As in the pre-test, a t-test was calculated using the marks obtained in the post-test. The results of the t-test on the post-test were compared in order to determine the impact of the computer simulations on the teaching and learning of electromagnetism in grade 11 Physics.

Also, the test items were analysed for the two groups to ascertain the levels of knowledge gained in the various concepts under electromagnetism. Details of this analysis are shown in 4.3.6 and 4.3.7. For the questionnaires, the index of agreement was calculated to help answer research questions 2 and 3. Section 4.4 presented the detailed analysis of the index of agreement.

After the lessons and the tests, the two groups came together in the Science laboratory where there were presentations by the two teachers involved in the research. The presentations were on the highlights of the two teaching methods used in the research. This is to give a feel of the computer simulations to the control group too and also to enable both groups to answer a structured questionnaire. The questionnaire was to enable the researcher to answer research questions 2, and 3. Figure 3.1 below, diagrammatically illustrates the research procedure followed in this study.

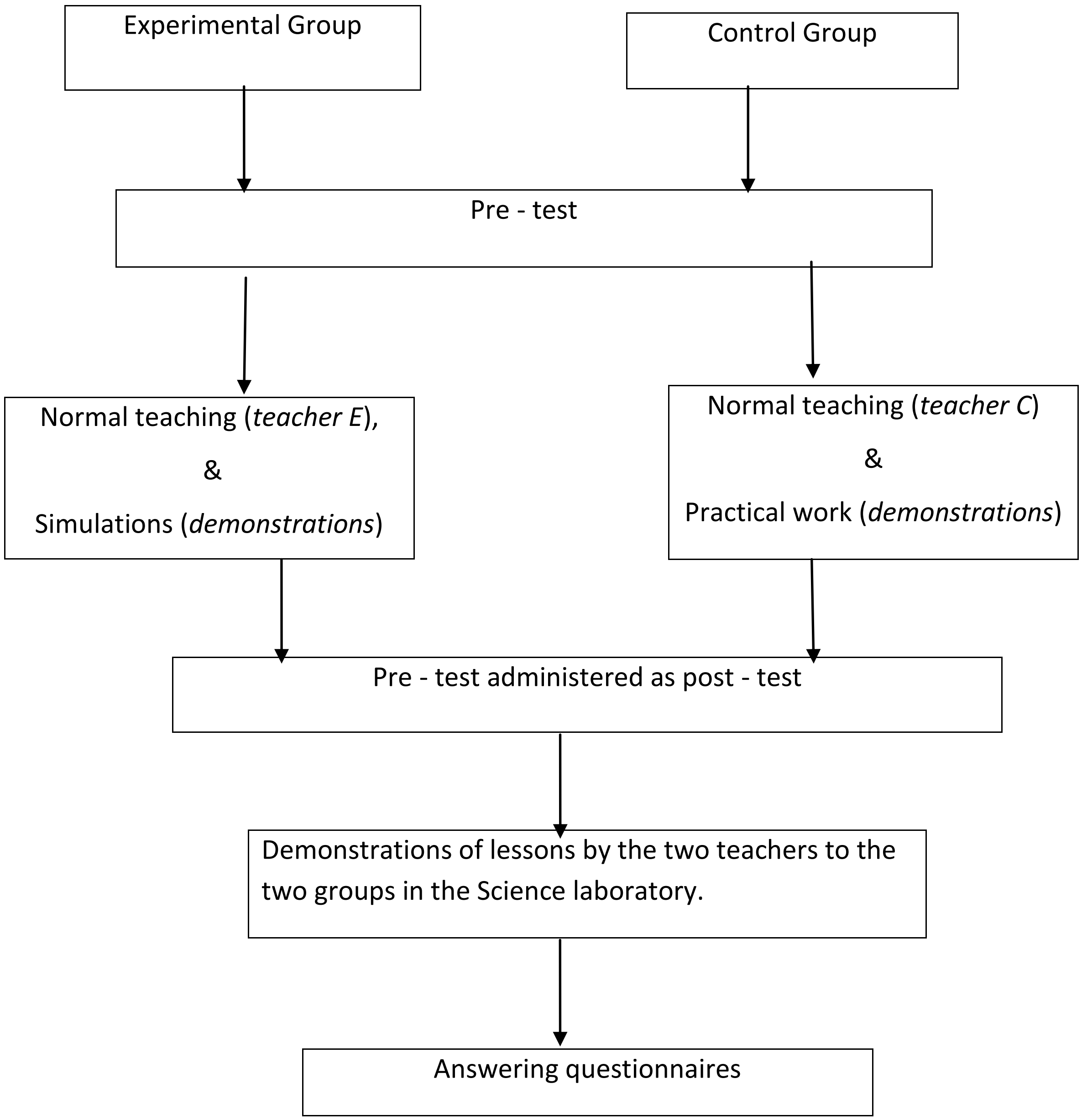

Figure 3.1: Research procedure

3.7 PILOT STUDY

Constructing a test is very important in research, since it impacts directly on the kind of data that are likely to be produced. It is therefore crucial that, before the actual research study, questions such as whether the research instruments are asking for what the researcher wants to establish must be carefully considered by the researcher. These questions regarding validity and reliability of research instruments are vital. Gay (1981) cited in Makomosela (1996) argues that a test is not valid per se; it is valid for a particular purpose and for a particular group. For this reason, a pilot sample was chosen and used to validate the instruments used in this study.

The sample used as pilot in this study comprises of one grade 11 Physical Science class, of 35 learners and their Physical Science teacher in another school. This school is located in the White River circuit of the Ehlanzeni region in the Mpumalanga province of South Africa. This circuit is the second closest circuit to the Mgwenya circuit where the actual study took place. The Physical Science teacher in the sample is well qualified and holds a B.Sc. degree in Physics and a diploma in education similar to teachers Mr. C and E. This teacher integrates computer simulations in his lessons. This motivated the researcher to choose his class for the piloting. Before the pilot study started the teacher has already taught electromagnetism to his grade 11 class. Therefore, this makes this pilot sample appropriate to be used for piloting the pre-test, post-test and also the questionnaire. This teacher was approached by the researcher and he willingly accepted the challenge for his class to be used as a pilot in this study. Three meetings followed within three weeks. The first meeting was an introduction to the study and the reasons were conveyed. The sample wrote the pre-test and took approximately 40 minutes to complete. The second meeting was used to answer the questionnaire and during the third meeting, the sample wrote the same test again to enable the researcher to check for the reliability of the test. The test scores are presented in appendix E.

3.8 ETHICAL CONSIDERATIONS

3.8.1 OFFICIAL PERMISSIONS

The researcher applied for ethics clearance and received approval from the Ethics Review Committee of the University of South Africa, and also applied to the Mpumalanga Department of Education for permission to conduct research in a school in the Mgwenya circuit of the province and received approval. These ethics clearance documents can be found in Appendices J and K respectively. These are requirements before any research can be carried out in the University of South Africa and in the Mpumalanga Department of Education. This is to ensure that the research done by the students of the university complies with the protection of the rights of the subjects as well as to ensure that due process is followed. The following paragraph describes how the researcher obtained ethics clearance from other stake holders in the study.

3.8.2 TEACHERS, LEARNERS AND PARENTS PERMISSIONS

Since the principal, teachers and learners as well as parents are required to give consent in any research, especially where minors in school are involved, their informed consents were sought through letters. These letters can be found in Appendices L, M, and N. Since they are instrumental to the success or failure of the research, the researcher believes that he has particular responsibility to the teachers and learners as subjects of the study. One of the responsibilities of the researcher to the participants in this study was to ensure that they are protected from any victimization, information distortions or any other forms of practices that may infringe on their rights as participants in the study. The researcher was guided by the fact that participants in a research study have the right to be informed about the aims, purposes and likely publication of findings of the research and of potential consequences for participants, and to give their informed consent before participating in the research. For this reason, the researcher met with the teachers and the learners to be involved in the study and explained to them what will be required of them in the research. It was also emphasized to them that participation in the study is voluntary and that nobody will be victimised in any way as stated in their ethics letters. They could also withdraw from the research if they wanted to. Consent forms (Appendices P, Q, R, and S) were later filled and signed by the teachers, learners, parents and the principal to allow the research to be conducted. In this study all the teachers and learners who signed the forms continued throughout.

3.9 SUMMARY

The chapter described the research design, the methodology used in carrying out the study and the participants in the study. It outlined the instruments used, how the instruments were constructed, and the validity and reliability of the instruments was also discussed. Furthermore, the chapter reported on the pilot study, methods of analyzing the data collected, and the ethical procedures followed. The data collected and analysis will be discussed in the next chapter in order to answer the research questions.

CHAPTER 4

PRESENTATION AND DATA ANALYSIS

4.1. INTRODUCTION

In this chapter, the data and the analysis of data are presented. The analysis is to help answer the three research questions which guided this research. The three research questions are:

1. Does the use of computer simulations have an impact on the performance of grade 11 learners in electromagnetism?
2. To what extent does the use of computer simulations influence the learning of electromagnetism in grade 11?
3. To what extent does the use of computer simulations influence the teaching of electromagnetism in grade 11?

Two tests were conducted, a pre-test and a post-test. The scores of these two tests were analysed quantitatively using the t-test to form the basis for comparison of the experimental group and the control group involved in the research. The t-test was used to determine whether the means of the post-test scores of the two groups were statistically significantly different from each other. This analysis was used to determine whether the null hypothesis should be accepted or rejected.

Classroom observations were done by using a classroom observation schedule to ascertain whether the teachers were following the work plan as agreed on by the two teachers and the researcher. The observation schedule also helped to record the teaching methods used by the two teachers in their six lessons.

Questionnaires were also used to collect data to help answer research questions 2, and 3. This was also analysed quantitatively using Microsoft excel spread sheets. The questionnaire has three sections, namely A, B and C. Section A is to collect data on the background of the respondents, sections B and C seeks data to help answer research question 2 and 3.

4.2. OBSERVATION OF LESSONS OF THE TEACHERS

Before the research started, the researcher observed the lessons of the two teachers who took part in the research. It was observed that they were following a common work plan which they had agreed upon earlier in the year. They were both teaching electricity when the researcher went to observe their lessons. The two classes do not have Physical Science lessons at the same time of the day. So, it was convenient for the researcher to observe the lessons, one after the other. The following is a report of the six lessons of the two teachers, starting with Mr. C's lessons followed by Mr. E's lessons.

4.2.1 MR. C'S LESSONS

Mr. C taught the topics in six lessons, of four 40 minutes periods and two 80 minutes periods. Two of the 40 minutes periods were extended by about 15 minutes each, because these two periods were last periods. This was agreed on by learners and the teacher to allow for completion of all the topics within a specified time, so it did not pose any problems as learners were prepared to stay on 15 minutes after school twice for the lessons. Below are the details of Mr. C's lessons as observed by the researcher using the observation schedule (Appendix A). These details of the observation of lessons given below are extracted from appendix A_1 to A_6 and field notes taken during the lesson observations.

LESSON 1: In the first lesson, Mr. C started by reviewing lessons on magnets taught in grade 10. He started by asking learners what a magnet is (See Appendix U). As mentioned in literature, learners are not able to visualise the directions of the magnetic field lines (see section 2.4). After some discussion on this with the learners, Mr. C asked the learners to draw a bar magnet, indicate the polarity of the magnet, and also show the magnetic field lines and their directions around the magnet. The learners struggled with this task, showing that they might have forgotten the concepts. Mr. C then called two learners to the chalk board to present their solutions to the problem on the chalk board. One of the learner's solutions was correct and the other could not indicate the direction of the field lines correctly. Mr. C then used the correct solution to explain the concept. He also showed the learners a real bar magnet with the North Pole painted red and the South Pole painted blue. Mr. C also used a paper, iron filings and the bar magnet to demonstrate the magnetic field lines to the learners. The figure below shows how the demonstrations look like on the paper. This figure is scanned from their grade 10 study and master Physical Science text book (Kelder, 2005).

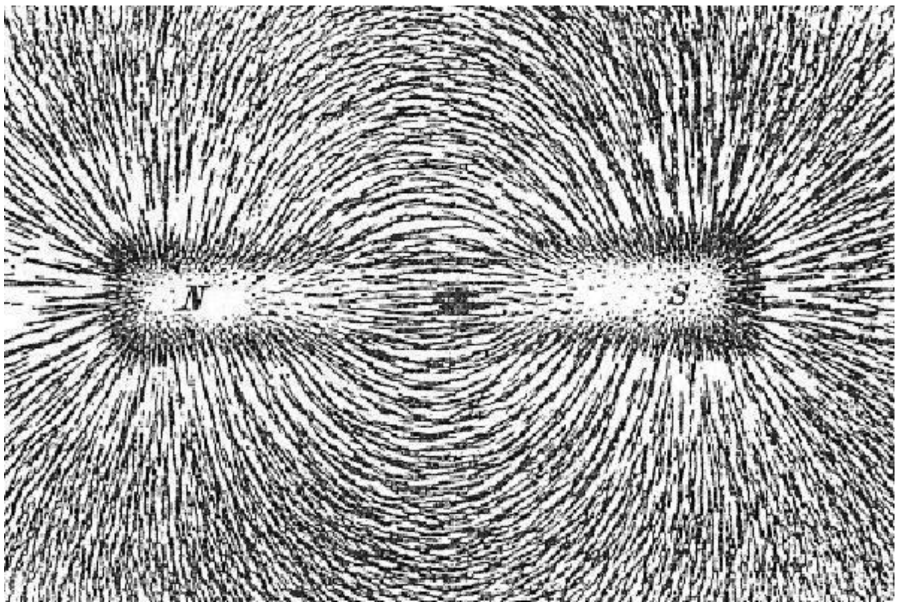

Figure 4.1: Magnetic field lines around a bar magnet

Learners were then put into groups to perform the activity with the magnets, iron filings and the papers to show the field lines.

LESSON 2: Mr. C's second lesson was on

- Field around a straight wire
- Right hand grip rule
- Field around circular wire and
- Field around a solenoid.

Learners normally consider these concepts as unseen especially where they were taught without demonstrations to enable learners to see the fields (see section 2.4). (Appendix U has the definitions of these concepts). Mr. C could not demonstrate the above concepts because he did not have the right equipment in the laboratory. Therefore, he taught the learners from the textbook and explained the concepts using the pictures in their textbook. But he showed the learners a real magnetic compass. The lesson therefore was more teacher-centred. In a teacher-centred or teacher-talk classroom environment, the learner is a passive participant. But with the nature of the topic Mr. C was teaching, without the right equipment in the laboratory, it was difficult for him to involve the learners actively in the lesson.

LESSON 3: In this lesson, Mr. C taught electromagnets and their uses (See Appendix U and V). He explained electromagnets and gave examples such as the electric bell and the magnetic relay where electromagnets are applied in everyday usage. He also showed the learners an old electric bell which is not functional after he discussed the working of the electric bell with the learners. He used a circuit diagram from their textbook (Kelder, 2005) to explain how the electric bell works. He gave the learners a summary of notes on how the electric bell works to paste in their note books.

LESSON 4: The Lesson on Fleming's left hand rule, force on current carrying conductor in a magnetic field (see Appendix U), and the motor effect were also taught using explanations and accompanying pictures from the learners' textbook. This was because the school laboratory does not have the equipment for Mr. C and the learners to practically perform these activities.

LESSON 5: For the lesson on electromagnetic induction and Faraday's law, Mr. C got the equipment from the laboratory to demonstrate induction for the learners. He used a coil of wire from the laboratory, connected to a galvanometer, and a bar magnet. He moved the bar magnet through the coil and there were deflections on the galvanometer. He used this to teach induction and Faraday's law of electromagnetic induction. Mr. C allowed some interested learners to also move the magnet through the coil themselves. Learners were given a summary of the lessons on the chalk board which they wrote into their note books. To evaluate learners conceptual learning, oral questions were also asked and learners answered by putting up their hands. Definition of electromagnetic induction and Faraday's law can be found in Appendix U.

LESSON 6: Mr. C concluded his lessons by using textbook pictures and explanations to teach transformers, power generation and distribution. They went through some calculations on transformers as well.

SUMMARY OF TEACHER AND LEARNERS ACTIVITIES DURING THE SIX LESSONS OF MR. C.

In order to view Mr. C's lessons as learner-centred or teacher-centred, the activities of Mr. C and his learners during all the six lessons have been summarized in table 4.1 below.

Table 4.1: MR C's LESSONS COMPARED TO A TEACHER CENTRED OR LEARNER CENTRED APPROACH

LESSONS	TEACHER ACTIVITY	LEARNER ACTIVITY	LEARNER/ TEACHER CENTRED APPROACH
Lesson 1: Magnets, magnetic poles and magnetic field lines	Teacher reviewed lessons on magnets by asking learners to draw a bar magnet showing magnetic field lines. Teacher called two learners to the chalk board to present their solutions. Teacher demonstrated magnetic field lines with paper, iron fillings, and a bar magnet. Teacher put into groups to perform the activity as well.	Learners responded by drawing bar magnets and the field lines. Two learners presented their drawings on the chalk board. Learners looked on as the teacher used iron filings to demonstrate the magnetic field lines and were asked to perform the same activity as well in their groups.	This lesson was learner centred as learners were actively involved and they used the skill of communication. As discussed in section 2.2.4 this is a features of learner centred lesson.
Lesson 2: Field around a straight wire, Right hand grip rule, Field around circular wire and Field around a solenoid	Teacher taught the learners from the textbook and explained the concepts using the pictures in their textbook. Teacher also showed learners a magnetic compass.	Learners listen to the teacher as he explained the concepts.	Lesson was abstract and learners were quiet in class as discussed in teacher centred teaching approach in section 2.2.3

Lesson 3: Electromagnets and their uses	Teacher taught electromagnets and explained its everyday application in the electric bell. Teacher showed learners a real electric bell as he explained its working and gave notes on the electric bell.	Learners listen to the teacher as he explained the concepts. Learners paste notes in their books.	This lesson was not abstract as learners saw the real electric bell but learners were quiet in class just listening to the teacher. The lesson was teacher centred.
Lesson 4: Fleming's left hand rule, force on current carrying conductor in a magnetic field, and motors	Teacher taught these topics using explanations and accompanying pictures from the learners' textbook.	Learners listen to the teacher as he explained these concepts.	This lesson was teacher centred as learners were passive participants because there was no activity for them to do.
Lesson 5: Electromagnetic induction and Faraday's law	Teacher used a coil of wire from the laboratory, connected to a galvanometer, and a bar magnet to teach electromagnetic induction and Faraday's law of electromagnetic induction. Teacher allowed some interested learners to also move the magnet through the coil themselves.	Learners looked on as the teacher demonstrated induction and Faraday's law. Some learners also perform the activity of induction.	After the demonstration by the teacher, some learners move the magnet through the coil. This lesson was not teacher centred since some learners were engaged in the activity.
Lesson 6: Transformers, power generation and distribution	Teacher concluded lessons by using textbook pictures and explanations to teach transformers, power generation and distribution. Teacher did some calculations on the chalk board with regards to transformers.	Learners listen to the teacher as he explained these concepts and wrote the examples on the calculations on transformers in to their note books.	In this lesson the teacher explained and wrote on the board. Learners were passive and only listened to the teacher and copy what was written on the chalk board. As mentioned in section 2.2.3, the focus was only on the teacher. This makes this lesson teacher centred.

4.2.2 MR. E'S LESSONS

Mr. E taught the topics in six lessons, of four 40 minutes periods and two 80 minutes periods. The double periods were extended by about 15 minutes each, because these two periods were last periods. This was agreed on by learners and the teacher to allow for completion of all the topics within a specified time, so it did not pose any problems as learners were prepared to stay on 15 minutes after school twice for the lessons just as it was in Mr. C lessons.

It was intended that the lessons of the experimental group will take place in the school's computer laboratory. But due to the use of the computer laboratory for teaching at the times it was needed for the research lessons, we could not use it. At the time of the research, the school's internet connections were also down, so Java software could not be downloaded to be able to play the simulations. For these reasons, the experimental group also had their classes in the Science laboratory. Instead of each learner sitting by a computer and working through the simulations, the teacher, Mr. E, used the researchers lap top and the schools data projector to teach electromagnetism using the PhET simulations and simulations from the Plato learning center**.** Below are the details of Mr. E's lessons as observed by the researcher using the observation schedule (Appendix A). These details of the observation of lessons given below are extracted from appendix A_7 to A_{12} and field notes taken during the lesson observations.

LESSON 1: Both Mr. E and Mr. C were following the same lesson plan and the same teaching sequence. So during his first lesson, Mr. E also reviewed grade 10 magnetism with the learners. Mr. E used a learner-centred approach in his teaching. As discussed in section 2.2.4 paragraph 2, Mr. E did not place himself as the active agent and his learners as passive vessels, so he started his lesson by distributing some bar magnets to the learners who were already grouped into five groups. He also gave each group a nail. The learners were asked to name these two apparatus by putting up their hands. After one learner identified the magnet and the nail, Mr. E instructed them to put the magnet and the nail about 15 cm apart, and observe what happens and take note. They then moved the nail closer to the magnet about 5 cm from its original position. This was done till the magnet attracted the nail; learners were then asked to discuss in their groups why the nail was not attracted at the earlier positions. It was concluded as part of the class discussion that the nail was not in the magnetic field that was why it was not attracted, and only got attracted when it got into the magnetic field. The lesson then proceeded, with Mr. E asking the learners to draw the bar magnet and indicate the north and the south poles, the field lines, and the direction of the field lines. Again the learners of Mr. E also struggled, just as Mr. C's learners as stated in lesson 1 of Mr. C's lesson. So Mr. E showed them a simulation of the field lines using the data projector. Below is a screen shot of the field lines.

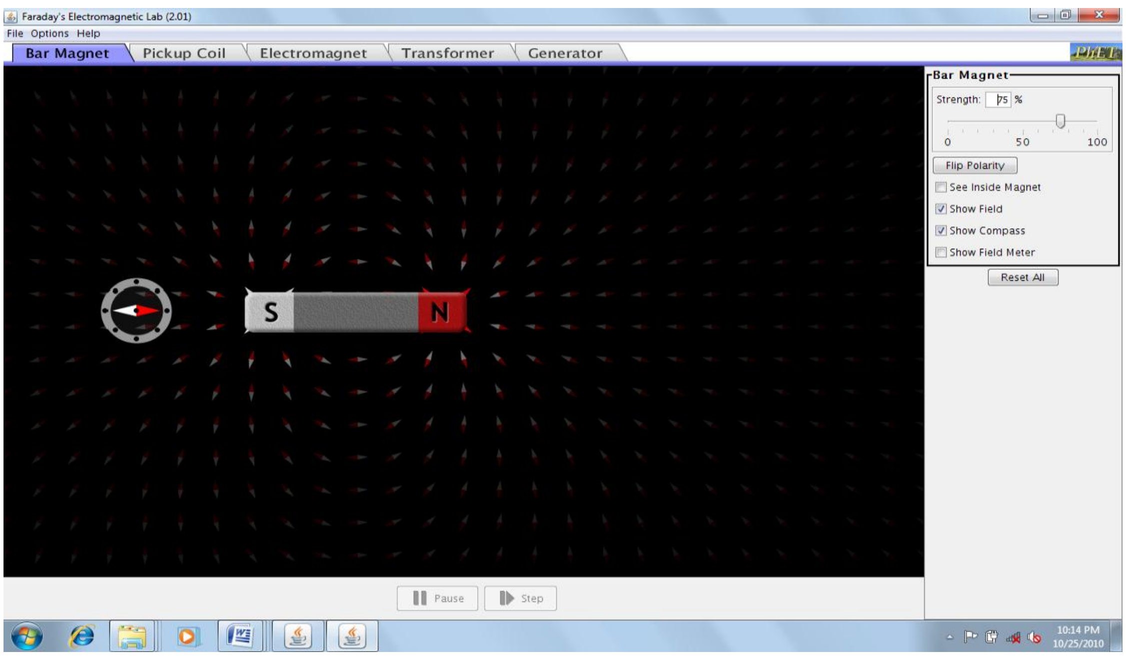

Figure 4.2: Screenshot from PhET Interactive Physics simulation showing magnetic field lines.

From this simulation, Mr. E could flip the magnet to change the polarities of the magnet and hence the directions of the field lines always move from north to south. Also there was a magnetic compass which also indicated the change in direction of the field lines each time the magnet was flipped. Mr. E then showed the learners a real magnetic compass from the school laboratory. But the difference between lesson 1 of Mr. C and that of Mr. E was that the learners of Mr. E could see the magnetic field lines and their directions from the simulation. They also saw the magnetic compass in use in the simulation. Here Mr. E was using the simulation as scaffold to help the learners as mentioned in the theoretical framework in this report. And this could address conceptual understanding as the learners could see the how the direction of the field lines changes when the magnetic poles are changed.

LESSON 2: Mr. E's second lesson was also on:

- Fields around a straight wire carrying current
- Right hand grip rule
- Field around a circular wire
- Field around a solenoid

Since the school laboratory does not have the appropriate equipment to practically demonstrate these concepts Mr. E used, pictures from the learners' textbook (Kelder, 2005). But unlike Mr. C, Mr. E supported his lessons with computer simulations. Below are screen shots of the simulations which Mr. E used to support his lessons.

Figure 4.3 below shows a screen shot from the Java applets on Physics. This is one of many free simulations downloaded from the internet by the researcher for the use of this research.
From this simulation, Mr. E's learners were able to predict what was going to happen to the field lines if the current in the conductor was reversed according to the right hand grip rule. This shows that learning has taken place and the learners took active part in the process. Learners were asked to observe these changes as they were used to further explain the right hand grip rule. This time learners could visualise the concepts.

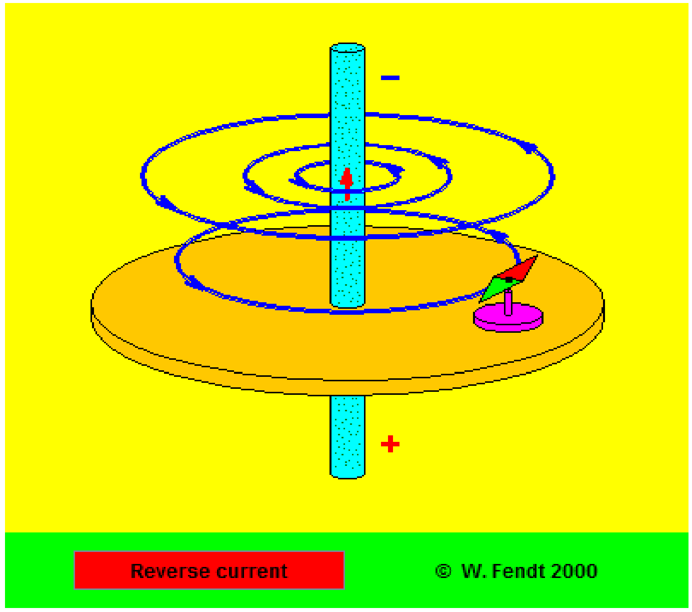

Figure 4.3: Screenshot from Interactive Physics simulation showing Fields around a straight wire carrying current to show the right hand grip rule.

LESSON 3: Mr. E used PhET simulations to teach electromagnetism. Faraday's electromagnetic laboratory (2.01) is a screen shot from PhET simulations (see Fig 4.4). In this simulation, Mr. E could pick, a bar magnet, a coil, an electromagnet, a transformer and a generator. This simulation allows the teacher to show, the field lines, compass, and the flow of electrons in the coil of wire. He used it to explain what an electromagnet is, how it works and its daily applications and uses.

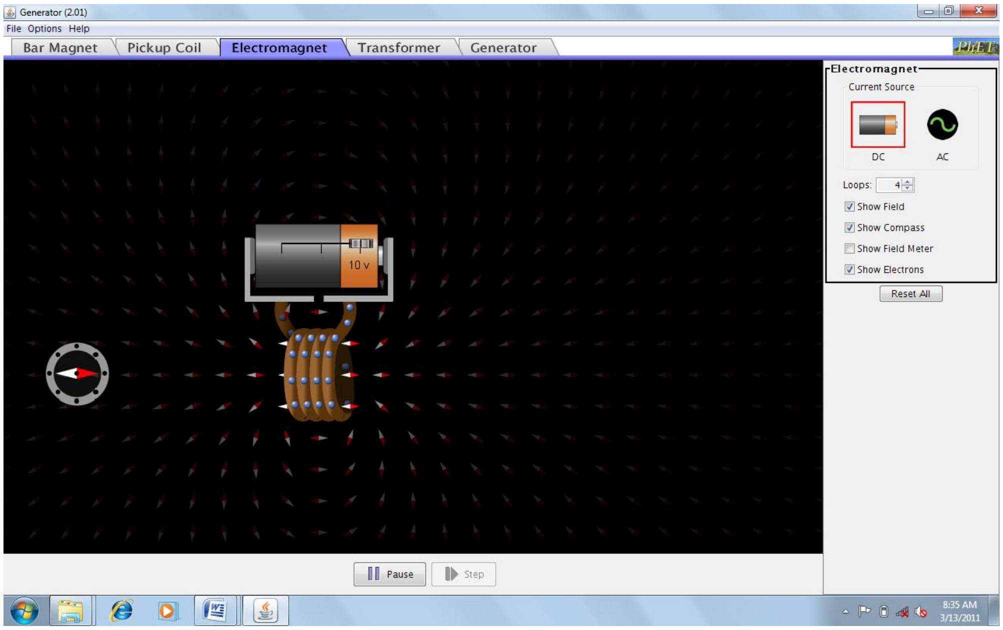

Figure 4.4: Screenshot from PhET Interactive Physics simulation showing electromagnet.

After using the simulation to teach electromagnets, Mr. E moved on to its use in electric bells and magnetic relays. This time Mr. E projected the circuit diagram of the electric bell scanned from their text book for learners to see. He used the diagram to teach learners how electromagnets are applied in the electric bell (See Appendix V). He also gave the learners a summary of notes on how the electric bell works to paste in their note books. These learners were also given the real electric bell in the laboratory to see just as Mr. C did in his lesson.

LESSON 4: This lesson was on Fleming's left hand rule, force on a current carrying conductor in a magnetic field and the motor effect. For the purposes of these topics the researcher borrowed a CD - ROM of simulations from Penryn College, a private high school in Nelspruit. These simulations are not free. The school bought the CD – ROM from Plato learning UK Ltd. With this CD-ROM, Mr. E was able to easily teach the three topics in this lesson. The screen shot below gives four scenarios. The first is field around a current carrying conductor, the second is the force on a current carrying conductor placed in a magnetic field, the third scenario is the motor effect and the last scenario is the DC motor based on Fleming's left hand rule.

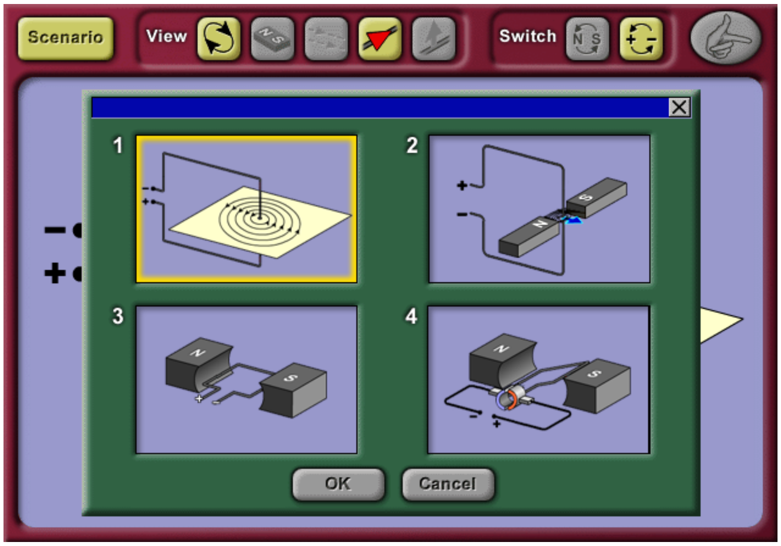

Figure 4.5: Screenshot from Plato learning Interactive Physics simulation showing the four scenarios.

Mr. E used the different scenarios to explain the concepts to the admiration of the learners and the researcher. In scenario one where the field around a current carrying conductor is presented, the simulations allow you to show: (a) the field lines (b) current directions in the wire (c) switch the positive and negative of the current in the wire. Below are screen shots of these different situations.

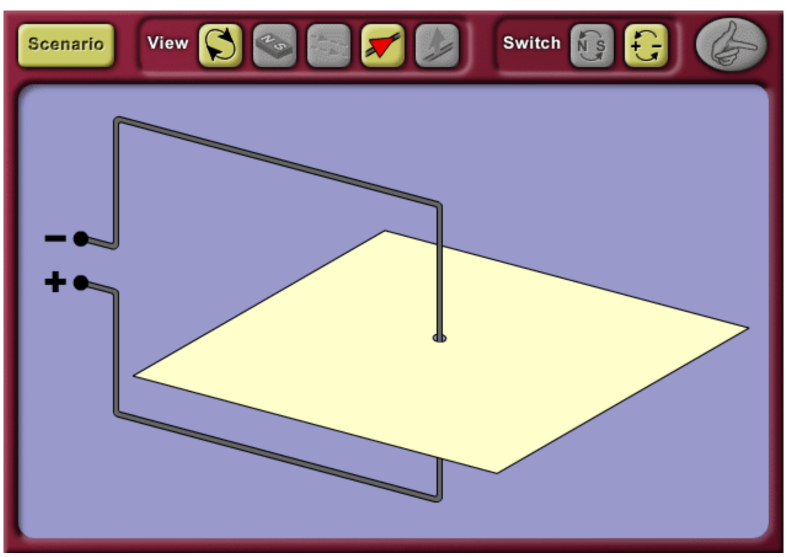

Figure 4.6: Screenshot from Plato learning Interactive Physics simulation showing a current carrying conductor.

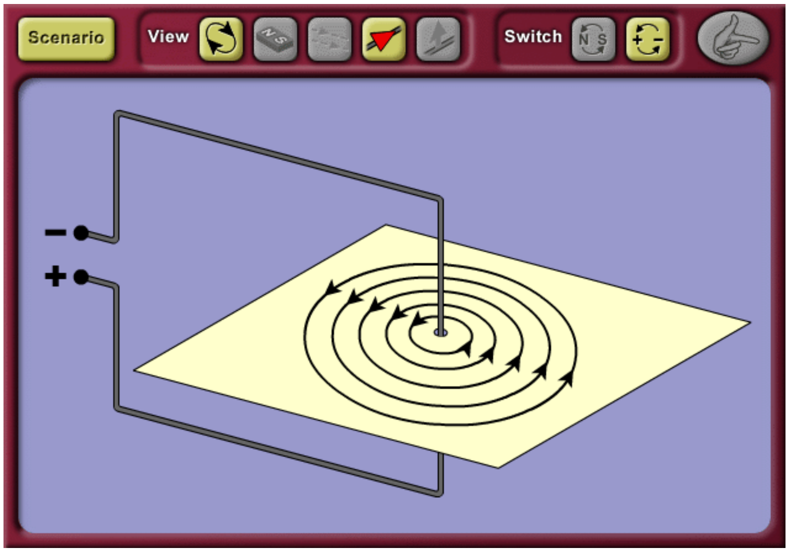

Figure 4.7: Screenshot from Plato learning Interactive Physics simulation showing the field lines. around a current carrying conductor.

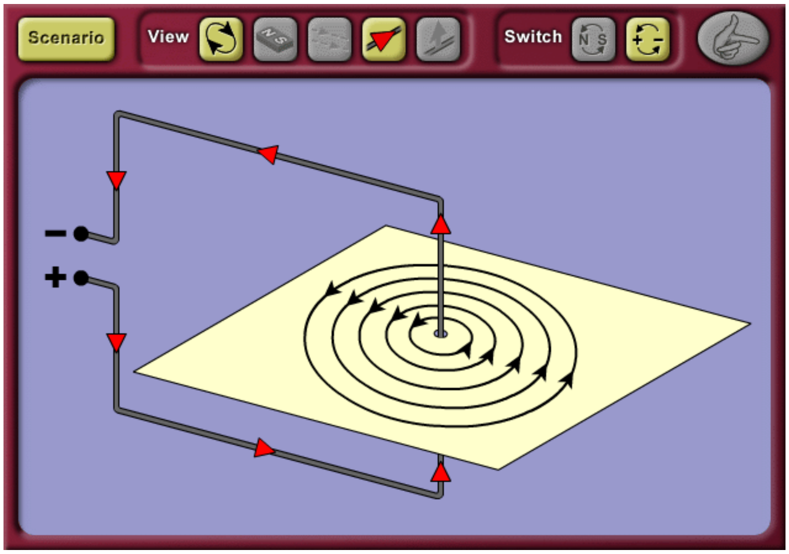

Figure 4.8: Screenshot from Plato learning Interactive Physics simulation showing current Direction (arrow), in the wire.

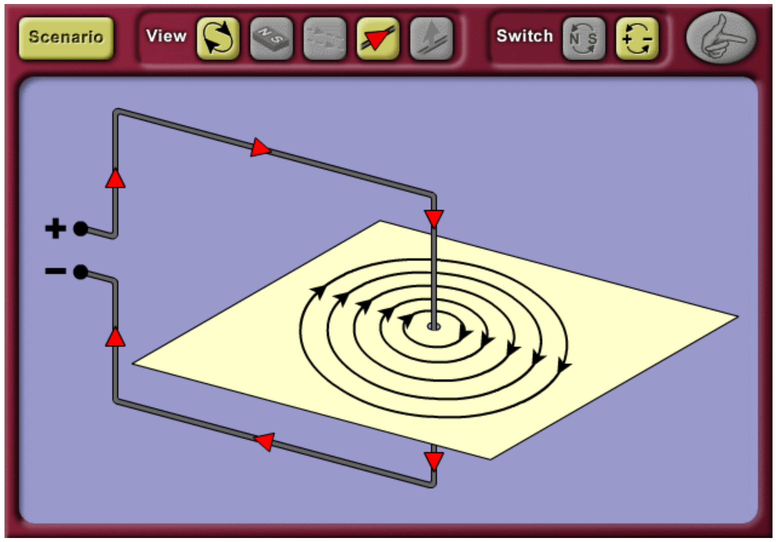

Figure 4.9: Screenshot from Plato learning Interactive Physics simulation showing a change in direction of the current in the wire.

From figure 4.8 and 4.10, Mr. E emphasized the change in the direction of the field lines around the conductor when the direction of the current was switched. This is because as stated in literature in section 2.4, Saglam and Millar (2006) contended that learners have a poor understanding of these basic concepts in electromagnetism. Also from section 1.1 paragraphs 4 of this report mentioned that many schools in South Africa do not have laboratories. Then in section 2.4, Saglam, (2010) suggests that teachers will have to come up with effective instructional designs to enable learners to understand the fundamental ideas in electromagnetism. And according to Dori and Belcher (2004), in the field of electromagnetism, technology-rich environments such as computer simulations are very crucial, as they can enable the presentation of spatial and dynamic images and depict relationships among difficult concepts for learners to understand.

In scenario 2, 3 and 4, the simulations allow you to show (a) magnetic field lines between the magnets, (b) current directions in the wire, (c) change the positions of north and south of the magnets, (d) the direction of force on the wire and (e) the Fleming's left hand in the scenario, demonstrating the Fleming's left hand rule. All this will go a long way to help learners to understand these basic concepts in electromagnetism. Below are the screen shots of the five different situations for the three scenarios, (scenario 2, 3 and 4).

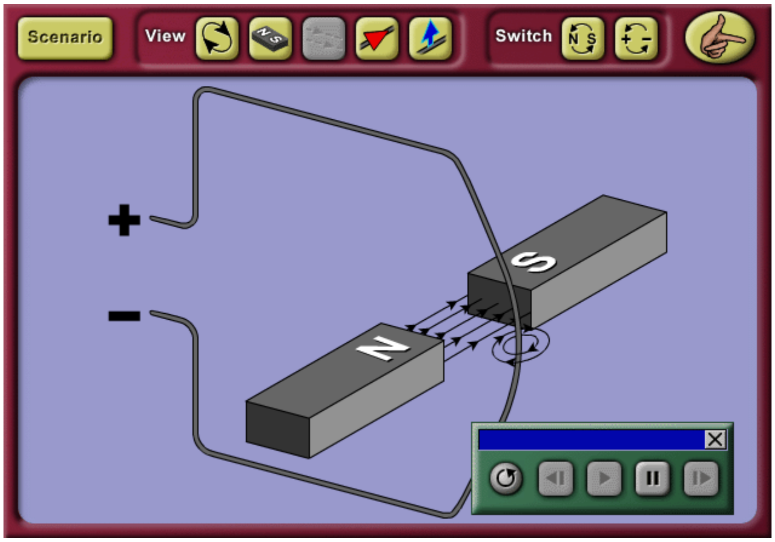

Figure 4.10: Screenshot from Plato learning Interactive Physics simulation showing magnetic field lines and field around the conductor.

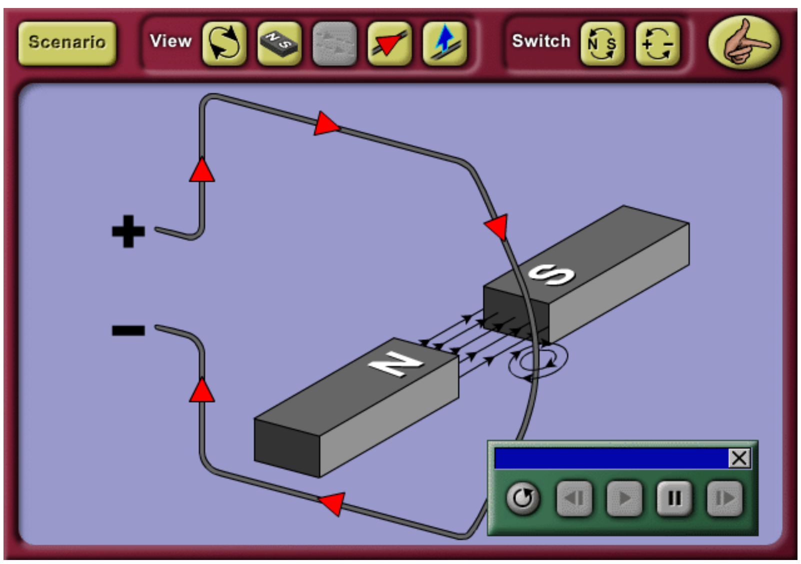

Figure 4.11: Screenshot from Plato learning Interactive Physics simulation showing current direction (arrow), in the Wire.

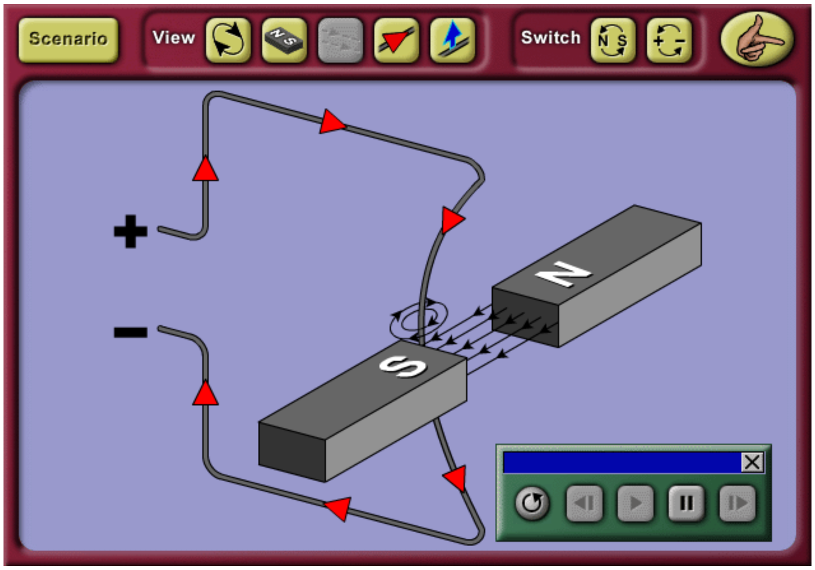

Figure 4.12: Screenshot from Plato learning Interactive Physics simulation showing a change in the positions of north and south of the magnets and hence, change in the direction of the force on the conductor.

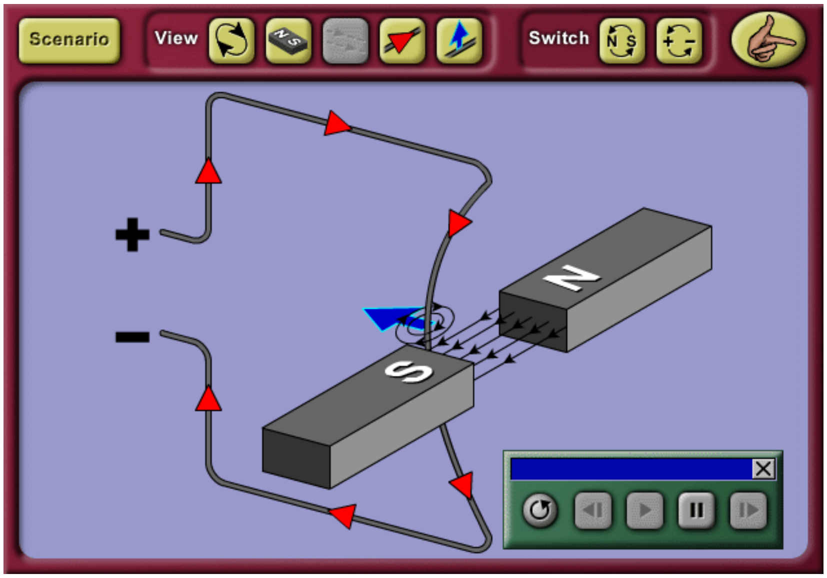

Figure 4.13: Screenshot from Plato learning Interactive Physics simulation showing the direction of force (big arrow), on the wire.

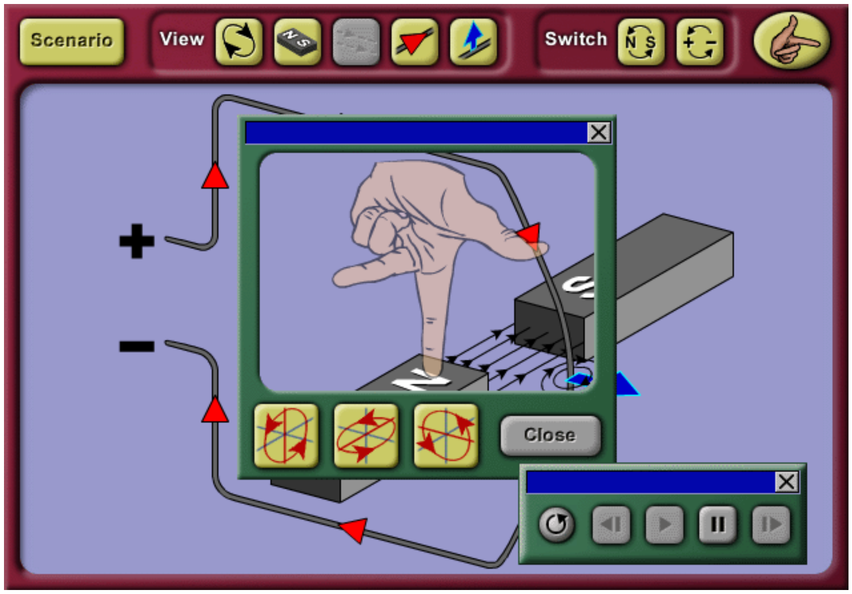

Figure 4.14: Screenshot from Plato learning Interactive Physics simulation showing the Fleming's left hand in the scenario.

These simulations helped the learners to comprehend the concepts as they responded correctly to oral evaluation conceptual questions asked by the teacher, Mr. E. The analysis of the post-test results as indicated in sections 4.3.3, 4.3.4 and 4.3.6 confirms that Mr. E's learners benefited from the simulations. The learners also gave correct predictions when they were asked to predict for instance the direction of the conductor when the positions of the north and south of the magnets were changed in figure 4.11 and 4.13. They predicted correctly by drawing figure 4.12 in their note books before Mr. E showed the simulation of it.

LESSON 5: Mr. E used simulations to teach electromagnetic induction and Faraday's law of electromagnetic induction which according to Dori and Belcher (2004) are considered difficult for learners to visualise (see section 2.4). The simulation of Faraday's law of electromagnetic induction is also another very interesting and elaborative simulation from the PhET. In this simulation the user could (a) use just one coil or two coils, (b) show field lines of the magnet, (c) flip the magnet to change the positions of the north and south of the magnet and these enable the learners to visualise the concept. Below are screen shots of these situations in the Faraday's law of electromagnetic induction simulation and how Mr. E used them in the lesson.

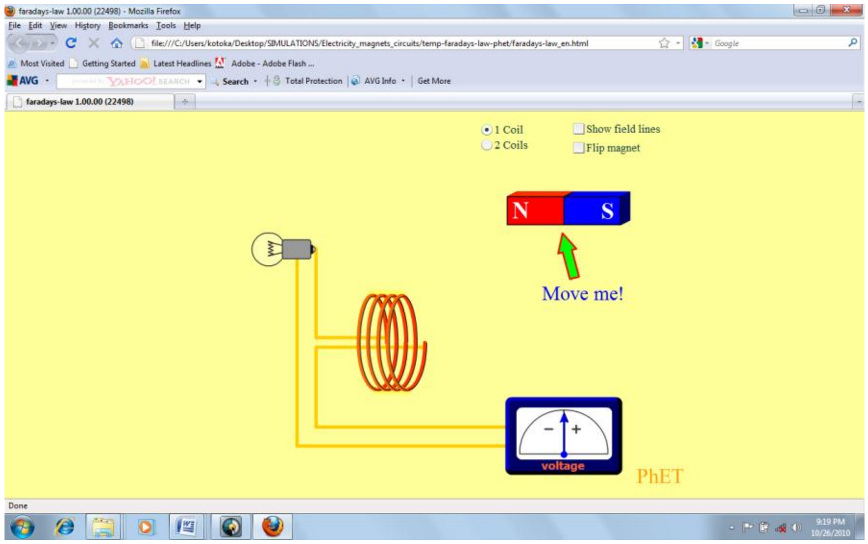

Figure 4.15: Screenshot from PhET Interactive Physics simulation showing a bar magnet with one coil.

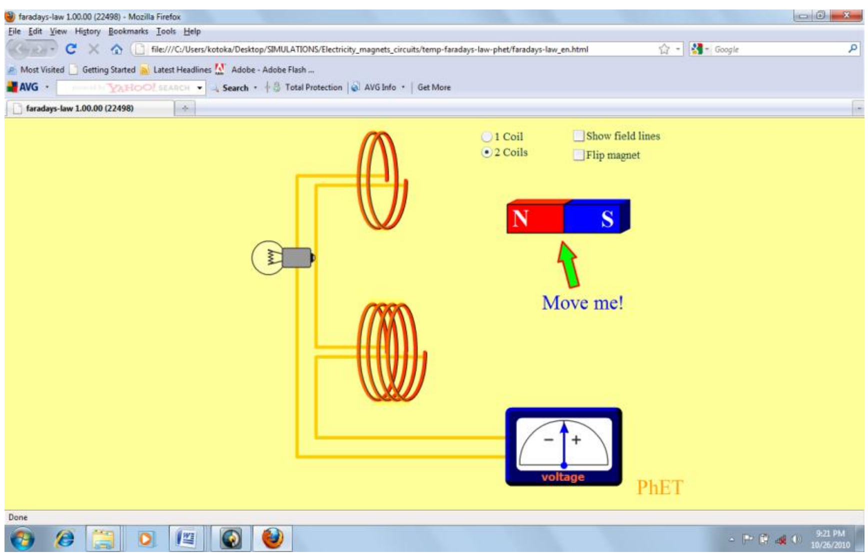

Figure 4.16: Screenshot from PhET Interactive Physics simulation showing a bar magnet with two coils.

After Mr. E picked the second coil, he moved the magnet through the upper coil (less winding) whiles learners were asked to observe what happens with the bulb and galvanometer critically. He then moved the magnet in the same way, through the lower coil (more winding). In the two instances the magnet went through the coil with the North Pole facing the coil, and then it was withdrawn. The speed of the movement was also maintained. The learners attention was brought to all these to enable them to make their judgments. Learners were then asked to discuss in their groups, what the differences were with respect to the brightness of the bulb and the deflection on the galvanometer.

From the verbal reports presented by the leaders from each group, all the groups observed that, the light bulb glow brighter and the galvanometer deflected more when the magnet was moved through the lower coil which has more winding. This signifies that learning has taken place as discussed in literature and mentioned in section 2.2.2. Meanwhile electromagnetic induction is one of the problem areas mentioned earlier in literature, section 2.4. Planic (2006) reported from a study conducted in Croatia and replicated in America that the most difficult area of electromagnetism found among learners in these two countries was electromagnetic induction. Mr. E emphasized that, the induced current depends on the:

- number of windings
- strength of the magnet and
- speed of the movement.

For figure 4.17 and 4.19, learners were asked to again observe and discuss what happens when the north and south poles of the magnet were flipped as shown below. Learners saw that the directions of the deflection on the galvanometer changed as the poles of the magnet was flipped and moved through the coils.

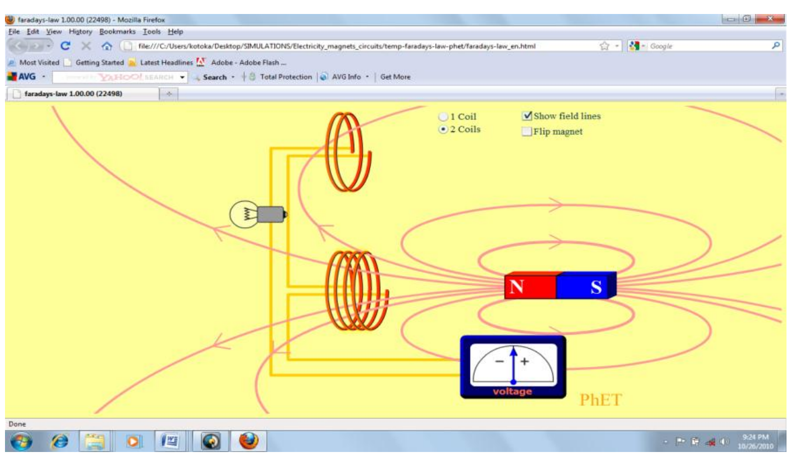

Figure 4.17: Screenshot from PhET Interactive Physics simulation showing the field lines of the Magnet.

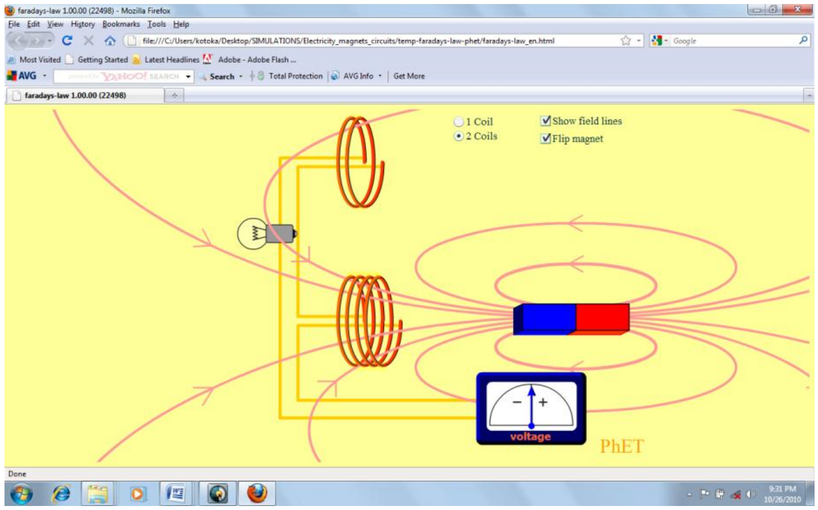

Figure 4.18: Screenshot from PhET Interactive Physics simulation showing a flip of the magnet to change the positions of the north and south, and the direction of the field lines of the magnet.

LESSON 6: This was Mr. E's last lesson; he combined simulations and pictures from learners' textbooks to teach transformers, power generation and power distribution linking the new lesson to Faraday's law in the previous lesson. The principle of mutual induction was explained using figure 4.19 below.

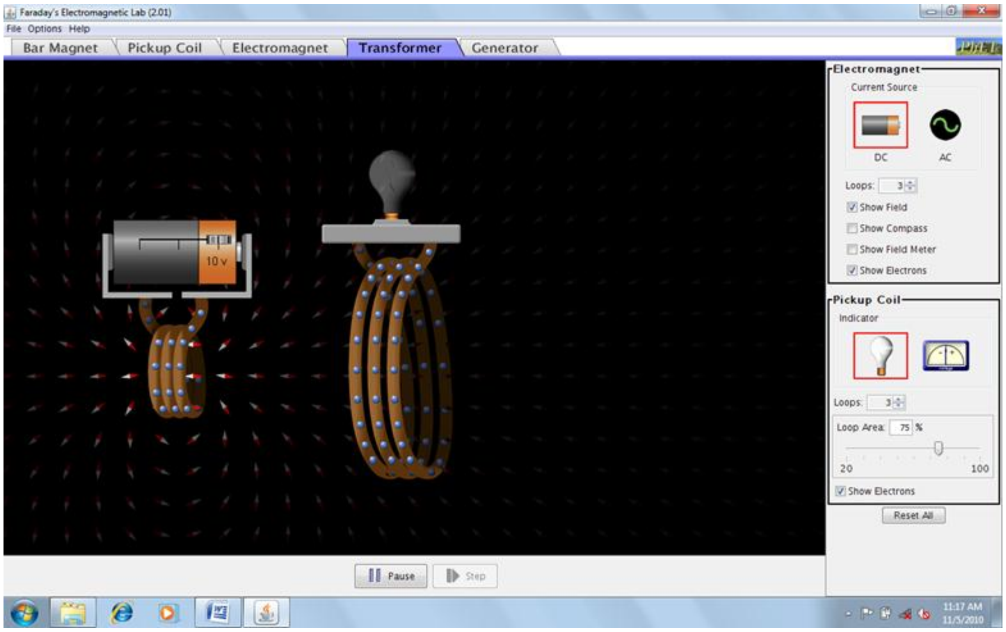

Figure 4.19: Screenshot from PhET Interactive Physics simulation showing a transformer.

From the transformer (figure 4.19), when the alternating current (which is continually changing direction) is passed through the primary coil, a continually changing magnetic flux induces a continually changing current in the secondary coil. The learners observed and listened as Mr. E explained using the simulation and pictures from their text book to demonstrate the induction.

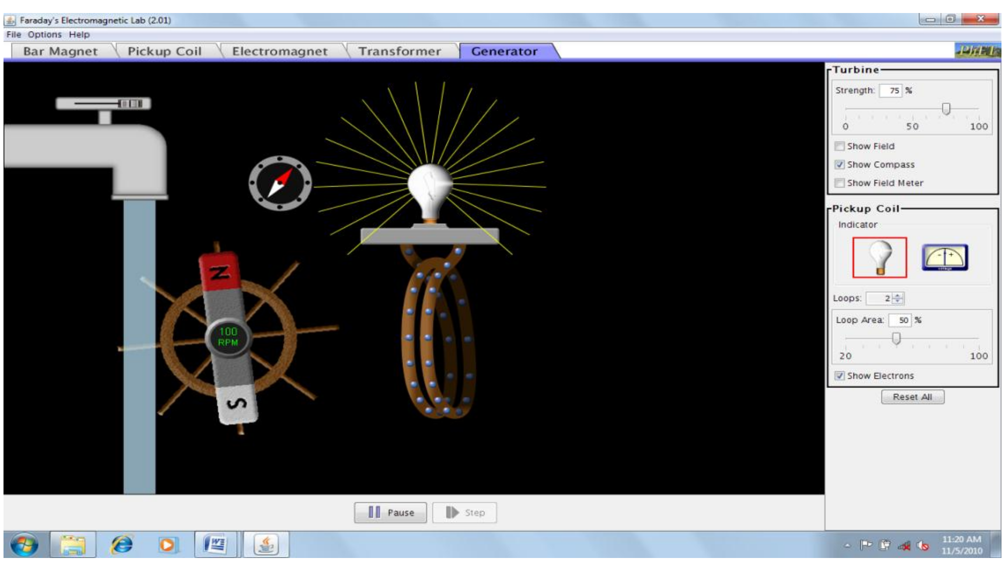

Figure 4.20: Screenshot from PhET Interactive Physics simulation showing the generator.

Figure 4.20 was used to explain power generation in a hydroelectric power system. From the simulation as more water was released from the tap (dam), the magnet (turbine) turns faster. This induces more alternating current in the coil carrying the bulb and the bulb glows brighter. As the water is reduced, the bulb glows dimmer as a result.

SUMMARY OF TEACHER AND LEARNERS ACTIVITIES DURING THE SIX LESSONS OF MR. E.

In order to view Mr. E's lessons as learner-centred or teacher-centred, the activities of Mr. E and his learners during all the six lessons have been summarized in table 4.2 below.

Table 4.2: MR E's LESSONS COMPARED TO A TEACHER CENTRED OR LEARNER CENTRED APPROACH

LESSONS	TEACHER ACTIVITY	LEARNER ACTIVITY	LEARNER/ TEACHER CENTRED APPROACH
Lesson 1: magnets, magnetic poles and magnetic field lines	Teacher distributed some bar magnets and nails to the learners in their five groups. The learners were asked to name these two apparatus. Leaners were asked to: put the magnet and the nail about 15 cm apart, and observe what happens, move the nail closer to the magnet about 5 cm from its original position till the magnet attracted the nail, discuss in their groups why the nail was not attracted at the earlier positions, draw a bar magnet showing magnetic field lines. Teacher then showed them a simulation of the field lines (Fig. 4.2).	One learner identified the magnet and the nail. Learners perform the activity as instructed in their groups. Learners discuss in their groups why the nail was not attracted at the earlier positions but was attracted when it got nearer to the magnet. Five learners, one from each group presented a verbal report of their group discussions to the class. Learners drew bar magnets showing magnetic field lines. Learners who got the directions of the field lines wrong corrected their mistakes after they visualized it from the simulation.	This lesson was learner centred as learners were actively involved using general skills of inquiry, communication, critical thinking, and problem solving. And these are features of learner centred lesson as discussed in section 2.2.4
Lesson 2: Field around a straight wire, Right hand grip rule, Field around circular wire and Field	Teacher used computer simulations to support his teaching of these concepts. Teacher asked learners to predict observe and explain what was going to happen to	Learners predicted and explain what was going to happen to the field lines if the current in the conductor was reversed according to the right hand grip rule using the	In this lesson, learners were actively predicting, observing and explaining

around a solenoid	the field lines if the current in the conductor was reversed according to the right hand grip rule using the computer simulations (Fig 4.3).	computer simulations as they could see the directions easily in fig 4.3.	concepts and the teacher used computer simulations to facilitate the learning process. So this lesson was learner centred.
Lesson 3: Electromagnets and their uses	Teacher used computer simulation which allowed him to show, the field lines, compass, and flow of electrons to explain electromagnets and how it works and its daily applications and uses such the electric bell. Teacher projected the circuit diagram of the electric bell scanned from their text book for learners to see. Teacher gave summary of notes on how the electric bell works to learners to paste in their note books.	Learners listen to the teacher as he explained the concept. Learners paste notes in their books	In this lesson, learners were not actively in involved. They mainly listened to explanations from the teacher. This as discussed in section 2.2.3 is a characteristic of teacher centred lesson.
Lesson 4: Fleming's left hand rule, force on current carrying conductor in a magnetic field, the motor	Teacher used computer simulation to teach current carrying conductor, force on a current carrying conductor placed in a magnetic field, the motor effect and the DC motor based on Fleming's left hand rule by asking learners to predict, observe and explain. Teacher asked learners to predict for instance the direction of the conductor when the north and south of the magnets were switched in figure 4.11 and 4.13.	Learners listened and watched the simulations with keen interest asking questions for clarification. Learners were correctly predicting directions of field lines, directions of force on the conductor after listening to explanations with the simulations. Learners for example predicted correctly by drawing figure 4.12 in their note books before its simulation was projected.	Learners were active predicting, observing and explaining concepts and the teacher used computer simulations to facilitate the learning process. So the lesson was learner centred.
Lesson 5:	Teacher asked learners to	Learners observe the	Learners then

electromagnetic induction and Faraday's law	observe what happens with the bulb and galvanometer in fig 4.17 critically while the teacher moved the magnet through the upper coil (less winding) and lower coil (more winding) with the same speed of the movement. In the two instances the magnet went through the coil with the North Pole facing the coil, and then it was flipped with the south Pole now facing the coil. Teacher then asked Learners to discuss in their groups, what the differences were with respect to the brightness of the bulb and the deflection on the galvanometer.	computer simulations and some asked the teacher to repeat some actions for better observations. Learners then discussed in their groups, what the differences were with respect to the brightness of the bulb and the deflection on the galvanometer. Five learners, one from each group presented a verbal report of their group discussions to the class.	Learners were involved actively in their groups discussing what they have observed. It was also evident that the leaners in their groups used skills of inquiry, communication, critical thinking, and problem solving. And from the discussion in section 2.2.4 paragraph 3, this lesson was learner centred.
Lesson 6: transformers, power generation and distribution	Teacher combined simulations and pictures from learners' textbooks to teach transformers, power generation and power distribution. Teacher explained the principle of mutual induction using figure 4.19. Teacher used Fig. 4.21 to explained power generation in a hydroelectric power system.	Learners listened to the explanations and visualise from the simulation that as more water was released from the tap (dam), the magnet (turbine) turns faster. This induces more alternating current in the coil carrying the bulb and the bulb glows brighter. As the water is reduced, the bulb glows dimmer as a result.	Even though learners could vsualise the concepts from the simulations, learners were not active in this lesson and that makes the lesson teacher centred.

4.2.3 ANALYTIC COMPARISON OF THE TWO LESSONS

From the discussion of the observations of the two lessons, Mr. C used a more teacher-centred teaching approach. Apart from lesson 1 where Mr. C allocated learners to groups to perform an activity, and lesson 5 where some learners could perform the activity by moving the magnet through the coil, the rest of his lessons were characterised by him giving explanations and learners being passive and listening. This could be attributed to the fact that the school did not have the relevant apparatus for Mr. C to be able to carry out all the activities with his learners.

On the other hand, Mr. E used simulations in almost all his lessons. He involved the learners in the lessons. He asked learners to predict, observe and explain. He assigned the learners to groups to discuss a phenomenon they have observed and this allowed learners to communicate amongst themselves but also between him and the learners. As discussed in the theoretical frame work he used the simulations to help learners to understand and to learn concepts that were described in the literature as difficult for learners by providing scaffolding. This is evident in table 4.5 under section 4.3.3 where learners in the experimental group improved better in the post-test. The performance of his learners in the post-test analysis in section 4.3.3 and 4.3.4 attests to this assertion. This teaching approach is also in line with the constructivist learner-centred approach discussed in section 2.2.4 of this report. Hake, (1998) described this approach of teaching as medium <g> course which combines both the traditional modes and the interactive-engagement models of teaching as discussed in section 4.3.7. Mr. E's lesson therefore was characterised by active participation of learners, where learners predicted, observed and explained concepts in electromagnetism using computer simulations as well as real equipment (magnets, nails and a real electric bell) in their assigned groups.

The zone of proximal development (ZPD) a critical component of constructivism (see theoretical framework), conceived that learning takes place by the learner completing tasks for which support (scaffolding) is initially required. This support may include a tutor, a peer or technology such as the applications of computer simulations, Mr. E, the teacher, the computer simulations, and the demonstrations acted as the support or the scaffolding which helped the learners to construct their knowledge and understanding of the topic electromagnetism as reflected in the analysis in table 4.7 in section 4.3.6 below.

4.3 ANALYSIS OF TEST RESULTS

The results of pre-test and post-test conducted for both experimental and control groups were analysed. As stated in the second paragraph under research design section 3.2, the previous terms marks of the two groups (June examination marks) were obtained by the researcher to establish whether or not the two groups were of the same academic ability before the research started. These scores were also analysed in this section to establish whether or not the two groups were of the same academic ability before the research started. The June examination scores are shown in appendix T. The researcher used Statistical analysis tools in Microsoft excel to analyse the results. The mean, the standard deviation, median and the t-test were calculated using this approach.

4.3.1. ANALYSIS OF JUNE EXAMS

Using the Microsoft excel spreadsheet program to calculate the independent t-test for the June examination scores (appendix T) of the two groups showed that, there was no statistically significant difference between the two groups. Below is the table representing the results of the calculations on the June examinations.

Table 4.3: t-test: Two-Sample Assuming Unequal Variances for the June Examinations.

	11A (Control)	*11C (Experimental)*
Mean	42.11320755	40.01851852
Variance	168.3330914	117.2638015
Observations	53	54
Hypothesized Mean Difference	0	
df	101	
t Stat	0.905812175	
P(T<=t) one-tail	0.183595554	
t Critical one-tail	1.660080631	
P(T<=t) two-tail	0.367191107	
t Critical two-tail	1.98373095	

From the Microsoft excel calculations, $t = 0.906$, $df = 101$, $p = 0.3672$. The t-critical two tail is 1.984 approximately 2.00 at $p > 0.05$. The interpretation of this analysis is that since the t-critical 2.00 is greater than the t-statistics 0.906 at p > 0.05, there is no statically significant difference in the achievement of the two classes in the June examination. This t-test therefore established that the two classes were of the same academic ability before the treatment started.

4.3.2 ANALYSIS OF THE PRE-TEST OF THE TWO GROUPS

Even though, the June examination analysis shows that the two groups were comparable academically, a pre-test was conducted before the treatment to establish whether or not the two groups were of the same ability in the topic electromagnetism before the research started. The scores of this test (appendix G and H) were also analysed using Microsoft excel spreadsheet and the result is indicated in the table 4.4 below. In this analysis, t statistics = 0.390, df = 63, p = 0.05, t-critical two tail = 1.998 which is approximately 2.00. The interpretation of this is that since the t-critical 2.00 is greater than the t-statistics 0.906 at p > 0.05, there is no statistically significant difference in the achievement of the two classes in the pre-test. This means before the research the two groups were at the same level in the topic electromagnetism. In the table 4.2 Y_1 indicates the experimental group and Y_2 indicates the control group.

Table 4.4: t-Test: Two-Sample Assuming Unequal Variances for Pre-Test

	11A (Control)	*11C (Experimental)*
Mean	42.11320755	40.01851852
Variance	168.3330914	117.2638015
Observations	53	54
Hypothesized Mean Difference	0	
df	101	
t Stat	0.905812175	
P(T<=t) one-tail	0.183595554	
t Critical one-tail	1.660080631	
P(T<=t) two-tail	0.367191107	
t Critical two-tail	1.98373095	

4.3.3. ANALYSIS OF POST-TEST OF THE TWO GROUPS

Testing the null hypothesis and answering research question 1, the post-test scores (Appendix G and H) for the two groups (experimental group and the control group) were analysed. The post-test scores were entered into the Microsoft excel spreadsheet to calculate the mean out of 30, median, standard deviation and the t-test. Below is a table presenting the results of the Microsoft excel calculations of the post-test scores.

Table 4.5: t-Test: Two-Sample Assuming Unequal Variances for Post-Test

	Post-Test(Experimental – X_1)	*Post-Test(Control – X_2)*
Mean	16.3	12.54285714
Variance	21.18275862	13.78487395
Observations	30	35
Hypothesized Mean Difference	0	
df	56	
t Stat	3.582383911	
P(T<=t) one-tail	0.000356697	
t Critical one-tail	1.672522304	
P(T<=t) two-tail	0.000713394	
t Critical two-tail	2.003240704	

From table 4.5 above t-statistic = 3.582, df = 56, $p<0.05$ and t-critical two tail = 2.00. The interpretation of this result is that since the t-critical two tail = 2.00, is less than t-statistics 3.582. There is therefore a statistically significant difference between the post-test scores of the experimental group and the control group. The null hypothesis which states that, the use of computer simulations has no impact on the performance of grade 11 learners in electromagnetism is rejected.

4.3.4 ANALYSIS OF THE PERFORMANCE OF THE TWO GROUPS USING GRAPHS

Even though a statistical difference was established using the t-test, the following tables and graphs were also used to further confirm the difference.

Table 4.6: Description of group's performances in pre-test and post-test

	Statistics in Pre - test		Statistics in Post - test	
Index	Experimental Group	Control Group	Experimental Group	Control Group
Mean	8.3	8.5	16.3	12.5
SD	2.6	3.1	4.6	3.7
Highest Score	12	16	24	20
Least score	2	1	8	6
Range	10	15	16	14

Table 4.6 shows that even though the means of the two groups were almost the same for the statistics in the pre-test with the control group having 8.5 and the experimental group 8.3, the statistics in post-test, shows that the experimental group's mean improved significantly. The experimental group had a mean of 16.3 and the control group's mean was 12.5. This data is also clearly shown in the bar graph below.

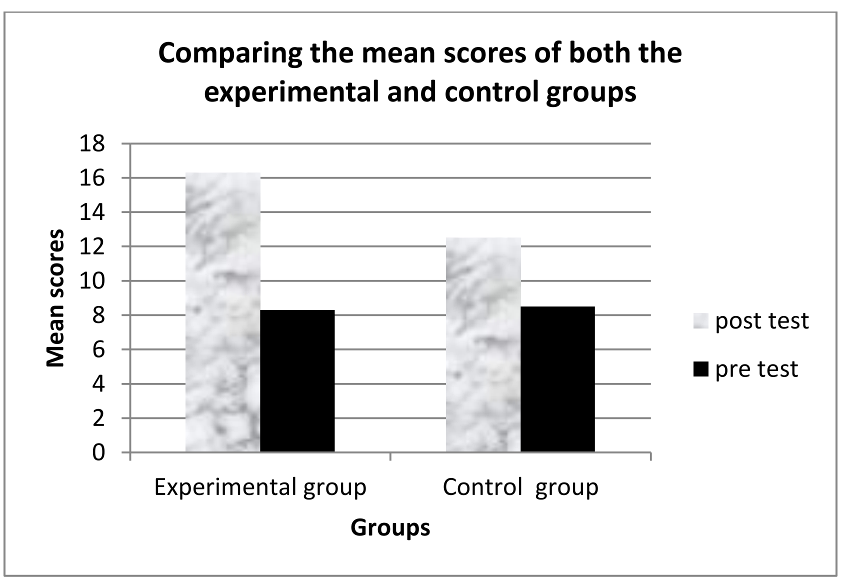

Figure 4.21: Mean performance of learners in the pre-test and post-test

The graph below is used to indicate the difference in performance of the learners from pre-test to the post test for the control group. Learners' names are represented with numbers (Learner representation) on the x – axis for anonymity.

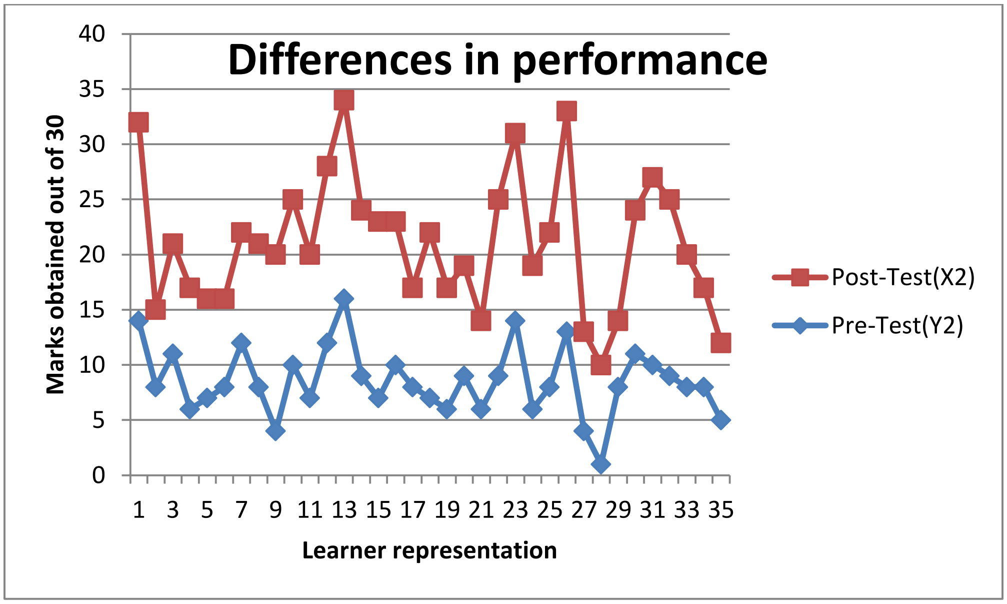

Figure 4.22: Graphical representation of pre-test and post-test of the control group

From the graph it is evident that each of the learners improved their marks after the topic electromagnetism was taught to them. But comparing figure 4.22 to figure 4.23 below further confirms that the learners in the experimental group have improved more in their performance than the learners in the control group after the intervention.

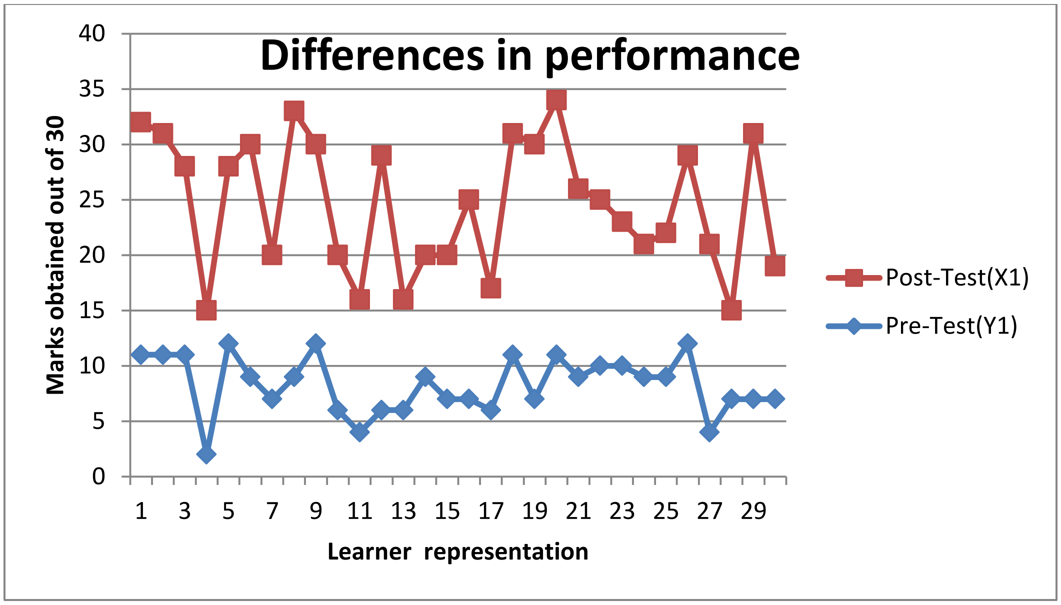

Figure 4.23: Graphical representation of pre-test and post-test of the experimental group

This graph also shows that all the learners have improved their marks from the pre-test to the post-test. And comparing the two graphs, the intervention helped the learners in the experimental group compared to the control group to improve their marks. This is attributed to the more learner-centred teaching approach used by Mr. E and the use of the simulations which help the learners to visualize the concepts and allow them to construct their own understanding by predicting, observing and explaining the topics presented.

4.3.5 RESEARCH QUESTION 1: Does the use of computer simulation have an impact on the performance of grade 11 learners in electromagnetism?

So, in answering research question 1, the results of the analysis in 4.3.3 above indicate that computer simulations does have an impact on the performance of grade 11 learners in electromagnetism, because, the results of the t-tests indicated statistical significance difference in the performance at $p < 0.05$. The null hypothesis which states that, the use of computer simulations has no impact on the performance of grade 11 learners in electromagnetism is therefore rejected.

4.3.6 ANALYSIS OF TEST ITEMS

As the t-test showed statistical significance in the performance between the post-test scores of the experimental group and the control group, the following analysis in table 4.7 was done to determine the conceptual improvement in the concepts taught under electromagnetism in this research. (See table 4.7)

Table 4.7: Analysis of test questions

Questions on	Question numbers	Control Group Performance in %			Experimental Group Performance in %		
		Pre test	Post test	Improvement	Pre test	Post test	Improvement
Current carrying conductor	1, 2	40	45	5	39	58	19
Induced emf	3, 4, 5, 6, 7	27	29	2	16	35	19
Electromagnets	8, 9, 15, 16, 22	32	34	2	31	44	13
Motors	10, 18, 24	14	30	16	9	39	30
Magnetic poles	11, 12, 21	76	73	-3	76	86	10
Magnetic field lines	13, 14, 17	47	67	20	40	77	37
Transformers	19, 20	23	79	56	28	63	35
Electromagnetic induction and Faradays Law	23, 25	5	5	0	0	15	15

From the analysis in table 4.7, the control group showed minimal improvements in aspects of the test, but a good improvement in questions on transformers (questions 19 and 20). Many of the learners in the control group were able to answer question 20, which is a calculation on transformers but only few of the learners in the experimental group answered that question 20 correctly. There was no conceptual improvement in electromagnetic induction and Faraday's law for the control group and limited improvement for the experimental group. There was about 3% drop from the pre-test on magnetic poles for the control group. This is due to many of them drawing the transformer instead of the magnetic poles and its field lines in the post-test. However the experimental group showed a better conceptual improvement in all aspects of the test except for the aspect on transformers.

4.3.7 HAKE'S NORMALIZED GAIN

Average normalized gain, (<g>), has been an important tool for the characterization of conceptual improvement in Physics courses since its use in Hake's extensive study on conceptual learning in introductory Physics (Stewart, 2010). So, to see the gains in the scores, the <g> was calculated. The <g> was calculated as 0.18 for the control group and 0.32 for the experimental group. The average normalized gain gives an index that helps in the comparison of the extent to which the treatment is effective (Hake, 2007). The effectiveness of the models of instruction was further classified according to the average normalized gain as follows:

(a) High-g courses: (<g>) > 0.7

(b) Medium-g courses: 0.3 < (<g>) < 0.7

(c) Low-g courses: (<g>) < 0.3

According to the classifications suggested above, low <g> courses are associated with traditional models of instruction which were operationally defined by Hake (1998) as those that relied primarily on passive-student lecturers, 'recipe-following' laboratory sessions and algorithmic quantitative problem solving examinations.

The high <g> courses were regarded as those that mostly used interactive-engagement models while the medium <g> courses were those that integrated both traditional models and the interactive-engagement models. These interpretations are consistent with the findings of this research as the experimental groups <g> were calculated as 0.32 and their teacher (Mr. E) also used a more learner-centred teaching approach. Mr. E used both traditional models and the interactive-engagement models. This is because he was using the computer simulation to help him explain the concept to the learners.

4.4 ANALYSIS OF QUESTIONNAIRES

As indicated in chapter three under instrumentation, questionnaires were administered to enable the researcher answer research questions 2 and 3. The data from sections B, and C were also entered into a Microsoft excel spread sheet (Appendix I) to calculate an index of agreement (IA). The index of agreement was calculated using the formula; IA = $\frac{\sum ni}{2.5N}$; Adopted from (Makomosela, 1996 p. 34). Where

n is the number of learners or teachers choosing one of the five points on the Likert scale,

i is a multiplier corresponding to the point on the scale as follows, 1 (strongly disagree) corresponds to -2, 2 (disagree) to -1, 3 (uncertain) to 0, 4 (agree) to +1 and 5 (strongly agree) to +2,

N is the total number of learners and teachers responding to that statement.

Division by 2.5 was done to confine IA within the range of -1 to +1.

If IA is negative the sample is assumed to disagree with the statement, but if IA is positive, the sample is assumed to agree with the statement and if IA is zero the sample is assumed to be undecided.

4.4.1 ANALYSIS OF SECTION B OF BOTH LEARNERS AND TEACHERS QUESTIONNAIRES

Section B of both learners and teachers questionnaires has 12 statements (see Appendix C and D). As the data collected from section B of the teachers' and learners' questionnaires were analysed, results of the analysis show that out of twelve (12) statements in the questionnaire, only statement 1 has a negative index of agreement (IA). Statement 1 was seeking to mean that the teachers have being using computer simulations to teach even before the research. Table 4.8 below shows the analysis of the learners and teachers questionnaires. From table 4.8 the IA for statements 1 is negative. This means that the learner and teacher sample disagreed with the statement in their questionnaires. Both teachers and learners disagreed with the statement that computer simulations were being used to teach even before the research. The rest of the 11 statements are in favour of using ICT to teach.

And both teachers and learners agreed to these 11 statements as these statements show positive IA in table 4.8.

Table 4.8: Index of agreement for section B of learners’ and teachers’ questionnaire.

Section B														
Statements	Codes					Codes					Total No. of respondents		Index of Agreement IA	
	1	2	3	4	5	1	2	3	4	5				
	No. of learners who responded					No. of teachers who responded					Leaners	Teachers	Leaners	Teachers
1	55	18	5	14	9	2					101	2	-0.380	-0.8
2	1	2	14	40	43				1	1	100	2	0.488	0.6
3	6	17	12	31	34				1	1	100	2	0.280	0.6
4	5	5	26	44	17					2	97	2	0.260	0.8
5	1	2	13	40	43				1	1	99	2	0.493	0.6
6	1	4	5	30	61					2	101	2	0.578	0.8
7	0	4	4	37	56					2	101	2	0.574	0.8
8	1	6	12	57	25				1	1	101	2	0.392	0.6
9	6	12	35	36	12				2		101	2	0.143	0.4
10	0	2	11	54	34					2	101	2	0.475	0.8
11	5	1	19	41	34				1	1	100	2	0.392	0.6
12	2	1	7	42	49				1	1	101	2	0.535	0.6

The rest 11 of the statements in section B to which both the teachers and learners agreed are as follows:

2. Teachers should be “work shopped” on the use of ICT in teaching.
3. ICT should always be used in teaching Physics topics.
4. ICT usage should be integrated with traditional normal teaching methods.
5. ICT usage makes teaching Physics easier.
6. ICT usage saves time used in drawing and labelling diagrams on chalk board.
7. ICT usage makes diagrams and writings clearer.
8. ICT usage captures learners’ attention in class.
9. ICT usage helps class control.
10. ICT usage brings improve excitement in learners.
11. ICT usage makes it easier for learners to visualize lessons.
12. ICT usage makes imaginary concepts (e.g. direction of magnetic field lines) real.

With this analysis, it is clear that both the teachers and their learners who took part in the research accept that, ICT (computer simulation) can improve the teaching and learning of Physics. This is because the rest of the 12 statements in the questionnaire to which both teachers and learners agree, are positive statements in favour of using ICT to teach. This means that the teachers and learners accept the use of ICT in the teaching of electromagnetism. This was also confirmed during informal interviews with teachers and learners after the intervention, but did not form part of the investigation.

4.4.2 ANALYSIS OF SECTION C OF BOTH LEARNERS AND TEACHERS QUESTIONNAIRES

Section C also has 12 statements for both the learners' and teachers' questionnaires (appendix C and D). Below is table 4.9 showing analysis of the learners' and teachers' questionnaires.

Table 4.9: Index of agreement for section C of learners' and teachers' questionnaire

Section C														
Statements	**Codes**					**Codes**					**Total No. of respondents**		**Index of Agreement IA**	
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**				
	No. of learners responding					**No. of teachers responding**					**Leaners**	**Teachers**	**Leaners**	**Teachers**
1	43	27	28	2	1	1	1				101	2	-0.432	-0.600
2	5	11	62	21	2	1	1				101	2	0.016	-0.600
3	3	12	45	36	4				2		100	2	0.104	0.400
4	11	19	30	27	13				1	1	100	2	0.048	0.600
5	7	10	57	32	4				1	1	110	2	0.058	0.600
6	5	6	46	37	9				2		103	2	0.151	0.400
7	7	5	26	47	15				2		100	2	0.232	0.400
8	6	12	24	42	14			1	1		98	2	0.188	0.200
9	15	29	21	22	13	1	1				100	2	-0.044	-0.600
10	36	39	14	10	0		2				99	2	-0.408	-0.400
11	7	18	10	30	36				1	1	101	2	0.277	0.600
12	59	18	13	4	7		2				101	2	-0.467	-0.400

The index of agreement (IA) for statements 1, 9, 10, and 12 are negative for both teachers and learners. This means the two samples (teachers and learners) disagreed with these statements. For statement 2 the teachers disagreed but the learners were mostly undecided. This is clear from table 4.9. As many as 62 out of 101 learner respondents were undecided for this statement. Since the teachers know better it is assumed they agreed that government is not ready to provide ICT infrastructure for all schools. Even though statements 1, 9, 10 and 12 have negative IA, this does not make all of them factors that may negatively influence the use ICT to teach. Statements 1 and 12 are factors that may negatively influence the use of ICT. This is because as the two statements have negative IA, it means that the sample is saying, not all schools in their district have ICT infrastructure (statement 1), and computers in their school are not enough for all learners in the class (statement 12). And these can negatively influence ICT use in teaching. However, statements 9 and 10 are not factors that may negatively influence the use of ICT. Statement 9 and 10 reads:

- I find it time consuming to use ICT in teaching Physics.
- Learners get distracted by ICT in teaching Physics.

Since the statements have negative IA, it means learners and teachers do not find it time consuming to use ICT in teaching. Also, learners do not get destructed by ICT in teaching Physics. This means that the two statements are eliminated as factors that may negatively influence the use of ICT to teach Physics.

From the 12 statements in section C of both the learners and teachers questionnaires, both teachers and learners agreed with 8 of the statements as can be seen in table 4.9. Because the teachers and learners agreed with these 8 statements, these statements are also therefore eliminated as factors that may negatively influence the use of ICT in teaching Physics. These statements are listed below.

- The curriculum support ICT usage in teaching Physics.
- The timetable of the school permits the use of ICT in teaching Physics.
- The workloads (content of Physical Science syllabus) allow the use of ICT in teaching.
- The simulation software programmes available currently are compatible with the South African syllabus.
- Schools and teachers can get access to software programmes that are compatible with the South African syllabus.

- Learners can get access to software programmes that are compatible with the South African syllabus.
- I find it time consuming to use ICT in teaching Physics.
- Learners cannot learn Physics with ICT on their own (they need help from the teacher).

The way these statements are structured, if the respondents had disagreed, to them, then, they may be considered as factors that may negatively influence the use of ICT to teach. But because of the way statements 1, 2, and 12 are structured, the respondent disagreeing with them makes them factors that may hamper the use of ICT to teach. Below are statements 1, 2, and 12 respectively.

- All schools have the ICT infrastructure in my district.
- Government is ready to make ICT infrastructure available to schools.
- Computers available in my school are enough for all students in my classroom.

Of the 12 statements under section C, which are some possible factors that may hamper the use of ICT in teaching Physics, it came out that only three of them may currently be hampering the use of ICT in teaching Physics. These are the fact that:

- All schools do not have the ICT infrastructure.
- Government is not ready to make ICT infrastructure available to all schools and
- Where there is ICT infrastructure, it is mostly inadequate.

4.5 RESEARCH QUESTION 2: To what extent does the use of computer simulations influence the learning of electromagnetism in grade 11?

Analysis of data from the observation schedule, and section B and C of the questionnaires were used in answering research question 2. From the classroom observation report in section 4.2.2, the computer simulations influenced learning of electromagnetism positively: learners were more active during their lessons, predicting, observing, discussing and explaining concepts by the help of the teacher and the computer simulations. Learners could construct their own understanding of scientific ideas within the framework of their existing knowledge. Then analysis of the tests in table 4.7 also showed that the simulations helped increase conceptual understanding for the experimental compared to the control group in these topics: current carrying conductor, induced emf, electromagnets, magnetic poles, magnetic field lines, electromagnetic induction and Faraday’s Law. This was further confirmed by the calculation of the Hake’s normalized gain <g> in conceptual improvement. The normalized gain was calculated for the experimental group as <g> = 0.32 (medium <g> course) and 0.18 for the control group (low <g> course). (See section 4.3.7) Finally, analysis of teachers and learners views from the questionnaires indicates that the teachers and learners accept the use of computer simulations in the learning of electromagnetism. From the analysis in sections 4.4.1 and 4.4.2, the teachers and learners agreed that , ICT (computer simulations) usage makes diagrams and writings clearer, it captures learners’ attention in class, it helps class control, it brings improve excitement in learners, it makes it easier for learners to visualise lessons and it makes imaginary concepts (e.g. magnetic field lines) real.

4.6 RESEARCH QUESTION 3: To what extent does the use of computer simulations influence the teaching of electromagnetism in grade 11?

In answering research question 3, the analysis from classroom observation indicated that the use of the computer simulation also positively influenced the teaching of electromagnetism (see section 4.2.2). It provided opportunities to enhance a learner centred teaching approach (see section 4.2.2). In the experimental group where the computer simulations were used, it supported the teacher in his effort that helped the learners to gain conceptual understanding because it created a learning environment that supports learning. As discussed in theoretical framework, the simulations acted as that support (scaffolding) that the learners need to construct knowledge (see section 4.3.3). This is an important component of the constructivist’s theories referred to as the Zone of Proximal Development (ZPD) (see section 2.10). The views of both teachers and learners from the analysis of the questionnaires showed that the teachers and learners accept the use of computer simulations in teaching even though before the research they were not exposed to it. From the analysis in sections 4.4.1 and 4.4.2, the teachers and learners agreed that, ICT (computer simulations) usage should be integrated with traditional normal teaching methods, it makes teaching Physics easier, it saves time used in drawing and labelling diagrams on chalk board. They also agreed that ICT should always be used in teaching Physics topics and that teachers should be "work shopped" on the use of ICT in teaching.

4.7 SUMMARY

The chapter presented the observation of lessons of the teachers, analysis of test results, and analysis of the questionnaires. The three research questions were also answered in this chapter.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 OVERVIEW

The topic electromagnetism is poorly understood by most learners and therefore they are not able to satisfactorily answer sections on it in the Physics final examination paper and teachers are also not very confident in teaching this section of the Physics curriculum (see section 1.3). Learners also find it difficult to visualize many of the concepts in electromagnetism (see section 2.4). Research suggests that computer simulations and more learner-centred, teacher-learner interactions can have a positive impact on Science teaching and learning (see section 1.5). Therefore, the aim of this research was to investigate the impact of computer simulations on the teaching and learning of the topic electromagnetism in grade 11 in one school in the Mpumalanga Province. Hence the following research questions guided the study:

1. Does the use of computer simulations have an impact on the performance of grade 11 learners in electromagnetism?
2. To what extent does the use of computer simulations influence the learning of electromagnetism in grade 11?
3. To what extent does the use of computer simulations influence the teaching of electromagnetism in grade 11?

To answer these questions, two teaching methods were compared. One teacher used the traditional teacher-centred method to teach. The other teacher used the learner-centred teaching approach with computer simulations. According to the constructivist theory (see theoretical framework), in a learner-centred teaching environment, technology such as computer simulation can serve as that initial scaffold that the learner needs, to be able to learn. In the following section, the major findings of the study are summarized and their implications for teaching and learning are highlighted.

5.2 SUMMARY OF FINDINGS

The first research question which guided this research was "Does the use of computer simulations have an impact on the performance of grade 11 learners in electromagnetism?"

In answering this research question, the analysis of the results using Microsoft excel spreadsheet to calculate the t-test of the post-test shows that even though the two groups show no statistically significant difference in the performance in the pre-test, there was a statistically significant difference in performance in the post-test which lead to the rejection of the null hypothesis that states: the use of computer simulation has no impact on the performance of grade 11 learners in electromagnetism.

The second research question that guided the research was: "To what extent does the use of computer simulations influence the learning of electromagnetism in grade 11?"

In order to answer this question, the data collected using the classroom observation schedule, as well as the analysis of the test items individually and section B of the teachers' and learners' questionnaires were quantitatively and qualitatively analysed.

From the classroom observation report in section 4.2.2, the computer simulations influenced learning of electromagnetism positively. Learners were more active during their lessons, predicting, observing, discussing and explaining concepts with the help of the teacher and the computer simulations. In addition, the simulations provided an opportunity to visualise many of the concepts in electromagnetism. Then quantitative analysis of the tests in table 4.7 also showed that the simulations helped increase conceptual understanding for the experimental group compared to the control group in these topics: current carrying conductor, induced emf, electromagnets, magnetic poles, magnetic field lines, electromagnetic induction and Faraday's law. This was further confirmed by the calculation of the Hake's normalized gain <g>. For the experimental group, <g> was calculated as 0.32 (medium <g> course) and 0.18 for the control group (low <g> course) also using table 4.7 and discussed in section 4.3.6. Also, a qualitative analysis of teachers and learners views from the questionnaires indicates that the teachers and learners accept the use of computer simulations in the teaching of electromagnetism. The teachers and learners agreed that , ICT (computer simulations) usage makes diagrams and writings clearer, it captures learners' attention in class, it helps class control, it brings improve excitement in learners, it makes it easier for learners to visualise lessons and it makes imaginary concepts (e.g. magnetic field lines) real. (See sections 4.4.1 and 4.4.2)

The third question that guided the research was: “To what extent does the use of computer simulations influence the teaching of electromagnetism in grade 11?”

In order to answer this question, the qualitative analysis from classroom observation was used. The analysis indicated that the use of the computer simulation positively influenced the teaching of electromagnetism (see section 4.2.2). The computer simulations supported the teacher of the experimental group to help his learners to gain conceptual understanding. As discussed in theoretical framework, the simulations acted as that support (scaffolding) that the learners need to enhance learning (see section 4.3.3). This is an important component of the constructivist’s theories referred to as the Zone of Proximal Development (ZPD) (see section 2.10). The views of both teachers and learners from the analysis of the questionnaires also showed that the teachers and learners accept the use of computer simulations in teaching even though before the research they were not exposed to it. They agreed that, ICT (computer simulations) usage should be integrated with traditional normal teaching methods, it makes teaching Physics easier, it saves time used in drawing and labelling diagrams on chalk board. They also agreed that ICT should always be used in teaching Physics topics and that teachers should be “work shopped” on the use of ICT in teaching. (See sections 4.4.1 and 4.4.2).

5.3 CONCLUSION

The improvement in the performance of the experimental group may be strongly attributed to the use of computer simulations that aided learners’ to visualise the concepts, as opposed to the teacher-centred teaching method used for teaching the control group (Gilbert, Justi & Aksela 2003) cited in Kriek & Stols (2010). From the observation of all the lessons and the analysis of both the tests and questionnaire, it can be concluded that all the lessons went well especially the lessons with the experimental group. This is because the simulations captured the attention of the learners, and this view is reflected by the learners in their responses in the questionnaire. According to the theory of constructivism (see theoretical framework), learning takes place by the learner completing tasks for which support (scaffolding) is initially required. This support may include a tutor, a peer or technology such as the applications of computer simulations. Mr. E, the teacher, the computer simulations, and the demonstrations acted as the support or the scaffolding which helped the learners to construct their knowledge and understanding of the topic electromagnetism as reflected in the analyses above.

5.4 IMPLICATIONS AND RECOMMENDATIONS

The intention of this research is not to attempt to generalize the present findings, but to do a case study regarding the impact of computer simulation on the teaching and learning of the topic electromagnetism in grade 11 Physics. The answers to this have implications for researchers, teacher trainers, teachers, learners and the Department of Education.

This study contributes to literature in two ways. Firstly, it provides evidence that the use of computer simulations combined with a more learner-centred method of teaching Physics could have significant effect on learners' performance. Secondly, it has provided a possible review of an instructional model for constructivist learning approach in conjunction with the use of computer technology. The researchers' argument is that, Physics teachers should make use of the computer simulations in teaching, since research suggests that it has the potential to make abstract concepts real. The zone of proximal development (ZPD) by Vygotsky (1978) on which this study was based was put into practice when the teacher used this simulation to create an environment that helped learners in the experimental group to perform significantly better than those in the control group. Indications are that computer simulation may hold the solution to help teachers teach difficult and abstract areas of the Physics syllabus such as electromagnetism as alluded to by the chief examiners report for the 2010 NCS examinations (DOE, 2010 p.299). It is therefore recommended that computer simulations be used to compliment the other methods, analogies, tutorials and practical lessons and not only as the only method of teaching Physics.

From the National Education Infrastructure Management System (NEIM) report in May 2011, it is evident that most schools in South Africa do not have laboratories and laboratory equipment as indicated earlier in chapter one section 1.1 paragraph 4 of this report. For this reason computer simulations must be seriously considered to be used which may help teachers and learners in these schools without Science laboratories and even compliment the effort of those having Science laboratories to help improve the performance in Science.

However, no matter how good a programme may be, its success depends heavily on the commitment and calibre of the people who implement it, the teachers in this case. One implication of classroom integration of technology is the need to train teachers in the use of technology as an instructional tool. Without the relevant knowledge and skills, teachers will find it difficult to weave technology attributes with the curriculum needs, classroom management, and other instructional skills (Stols & Kriek, 2011). Therefore, it is recommended that the teacher training programmes of the Universities are updated so as to equip new teachers with the required knowledge and skills to handle computer-based teaching effectively. Also, in-service training programmes need to be organized for the serving teachers.

Based on the encouraging findings of this study it is recommended that the study be repeated with a larger and more representative sample. During such a replication, efforts should be made to identify specific teacher needs for purposes of teacher training before implementation.

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APPENDICES

APPENDIX A

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: ___________________________________ Lesson: _____________________

Observer: ________________________________

Subject: Physical Science

Topic: ___________________________________

Grade: 11

Instructions: For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	**Excellent**	**Good**	**Fair**	**Poor**
1	Teacher reviews learners previous knowledge				
2	Evidence of teacher preparation prior to the lesson				
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)				
4	Teacher appropriately uses teaching aids to facilitate teaching and learning				
5	Teacher is able to simplify difficult concepts to learners				
6	Teacher encourages learners to answer other learners questions				
7	Teacher provides relevant examples on concepts that relates to their everyday experiences				
8	Teacher presents well planned lesson according to the curriculum and the work schedule				
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)				
10	Teacher evaluates lesson to check the achievement of lesson objectives				

APPENDIX A_1

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. C. Lesson: One

Observer: Researcher

Subject: Physical Science

Topic: Magnets, magnetic poles and magnetic field lines

Grade: 11

Instructions: For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge	X			
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)	X			
4	Teacher appropriately uses teaching aids to facilitate teaching and learning	X			
5	Teacher is able to simplify difficult concepts to learners	X			
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule	X			
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)	X			
10	Teacher evaluates lesson to check the achievement of lesson objectives		X		

APPENDIX A_2

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. C. Lesson: Two

Observer: Researcher

Subject: Physical Science

Topic: Field around a straight wire, Right hand grip rule, Field around circular wire and Field around a solenoid

Grade: 11

Instructions: For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge		X		
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)			X	
4	Teacher appropriately uses teaching aids to facilitate teaching and learning			X	
5	Teacher is able to simplify difficult concepts to learners		X		
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule		X		
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)			X	
10	Teacher evaluates lesson to check the achievement of lesson objectives			X	

APPENDIX A_3

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. C. Lesson: Three

Observer: Researcher

Subject: Physical Science

Topic: Electromagnets and their uses

Grade: 11

Instructions: For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge		X		
2	Evidence of teacher preparation prior to the lesson		X		
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)			X	
4	Teacher appropriately uses teaching aids to facilitate teaching and learning		X		
5	Teacher is able to simplify difficult concepts to learners		X		
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences	X			
8	Teacher presents well planned lesson according to the curriculum and the work schedule		X		
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)		X		
10	Teacher evaluates lesson to check the achievement of lesson objectives		X		

APPENDIX A_4

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. C. Lesson: Four

Observer: Researcher

Subject: Physical Science

Topic: Fleming's left hand rule, force on current carrying conductor in a magnetic field, and motors

Grade: 11

<u>Instructions:</u> For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge		X		
2	Evidence of teacher preparation prior to the lesson		X		
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)			X	
4	Teacher appropriately uses teaching aids to facilitate teaching and learning			X	
5	Teacher is able to simplify difficult concepts to learners		X		
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule		X		
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)			X	
10	Teacher evaluates lesson to check the achievement of lesson objectives			X	

APPENDIX A_5

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. C. Lesson: Five

Observer: Researcher

Subject: Physical Science

Topic: Electromagnetic induction and Faraday's law

Grade: 11

Instructions: For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge	X			
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)	X			
4	Teacher appropriately uses teaching aids to facilitate teaching and learning	X			
5	Teacher is able to simplify difficult concepts to learners	X			
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences	X			
8	Teacher presents well planned lesson according to the curriculum and the work schedule	X			
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)		X		
10	Teacher evaluates lesson to check the achievement of lesson objectives		X		

APPENDIX A_6

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. C. Lesson: Six

Observer: Researcher

Subject: Physical Science

Topic: Transformers, power generation and distribution

Grade: 11

Instructions: For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge		X		
2	Evidence of teacher preparation prior to the lesson		X		
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)			X	
4	Teacher appropriately uses teaching aids to facilitate teaching and learning		X		
5	Teacher is able to simplify difficult concepts to learners			X	
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule		X		
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)				
10	Teacher evaluates lesson to check the achievement of lesson objectives		X		

APPENDIX A_7

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. E. Lesson: One

Observer: Researcher

Subject: Physical Science

Topic: magnets, magnetic poles and magnetic field lines

Grade: 11

<u>Instructions:</u> For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	**Excellent**	**Good**	**Fair**	**Poor**
1	Teacher reviews learners previous knowledge	X			
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)	X			
4	Teacher appropriately uses teaching aids to facilitate teaching and learning	X			
5	Teacher is able to simplify difficult concepts to learners	X			
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule	X			
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)	X			
10	Teacher evaluates lesson to check the achievement of lesson objectives	X			

APPENDIX A_8

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. E. Lesson: Two

Observer: Researcher

Subject: Physical Science

Topic: Field around a straight wire, Right hand grip rule, Field around circular wire and Field around a solenoid

Grade: 11

<u>Instructions:</u> For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge		X		
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)		X		
4	Teacher appropriately uses teaching aids to facilitate teaching and learning	X			
5	Teacher is able to simplify difficult concepts to learners	X			
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule	X			
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)	X			
10	Teacher evaluates lesson to check the achievement of lesson objectives		X		

APPENDIX A_9

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. E. Lesson: Three

Observer: Researcher

Subject: Physical Science

Topic: Electromagnets and their uses

Grade: 11

<u>Instructions:</u> For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge	X			
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)		X		
4	Teacher appropriately uses teaching aids to facilitate teaching and learning	X			
5	Teacher is able to simplify difficult concepts to learners	X			
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences	X			
8	Teacher presents well planned lesson according to the curriculum and the work schedule	X			
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)	X			
10	Teacher evaluates lesson to check the achievement of lesson objectives		X		

APPENDIX A_{10}

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. E. Lesson: Four

Observer: Researcher

Subject: Physical Science

Topic: Fleming's left hand rule, force on current carrying conductor in a magnetic field, and motors

Grade: 11

Instructions: For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge	X			
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)	X			
4	Teacher appropriately uses teaching aids to facilitate teaching and learning	X			
5	Teacher is able to simplify difficult concepts to learners	X			
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule	X			
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)	X			
10	Teacher evaluates lesson to check the achievement of lesson objectives	X			

APPENDIX A_{11}

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. E. Lesson: Five

Observer: Researcher

Subject: Physical Science

Topic: Electromagnetic induction and Faraday's law

Grade: 11

Instructions: For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge	X			
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)	X			
4	Teacher appropriately uses teaching aids to facilitate teaching and learning	X			
5	Teacher is able to simplify difficult concepts to learners	X			
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule	X			
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)	X			
10	Teacher evaluates lesson to check the achievement of lesson objectives	X			

APPENDIX A_{12}

CLASSROOM OBSERVATION SCHEDULE

Teacher observed: Mr. E. Lesson: Six

Observer: Researcher

Subject: Physical Science

Topic: Transformers, power generation and distribution

Grade: 11

<u>Instructions:</u> For each of these statements indicate in the appropriate box in front of it with **X**

	Teachers teaching style	Excellent	Good	Fair	Poor
1	Teacher reviews learners previous knowledge	X			
2	Evidence of teacher preparation prior to the lesson	X			
3	Teacher involves learners in the lesson (e.g. puts learners in groups to perform activities or to have discussions and report to the class)		X		
4	Teacher appropriately uses teaching aids to facilitate teaching and learning	X			
5	Teacher is able to simplify difficult concepts to learners	X			
6	Teacher encourages learners to answer other learners questions			X	
7	Teacher provides relevant examples on concepts that relates to their everyday experiences		X		
8	Teacher presents well planned lesson according to the curriculum and the work schedule	X			
9	Teacher's general class management (e.g. managing class discussions, activities and learner discipline)	X			
10	Teacher evaluates lesson to check the achievement of lesson objectives		X		

APPENDIX B

NAME: ________________________________

GRADE: ________

ELECTROMAGNETISM TEST:
CIRCLE THE CORRECT ANSWER FOR EACH QUESTION IN THIS PART.
Part I; Multiple Choices (1 point each) **(40 Minutes)**

1. A current carrying conductor placed in a magnetic field experiences a force, the direction of the force depends on
   (a) The direction of the current flow
   (b) The switch
   (c) The type of conductor used
   (d) The strength of the magnet

2. Which of the following devices are based on the principles that a current carrying conductor in a magnetic field experience a force

   (a) A relay
   (b) A DC motor
   (c) A coil
   (d) An electromagnet

3. An EMF is induced when
   (a) The electric flux threading a coil changes
   (b) The magnetic flux threading coil changes
   (c) The galvanometer is connected to a device
   (d) The galvanometer is connected to a device

4. When the north pole of a magnet is pushed into a coil connected to galvanometer, the needle
   (a) Moves to the left
   (b) Moves to the right
   (c) Stays still
   (d) Moves down

5. The direction in which an induced current flows depends on
   (a) Ohm's law
   (b) Kirchhoff's law
   (c) Lenz's law
   (d) Faraday's law

6. Which of the following devices **DOES NOT** operate on the principle of induced EMF?
   (a) An alternator
   (b) A dynamo
   (c) An AC generator
   (d) An electromagnet

7. The size of the induced EMF depends on
   - (a) Rate of change of magnet flux with respect to time
   - (b) Rate of change of electric flux with respect to time
   - (c) Rate of change of voltage with respect to time
   - (d) Rate of change of induced current

8. The principle of operation of an electromagnetic relay is
   - (a) A current flowing through a conductor produces a concentric magnetic field
   - (b) A current flowing through a conductor produces a concentric electric field
   - (c) A changing magnetic field includes a current
   - (d) A changing electric field induces a current

9. Electromagnetic relays can be found in
   - (a) The starter motor of a car
   - (b) A dynamo
   - (c) A computer
   - (d) A transformer

10. Which of these inventions uses the generation of electricity from a magnet?
   - (a) A microphone
   - (b) A generator
   - (c) A galvanometer
   - (d) A motor

11. What are the opposite ends of a magnet called?
   - (a) Its terminals
   - (b) Its north and south poles
   - (c) Its magnetic fields
   - (d) Its electromagnetic poles

12. What force would result if the north poles of two magnets were brought near one another?
   - (a) Repulsion
   - (b) Attraction
   - (C) Friction
   - (d) Compaction

13. What can iron filings sprinkled on a piece of paper with a magnet under the paper show you?
   - (a) That current can flow through the filings
   - (b) That paper distorts magnetism
   - (c) That magnetic fields are counter clockwise
   - (d) The pattern of a magnetic force field

14. How can you show that electricity creates a magnetic field?
   - (a) Use a compass near a wire with current flowing through it
   - (b) Move wire through an electric field
   - (c) Move wire through a magnetic field
   - (d) Connect a battery to the magnetic field

15. How do you make an electromagnet?
   (a) Connect a magnet to battery
   (b) Run current through a wire wrapped around an iron rod
   (c) Place a wire in a magnetic field
   (d) Place a wire in a magnetic field with current flowing through it

16. What happens when you turn off current in an electromagnet?
   (a) The magnetism is lost
   (b) The current keeps flowing because of the magnetic force
   (c) The electromagnet loses its polarity
   (d) The electromagnet becomes a generator

17. The area surrounding a magnet that exerts a force on all magnetic materials located near it
   (a) Electric field
   (b) Magnetic poles
   (c) Magnetic field
   (d) Electric flux

18. Can you generate electricity with a magnet?
   (a) No, because only friction on electric charges or batteries create electricity
   (b) Yes, by moving a wire thorough a magnetic field
   (c) Yes, by putting a current through a wire around a magnet
   (d) Yes, because magnets use electricity to stay effective

19. Transformers can
   (a) Increase voltage
   (b) Decrease voltage
   (c) Neither decrease nor increase voltage
   (d) Increase or decrease voltage

20. A transformer is needed to step down the 230V mains supply to 6V. If the primary coil has 1 000 turns, how many turns must the secondary coil have?
   (a) 36 turns
   (b) 46 turns
   (c) 16 turns
   (d) 26 turns

PART 2: (2 point each): Answer this part on the plane sheets attached.

21. Draw a bar magnet indicating the north and south poles. Show on the same diagram, the magnetic flux.

22. What are electromagnets composed of?

23. What is electromagnetic induction? How does it work?

24. State Flemings Left-hand Rule.

25. State Faradays Law of electromagnetic induction.

APPENDIX C

A QUESTIONNAIRE FOR LEARNERS ON ICT USE IN TEACHING AND LEARNING PHYSICS

Instructions: Please tick or fill in where necessary. For the purpose of this questionnaire Information and Communication Technology (ICT) is defined as a range of technologies for gathering, storing, retrieving, processing, analyzing and transmitting information like computers, projectors and internet.

SECTION A: Background Information

1. Name of Learner: ________________________

2. Gender? Male ☐ Female ☐

3. Age?

☐ 13 -15 years

☐ 15 - 17 years

☐ 17 - 19 years

☐ over 19 years

Instructions: For sections B, C and D, use the codes given, by writing a code (e.g. 1, 2, 3, 4 or 5) of your choice against the questions. The codes are given below.

Strongly disagree (SD)	Disagree (D)	Undecided (U)	Agree (A)	Strongly agree (SA)
1	**2**	**3**	**4**	**5**

SECTION B: Learners views on teaching electromagnetism using computer simulation.						
		SD	D	U	A	SA
		1	2	3	4	5
1	The teacher uses ICT (computer simulation) to teach even before this research.					
2	Teachers should be “work shopped” on the use of ICT in teaching.					
3	ICT should always be used in teaching Physics topics.					
4	ICT usage should be integrated with traditional normal teaching methods.					
5	ICT usage makes teaching Physics easier.					
6	ICT usage saves time used in drawing and labeling diagrams on chalk board.					
7	ICT usage makes diagrams clearer than drawing them on the chalk board.					
8	ICT usage captures learners’ attention in class.					
9	ICT usage helps class control.					
10	ICT usage brings excitement in learners.					
11	ICT usage makes it easier for learners to visualize lessons.					
12	ICT usage makes imaginary concepts (e.g. magnetic field lines) real					

SECTION C: Factors that may influence the use of ICT in teaching.						
		SD 1	D 2	U 3	A 4	SA 5
1	All schools have the ICT infrastructure in my district.					
2	Government is ready to make ICT infrastructure available to schools.					
3	The curriculum support ICT usage in teaching Physics.					
4	The timetable of the school permits the use of ICT in teaching Physics.					
5	The workloads (content of Physical Science syllabus) allow the use of ICT in teaching.					
6	The simulation software programmes available currently are compatible with the South African syllabus.					
7	Teachers can get access to software programmes that are compatible with the South African syllabus.					
8	Learners can get access to software programmes that are compatible with the South African syllabus.					
9	I find it time consuming to use ICT in teaching Physics.					
10	Learners get distracted by ICT in teaching Physics.					
11	Learners cannot learn Physics with ICT on their own (they need help from the teacher).					
12	Computers available in my school are enough for all learners in my class.					

APPENDIX D

A QUESTIONNAIRE FOR TEACHERS ON ICT USE IN TEACHING AND LEARNING PHYSICS

Instructions: Please tick or fill in where necessary. For the purpose of this questionnaire Information and Communication Technology (ICT) is defined as a range of technologies for gathering, storing, retrieving, processing, analyzing and transmitting information like computers, projectors and internet.

SECTION A: Background Information

1. Name of Teacher ________________________

2. Gender: Male ☐ Female ☐

3. Age

☐ 20 -25 years

☐ 25 - 30 years

☐ 30 - 35 years

☐ over 35 years

4. Qualifications:
- Academic ___________________________
- Professional ___________________________
- Others ___________________________

Instructions: For sections B, C and D, use the codes given, by writing a code (e.g. 1, 2, 3, 4 or 5) of your choice against the questions. The codes are given below.

Strongly disagree (SD)	Disagree (D)	Undecided (U)	Agree (A)	Strongly agree (SA)
1	2	3	4	5

SECTION B: Teachers views on teaching electromagnetism using computer simulation.						
		SD	D	U	A	SA
		1	2	3	4	5
1	I, the teacher do use ICT (computer simulation) to teach even before this research.					
2	Teachers should be "work shopped" on the use of ICT in teaching.					
3	ICT should always be used in teaching Physics topics.					
4	ICT usage should be integrated with traditional normal teaching methods.					
5	ICT usage makes teaching Physics easier.					
6	ICT usage saves time used in drawing and labeling diagrams on chalk board.					
7	ICT usage makes diagrams clearer than drawing them on the chalk board.					
8	ICT usage captures learners' attention in class.					
9	ICT usage helps class control.					
10	ICT usage brings excitement in learners.					
11	ICT usage makes it easier for learners to visualize lessons.					
12	ICT usage makes imaginary concepts (e.g. magnetic field lines) real					

SECTION C: Factors that may influence the use of ICT in teaching.						
		SD	D	U	A	SA
		1	2	3	4	5
1	All schools have the ICT infrastructure in my district.					
2	Government is ready to make ICT infrastructure available to schools.					
3	The curriculum support ICT usage in teaching Physics.					
4	The timetable of the school permits the use of ICT in teaching Physics.					
5	The workloads (content of Physical Science syllabus) allow the use of ICT in teaching.					
6	The simulation software programmes available currently are compatible with the South African syllabus.					
7	Teachers can get access to software programmes that are compatible with the South African syllabus.					
8	Learners can get access to software programmes that are compatible with the South African syllabus.					
9	I find it time consuming to use ICT in teaching and Physics.					
10	Learners get distracted by ICT in teaching Physics.					
11	Learners cannot learn Physics with ICT on their own (they need help from the teacher).					
12	Computers available in my school are enough for all learners in my class.					

APPENDIX E

Pilot Group Test Scores				
Learner	**Test 1 (X_1)**	**X_1^2**	**Test 2 (X_2)**	**X_2^2**
1	19	361	21	441
2	20	400	19	361
3	12	144	15	225
4	13	169	13	169
5	12	144	11	121
6	11	121	14	196
7	12	144	14	196
8	15	225	15	225
9	15	225	15	225
10	14	196	15	225
11	16	256	15	225
12	21	441	20	400
13	14	196	16	256
14	16	256	20	400
15	11	121	10	100
16	17	289	19	361
17	10	100	15	225
18	8	64	9	81
19	14	196	15	225
20	21	441	20	400
21	9	81	14	196
22	10	100	12	144
23	15	225	15	225
24	11	121	16	256
25	15	225	7	49
26	9	81	6	36
27	10	100	12	144
28	12	144	13	169
29	7	49	8	64
30	13	169	16	256
31	15	225	9	81
32	15	225	10	100
33	13	169	16	256
34	10	100	9	81
35	6	36	10	100
TOTAL	**461**	**6539**	**484**	**7214**

APPENDIX F

CALCULATING SPEARMAN'S CORRELATIONS COEFICIENT FOR THE PILOT GROUP

			Pre-test	Post-test
Spearman's rho	Pre - test	Correlation Coefficient	1.000	.648**
		Sig. (2-tailed)	.	0.000
		N	35	35
	Post-test	Correlation Coefficient	0.648**	1.000
		Sig. (2-tailed)	0.000	.
		N	35	35

****. Correlation is significant at the 0.01 level (2-tailed).**

APPENDIX G

Grade 11A – Control Group Test Scores						
Learner(n_2)	**Pre-Test(y_2)**	**% Pre-Test**	**y_2^2**	**Post-Test(x_2)**	**% Post-Test**	**x_2^2**
1	14	46.67	196	18	60.00	324
2	8	26.67	64	7	23.33	49
3	11	36.67	121	10	33.33	100
4	6	20.00	36	11	36.67	121
5	7	23.33	49	9	30.00	81
6	8	26.67	64	8	26.67	64
7	12	40.00	144	10	33.33	100
8	8	26.67	64	13	43.33	169
9	4	13.33	16	16	53.33	256
10	10	33.33	100	15	50.00	225
11	7	23.33	49	13	43.33	169
12	12	40.00	144	16	53.33	256
13	16	53.33	256	18	60.00	324
14	9	30.00	81	15	50.00	225
15	7	23.33	49	16	53.33	256
16	10	33.33	100	13	43.33	169
17	8	26.67	64	9	30.00	81
18	7	23.33	49	15	50.00	225
19	6	20.00	36	11	36.67	121
20	9	30.00	81	10	33.33	100
21	6	20.00	36	8	26.67	64
22	9	30.00	81	16	53.33	256
23	14	46.67	196	17	56.67	289
24	6	20.00	36	13	43.33	169
25	8	26.67	64	14	46.67	196
26	13	43.33	169	20	66.67	400
27	4	13.33	16	9	30.00	81
28	1	3.33	1	9	30.00	81
29	8	26.67	64	6	20.00	36
30	11	36.67	121	13	43.33	169
31	10	33.33	100	17	56.67	289
32	9	30.00	81	16	53.33	256
33	8	26.67	64	12	40.00	144
34	8	26.67	64	9	30.00	81
35	5	16.67	25	7	23.33	49
Total	**299**	**996.67**	**2881**	**439**	**1463.33**	**5975**
Average	**8.54**	**28.48**	**82.31**	**12.54**	**41.81**	**170.7**

APPENDIX H

Grade 11C – Experimental Group Test Scores						
Learner(n_1)	Pre-Test(y_1)	% Pre-Test	y_1^2	Post-Test(x_1)	% Post-Test	x_1^2
1	11	36.67	121	21	70.00	441
2	11	36.67	121	20	66.67	400
3	11	36.67	121	17	56.67	289
4	2	6.67	4	13	43.33	169
5	12	40.00	144	16	53.33	256
6	9	30.00	81	21	70.00	441
7	7	23.33	49	13	43.33	169
8	9	30.00	81	24	80.00	576
9	12	40.00	144	18	60.00	324
10	6	20.00	36	14	46.67	196
11	4	13.33	16	12	40.00	144
12	6	20.00	36	23	76.67	529
13	6	20.00	36	10	33.33	100
14	9	30.00	81	11	36.67	121
15	7	23.33	49	13	43.33	169
16	7	23.33	49	18	60.00	324
17	6	20.00	36	11	36.67	121
18	11	36.67	121	20	66.67	400
19	7	23.33	49	23	76.67	529
20	11	36.67	121	23	76.67	529
21	9	30.00	81	17	56.67	289
22	10	33.33	100	15	50.00	225
23	10	33.33	100	13	43.33	169
24	9	30.00	81	12	40.00	144
25	9	30.00	81	13	43.33	169
26	12	40.00	144	17	56.67	289
27	4	13.33	16	17	56.67	289
28	7	23.33	49	8	26.67	64
29	7	23.33	49	24	80.00	576
30	7	23.33	49	12	40.00	144
Total	**248**	**826.67**	**2246**	**489**	**1630.00**	**8585**
Average	**8.27**	**27.56**	**74.867**	**16.30**	**54.33**	**286.2**

APPENDIX I

Section B														
Statements	**Codes**					**Codes**					**Total No. of respondents**		**Index of Agreement IA**	
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**				
	No. of learners who responded					**No. of teachers who responded**					**Leaners**	**Teachers**	**Leaners**	**Teachers**
1	55	18	5	14	9	2					101	2	-0.380	-0.8
2	1	2	14	40	43				1	1	100	2	0.488	0.6
3	6	17	12	31	34				1	1	100	2	0.280	0.6
4	5	5	26	44	17					2	97	2	0.260	0.8
5	1	2	13	40	43				1	1	99	2	0.493	0.6
6	1	4	5	30	61					2	101	2	0.578	0.8
7	0	4	4	37	56					2	101	2	0.574	0.8
8	1	6	12	57	25				1	1	101	2	0.392	0.6
9	6	12	35	36	12				2		101	2	0.143	0.4
10	0	2	11	54	34					2	101	2	0.475	0.8
11	5	1	19	41	34				1	1	100	2	0.392	0.6
12	2	1	7	42	49				1	1	101	2	0.535	0.6

Index of agreement for section B of learners' and teachers' questionnaire

Section C														
Statements	**Codes**					**Codes**					**Total No. of respondents**		**Index of Agreement IA**	
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**				
	No. of learners responding					**No. of teachers responding**					**Leaners**	**Teachers**	**Leaners**	**Teachers**
1	43	27	28	2	1	1	1				101	2	-0.432	-0.600
2	5	11	62	21	2	1	1				101	2	0.016	-0.600
3	3	12	45	36	4				2		100	2	0.104	0.400
4	11	19	30	27	13				1	1	100	2	0.048	0.600
5	7	10	57	32	4				1	1	110	2	0.058	0.600
6	5	6	46	37	9				2		103	2	0.151	0.400
7	7	5	26	47	15				2		100	2	0.232	0.400
8	6	12	24	42	14			1	1		98	2	0.188	0.200
9	15	29	21	22	13	1	1				100	2	-0.044	-0.600
10	36	39	14	10	0		2				99	2	-0.408	-0.400
11	7	18	10	30	36				1	1	101	2	0.277	0.600
12	59	18	13	4	7		2				101	2	-0.467	-0.400

Index of agreement for section C of learners' and teachers' questionnaire

APPENDIX J

UNISA university of south africa

PROF T S MALULEKE
EXECUTIVE DIRECTOR: RESEARCH
: *+27 12 429 2970/2446* : *+27 12 429 6960*
: +27 (0)82 925 5232 : *malults@unisa.ac.za*
Theo van Wyk Building, 10th Floor, Office no. 50 -52 [TvW 10-50-52]

12 May 2010

Mr J K Kotoka
P O Box 23814
GEZINA
0031

Dear Mr Kotoka

REQUEST FOR ETHICAL CLEARANCE/Impact of information and communication technology (computer simulation) usage on the teaching and learning of the concept electromagnetism in grade 11 physics

Your application for ethical clearance in respect of the above study has been received and was considered by the Unisa Research Ethics Review Committee on 5 May 2010.

The Committee is pleased to inform you that ethical clearance has been granted for this study as set out in your application for ethical clearance.

We trust that sampling and processing of the relevant data will be undertaken in a manner that is respectful of the rights and integrity of Unisa's students, as stipulated in the Unisa Research Ethics Policy, which can be found at the following website:

http://www.unisa.ac.za/contents/research/docs/ResearchEthicsPolicy_apprvCounc_21Sept07.pdf

Congratulations on an interesting and very relevant study. We would like to wish you well in this research undertaking.

Kind regards

PROF TS MALULEKE
EXECUTIVE DIRECTOR: RESEARCH

cc. **PROF M N SLABBERT**

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
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APPENDIX K

education
DEPARTMENT: EDUCATION
MPUMALANGA PROVINCE

Private Bag X 11341
Nelspruit 1200
Government Boulevard
Riverside Park
Building 5
Mpumalanga Province
Republic of South Africa

Litiko leTemfundvo Umnyango weFundo Departement van Onderwys Umnyango wezeMfundo

Enquiries: A.H Baloyi (013) 766 5476

Mr. J.K Kotoka
P.O. BOX 5326
NELPRUIT
1200

RE: APPLICATION TO CONDUCT RESEARCH IN OUR SCHOOLS:

Your application (dated 08 September 2009) to conduct research in our schools was received on the 16 September2009.

Your motivation for the research demonstrates that the findings and the subsequent recommendations will also benefit the Department and the schools in the Mngwenya Circuit in particular. Based on the strength of your motivation the Department therefore approves your application and further wishes you a successful research study in the Department. Attached is the Department of Education's research manual which helps to regulate all research activities in our schools. I therefore request that you observe the guidelines as provided in the manual as far as possible.

We request that after the completion of your research project you prepare a presentation of the findings and recommendations to the Mpumalanga Department of Education.

If you need more support, please contact Mr. A.H. Baloyi at 013 766 5476 or 072 201 4043.

Best wishes with this important research.

MRS MOC MHLABANE
HEAD OF DEPARTMENT

20/11/2009
DATE

Together Educating the Nation

MPUMALANGA
A Pioneering Spirit

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APPENDIX L

Letter to the Principal

Dear Principal,

I am Kotoka Jonas Kwadzo, a full time teacher at Lihawu High School, and a Master's student at UNISA. As a requirement for the award of a Master of Science degree in Science, Mathematics and Technology Education, I am investigating the impact of information and communication technology (computer simulations) on the teaching and learning of electromagnetism in grade 11 Physics. I would like to humbly request your permission to use a computer simulation to teach learners in Grade 11 Physics, administer a pre-test, post-test and questionnaires to collect data from the Grade 11 Physical Science learners by the help of the class teacher(s).

There would be no interruption of your normal school programme, I would follow the normal school timetable and the Physical Science teacher(s) would use the computer simulation to teach electromagnetism in the computer lab while a control group will be taught using the traditional (normal) teaching methods. After the intervention, I would collect data by learners answering a post-test and a questionnaire. Teacher(s) on the other hand will only answer a questionnaire. The data collected will be treated with confidentiality and the names of your school, the teachers and the learners will not be used in the analysis of the data.

The teacher(s) may benefit from the research since they would be trained in the use of the simulations. The learners would also benefit from the method of instruction as it is hoped that this would enhance their understanding of the concepts.

Please do not hesitate to contact me if you have any further queries or clarifications. My contact details are as follows:

Cell numbers: 0734639661 and 0728568824.

Email: kotoka2002@yahoo.com and kotokajk@gmail.com

I look forward to your anticipated positive response.

Thank you.

Yours faithfully,

( )

Kotoka Jonas Kwadzo.

APPENDIX M

Letter to the educator

Dear Educator,

I am Kotoka Jonas Kwadzo, a full time teacher at Lihawu High School, and a Master's student at UNISA. As a requirement for the award of a Master of Science degree in Science, Mathematics and Technology Education, I am investigating the impact of information and communication technology (computer simulations) on the teaching and learning of electromagnetism in grade 11 Physics. I would like to request you to be part of my study. The study will involve the use of computer simulations to teach learners in Grade 11 Physical Science.

I would follow the normal school timetable and you will use the computer simulation to teach electromagnetism in the computer lab while a control group will also be taught using the traditional (normal) teaching methods. After the intervention, I would collect data from the learners, by the learners answering a post-test and a questionnaire. You on the other hand will only answer a questionnaire.

Participation in this research is voluntary and there will be no victimization whatsoever for refusal to participate. There would be no interruption of your normal school programme. The data collected will be treated with confidentiality and the names of your school, yourself and learners will not be divulged. It is hoped that you may benefit from the research since you would be trained in the use of the simulations. The learners would also benefit from the method of instruction as it is hoped that this would enhance their understanding of the concepts.

Please do not hesitate to contact me if you have any further queries or clarifications. My contact details are as follows:

Email: kotoka2002@yahoo.com. Cell numbers: 0734639661 and 0728568824.

I look forward to your anticipated positive response.

Thank you.

Yours faithfully,

( )

Kotoka Jonas Kwadzo.

APPENDIX N

Letter to the parent

Dear parent,

I am Kotoka Jonas Kwadzo, a full time teacher at Lihawu High School, and a Master's student at UNISA. As a requirement for the award of a Master of Science degree in Science, Mathematics and Technology Education, I am investigating the impact of information and communication technology (computer simulations) on the teaching and learning of electromagnetism in grade 11 Physics. I will like to seek your consent for your child to be part of my study. The study will involve the use of computer simulations to teach learners in Grade 11 Physics. I will collect data by administering tests, questionnaires and do lesson observations.

Participation in this research is voluntary and there will be no negative consequences whatsoever for refusal to participate.

There will be no interruption of your child's normal school programme, the normal school timetable shall be followed and your child will be taught with the use of computer simulation in the computer laboratory. The data collected will be treated with confidentiality and the name of your child will not be mentioned in the analysis of the data. That is, the name and identity of your child will be protected in this study.

It is hoped that your child will benefit from the research since the simulation is to enhance the learners' understanding of Physics concepts.

Please do not hesitate to contact me if you have any further queries or clarifications. My contact details are as follows:

Cell numbers: 0734639661 and 0728568824.

Email: kotoka2002@yahoo.com

I look forward to your anticipated positive response.

Thank you.

Yours faithfully,

(   )

Kotoka Jonas Kwadzo.

APPENDIX O

Letter to The Provincial Education Office.

Dear Sir/Madam,

I am Kotoka Jonas Kwadzo, a full time teacher at Lihawu High School, and a Master's student at UNISA. As a requirement for the award of a Master of Science degree in Science, Mathematics and Technology Education, I am investigating the impact of information and communication technology (computer simulations) on the teaching and learning of electromagnetism in grade 11 Physics. I would like to humbly request your permission to use a computer simulation to teach learners in Grade 11 Physics, administer a pre-test, post-test and questionnaires to collect data from the Grade 11 Physical Science learners with the help of the class teacher(s) in a school in the province.

There would be no interruption of the normal school programme, I would follow the normal school timetable and the Physical Science teacher(s) would use the computer simulation to teach electromagnetism in the computer lab while a control group will be taught using the traditional (normal) teaching methods. After the intervention, I will collect data by administering tests, questionnaires and do lesson observations. The data collected will be treated with confidentiality and the names of the school, the teachers and the learners will not be used in the analysis of the data.

The teacher(s) may benefit from the research since they would be trained in the use of the simulations. The learners would also benefit from the method of instruction as it is hoped that this would enhance their understanding of the concepts.

Please do not hesitate to contact me if you have any further queries or clarifications. My contact details are as follows:

Email: kotoka2002@yahoo.com.   Cell numbers: 0734639661 and 0728568824.

I look forward to your anticipated positive response.

Thank you.

Yours faithfully,

(   )

Kotoka Jonas Kwadzo.

APPENDIX P

Consent form for teachers to participate

I___________________________________ a teacher at

_____________________________________ School hereby grants consent to Mr. Kotoka Jonas Kwadzo to be part of his research. The data that will be collected from me and my class should only be used for research purposes and conferences. The data collected should be treated with confidentiality and the name of the participants (teachers and learners) should not be mentioned in the analysis of the data. The participants (teachers and learners) may withdraw from the study at any time.

Signature: _______________________________________ Date: ______________

APPENDIX Q

Consent form for learner participants in the study

I, ……………………………………………………, of …………………………………………(school) have read and understood the procedures involved in the study and what is expected of me as a participant. I understand that my name and identity will be protected in the study. I willingly give the following consent:

Please put a tick in the appropriate box

- ☐ I am willing to participate in the study
- ☐ I give consent for being observed during my Physical Science lessons
- ☐ I give consent for my Physical Science notebook being checked
- ☐ I give consent for part(s) of my Physical Science notebook to be photocopied if necessary

The data collected shall be treated with confidentiality and the name of the participants (teachers and learners) will not be mentioned in the analysis of the data. The participants (teachers and learners) may withdraw from the study at any time. The extra copy of this form is for you to keep.

Thank you.

------------------------- ------------------------

Signature of learner Date

Name (Please print)

APPENDIX R

Consent form for parents

I __________________________________ the parent of

___________________________________ hereby grant consent to Kotoka Jonas Kwadzo to allow my ward to be part of his research. The data that will be collected from my ward and his/her class should only be used for research purposes and presentations at conferences. The data collected should be treated with confidentiality and neither the name of the school, my ward or the teacher should be mentioned in the analysis of the data. The participants (teachers and learners) may withdraw from the study at any time.

Parents Signature: ______________________________ Date: ______________

Ward's name _________________________ Ward's Signature: __________Date: __________

Appendix S

Consent form for principal

I______________________________________ the principal of

_____________________________________ School, hereby grants consent to Mr.
Kotoka Jonas Kwadzo, to involve the Grade 11 learners and teacher(s) in his research.
The data collected should be treated with confidentiality and the name of the participants (teachers and learners) should not be mentioned in the analysis of the data. The participants (teachers and learners) may withdraw from the study at any time.

Signature: -- Date: ______________

Appendix T

GRADE 11C - JUNE EXAMS			
Learner	**Scores**	**Learner**	**Scores**
1	20	28	55
2	30	29	58
3	48	30	64
4	55	31	41
5	30	32	30
6	31	33	45
7	38	34	70
8	55	35	30
9	55	36	32
10	57	37	31
11	56	38	31
12	59	39	33
13	33	40	56
14	34	41	30
15	60	42	30
16	32	43	40
17	40	44	32
18	48	45	51
19	36	46	30
20	40	47	68
21	38	48	30
22	34	49	52
23	52	50	21
24	35	51	65
25	30	52	38
26	32	53	58
27	33		
		TOTAL SCORES	**2232**

GRADE 11A - JUNE EXAMS			
Learner	**Scores**	**Learner**	**Scores**
1	68	28	63
2	45	29	48
3	35	30	46
4	32	31	31
5	36	32	33
6	56	33	49
7	54	34	50
8	36	35	37
9	63	36	50
10	28	37	20
11	33	38	31
12	34	39	30
13	51	40	35
14	34	41	22
15	38	42	48
16	31	43	40
17	41	44	43
18	30	45	36
19	41	46	34
20	32	47	45
21	26	48	45
22	55	49	36
23	36	50	34
24	41	51	20
25	35	52	50
26	54	53	54
27	31	54	35
		TOTAL SCORES	**2161**

APPENDIX U

DEFINITIONS OF SOME CONCEPTS IN ELECTROMAGNETISM

1. Magnet

A magnet is a material that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet.

2. Magnetic fields.

The region around a magnet, where magnetic force will be experienced by a magnetic substance.

3. Magnetic field lines around a long wire

The magnetic field lines around a long wire which carries an electric current form concentric circles around the wire. The direction of the magnetic field is perpendicular to the wire and is in the direction the fingers of your right hand would curl if you wrapped them around the wire with your thumb in the direction of the current.

4. Right-hand grip rule

Right-hand grip rule is used to determine the direction of a magnetic field from the current direction in a conducting wire. It says that if the right hand grips the wire so that the thumb points the same way as the current, the fingers curls the same way as the field lines.

5. Solenoid

Solenoid refers to a long, thin loop of wire, often wrapped around a metallic core, which produces a magnetic field when an electric current is passed through it.

6. Electromagnets

An electromagnet is made from a coil of wire that acts as a magnet when an electric current passes through it but stops being a magnet when the current stops.

8. Force on current carrying conductor

When a conductor carrying a current is placed in a magnetic field, the conductor experiences a magnetic force. The direction of this force is always right angles to the plane containing both the conductor and the magnetic field, and is predicted by Fleming's Left-Hand Rule.

9. Fleming's left-hand rule

Fleming's left-hand rule says that if you hold the thumb and the first two fingers of your left hand at right angles, the thumb gives the direction of the force, the first finger shows the direction of the magnetic field (which is taken from north to south) while the centre finger points in the direction of the current (which is from the positive terminal to the negative terminal of the battery).

10. Electric motors and generators

An electric motor is an electromechanical device that converts electrical energy into mechanical energy. Most electric motors operate through the interaction of magnetic fields and current-carrying conductors to generate force. The reverse process, producing electrical energy from mechanical energy, is done by generators such as an alternator or a dynamo.

11. Fleming's right hand rule

Fleming's right hand rule (for generators) tells us that if we have to know the direction of the motion of the conductor and the direction of the magnetic field. We have our right hand out and the thumb and first two fingers at right angles, each to the other. The thumb will point in the direction of the motion of the conductor. The index finger will point in the direction of the magnetic lines of force. We have motion of the conductor and the direction of the magnetic field. The middle finger will now point in the direction of conventional current flow.

12. Transformers

A transformer is a device for increasing or decreasing an ac Voltage

13. Electromotive force, (emf)

In Physics, electromotive force, emf and measured in volts refers to voltage generated by a battery or by the magnetic force according to Faraday's Law, which states that a time varying magnetic field will induce an electric current.

14. Faraday's law of electromagnetic induction

Any change in the magnetic environment of a coil of wire will cause a voltage (emf) to be "induced" in the coil. No matter how the change is produced, the voltage will be generated. The change could be produced by changing the magnetic field strength, moving a magnet toward or away from the coil, moving the coil into or out of the magnetic field, rotating the coil relative to the magnet.

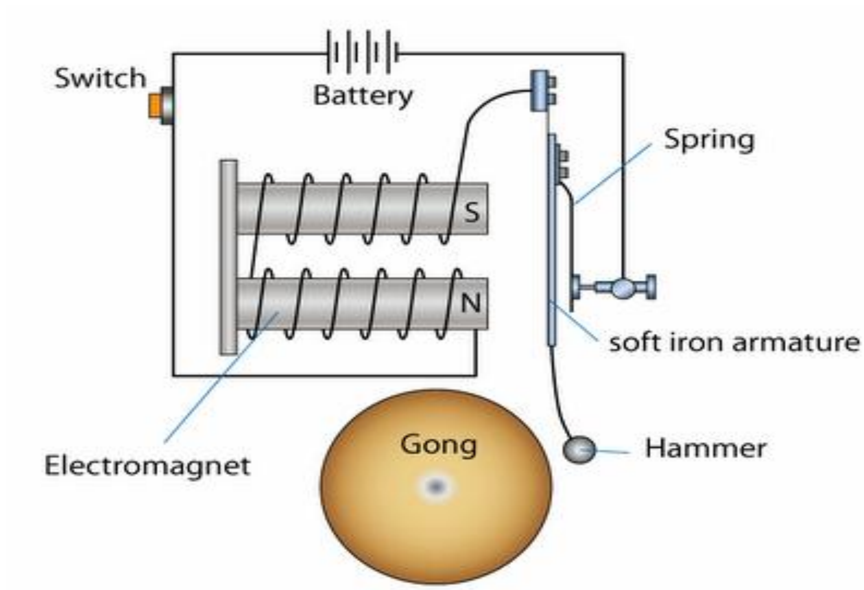
15. Induced electromotive force (emf)

Emf is induced (produced) in a wire if there is a relative motion between the wire and a magnetic field. Which can happen: If the wire/coil moves, if the magnet or electromagnet moves, if the electromagnet is switched on or off or is alternating. The induced electromotive force (emf) in any closed circuit is equal to the time rate of change of the magnetic flux through the circuit. OR The emf generated is proportional to the rate of change of the magnetic flux.

The definitions of these concepts are taken from Cutnell & Johnson, (2005), Nelkon & Parker, (1984), Abbott, (1982)

APPENDIX V

THE ELECTRIC BELL



The circuit diagram of the electric bell

How the electric bell works:

The bell system is a circuit consisting of an electromagnet, a switch, set to off, which the ringer presses, a power source, a gong, a hammer (which forms part of a second switch), and electrical contact point.

Once the ringer presses the switch the circuit is completed, and the electromagnet becomes active and attracts the hammer.

The hammer moves towards the magnet, striking the gong, but as it does so the circuit is broken (the hammer is part of the second switch completing the circuit), and the hammer falls back.

Once it has fallen back into place, the circuit is completed and it moves forward, striking the gong and breaking the circuit again, this cycle is repeated until the ringer releases the switch.