EFFICACY OF DEMONSTRATION-GUIDED SIMULATIONS ON MALE AND FEMALE LEARNERS' CONCEPTUAL UNDERSTANDING. LESSONS FROM ELECTROMAGNETIC INDUCTION IN SELECTED SECONDARY SCHOOLS OF LUSAKA DISTRICT

BY

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I, **Kaluba Christopher**, hereby declare that this dissertation is my own work and that it has not been previously submitted for award of any degree at the University of Zambia or any other University. The sources that I have used or quoted have been indicated and acknowledged by means of complete references.

Signed...

Date......................................

APPROVAL

This dissertation by Kaluba Christopher is approved as partial fulfilment of the requirement for the award of the Degree of Master of Education in Science Education by the University of Zambia.

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ABSTRACT

The purpose of the study was to determine the efficacy of demonstration-guided simulations (DGSs) on male and female learner's conceptual understanding of Electromagnetic Induction. The study employed a pre-test–post-test quasi-experimental design with a Solomon four arrangement of groups, involving two experimental and two control groups.

The study sample consisted of 132 grade 12 learners, of which 37 came from Experimental group 1, 26 came from Experimental group 2, 33 came from Control group 1 and 36 came from Control group 2. A Physics Achievement Test (PAT) with a 0.75 reliability coefficient was used for collecting data. Experimental group 1 and Control group 1 were pretested and then all the groups were taught Electromagnetic Induction, with the two experimental groups being taught using a Physics Education Technology (PhET) simulation called Faraday's Electromagnetic Lab while the other two control groups were taught using the traditional method. Finally, all the groups were post tested and data was analysed quantitatively using SPSS Version 25. All statistical tests were evaluated at $p < 0.05$ confidence level.

Results from independent samples t tests revealed that all experimental groups performed statistically significantly better than all the control groups with p values ranging from 0.0004 to 0.044 and effect sizes ranging from 0.51 to 1.03. This showed that demonstration-guided simulations are able to significantly improve learner's performance. The study also found that even if boys performed statistically significantly better than girls in the experimental group, the girls from the experimental group performed statistically significantly better than the girls from the control group which showed that simulations are equally gender friendly. Based on the findings of this study, it was concluded that the use of the demonstration-guided simulation in teaching electromagnetic induction is more effective than the than the traditional method of instruction and should therefore be encouraged.

It was therefore recommended that; the Curriculum Development Centre (CDC) should incorporate the use of demonstration-guided simulations into the curriculum, Ministry of General Education (MoGE) through Teacher Education and Specialised Services (TESS) should include into the teacher-training curriculum, the use of simulations as a teaching method/aid so as to adequately prepare would-be science

teachers on the skills and knowledge on how to use simulations. Schools and district administrators should develop regular Continuing Professional Development (CPD) programs in form of seminars, conferences and workshops on the integration of simulations in the teaching process.

DEDICATION

This dissertation is dedicated to my beloved wife Lombe Mupeseni Kaluba for the unwavering support and encouragement offered throughout my academic journey. I am forever grateful for your sacrifice to see me progress in my education.

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I am eternally grateful to God's interminable grace over my life. I would equally like to convey my sincere gratitude to my research supervisor Dr Mbewe S., for his dedication and firm supervision. Your unique style of supervision has been very inspirational. I also extend my gratitude to Dr Nachiyunde K., the post graduate coordinator, Dr Haambokoma C., Dr Kaulu G. and Dr Nalube P., the Head of Science Department in the School of Education. Your constructive criticism during my study inculcated a new level of professionalism in me.

I would like to thank the staff at Examinations Council of Zambia and the Head Teachers of the secondary schools where I drew my study sample from, for their support during the time I collected data. I would also like to convey my sincere gratitude to the teachers and learners who willingly participated in my study. Special thanks to my research assistants Mr Kapaso A. and the late Mr. Nqumayo F.

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ACRONYMS

CDC	Curriculum Development Centre
CSIP	Computer Self-Interactive Package
DGSs	Demonstration-Guided Simulations
ECZ	Examination Council of Zambia
EMI	Electromagnetic Induction
ICT	Information Communication and Technology
MoGE	Ministry of General Education
NSC	National Science Centre
PAT	Physics Achievement Test
PhET	Physics Education Technology
SPSS	Statistical Package for Social Sciences
TESS	Teacher Education by Specialised Services
ZPD	Zone of Proximal Development

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter presents the background to the study, which concisely introduces and provides the motivation to the study. It then gives the statement of the problem, the purpose of the study, research objectives, research questions, research hypotheses, significance of the study, delimitation, limitations of the study, theoretical and conceptual framework and finally some operational definitions of key terms.

1.2 Background to the study

Science is one of the subjects that is poorly performed at grade 12 National Examination and the current situation regarding learners' performance in physics to be specific leaves much to be desired especially the performance of girls in comparison with the boys. With regard to poor performance by girls in physics compared to boys, some scholars have attributed this to the negative attitude which most girls have towards science and mathematics. This is strongly supported by Kafata and Mbetwa (2016) and Maguswi (2012) who both noted that female students in Zambia and worldwide perform badly in O-level physics both in class and at national examination. In all these findings, the traditional method of instruction is usually the most dominantly followed, showing that the method itself has been ineffective. In traditional teaching - a method that has been used by many teachers during their long experience in education, the basic scientific information was conveyed by means of direct lecturing and guidelines provided by teachers. This method, having the teacher as the centre of teaching during classes, emphasizes teaching processes are led by teachers. Students expect to listen to lectures and learn by them (Balliu, 2017). This method of instruction has a major focus on the teacher's skills, knowledge and understanding of the subject matter and it also focussed on remember and understand, which are the low order thinking level of Bloom's taxonomy.

It therefore becomes imperative to find out whether a different approach to instruction apart from the traditional one can bring about a positive change in the performance of learners especially girls in physics. One such an approach is the use of technology, specifically simulations in the delivery of lessons.

According to (Haamoonga, 2017), the Zambian government has over the years tried to provide an environment that would improve learner performance, such as reducing class size, providing learning materials and upgrading teacher qualifications, but not much success was recorded. Even though efforts like these are being made to improve the performance of learners in science and physics in particular, the situation of recording poor results at national examination still persists. As can be seen in Tables 1.1 and 1.2, the performance of learners in physics between 2013 and 2017 had been very poor, falling way below 50%.

Table 1.1: Mean performance (%) in Science (5124) per paper (From 2013 to 2017)

	2013	**2014**	**2015**	**2016***	**2017***
Paper 1 (Physics/Chemistry)	55.40	33.10	33.07	***17.05***	***37.01***
Paper 2 (Physics)	***13.71***	***9.72***	***8.74***	43.95	38.79
Paper 3 (Chemistry)	40.88	16.30	17.0	42.24	23.80
Total (%)	33.94	17.76	17.65	32.83	35.28

Source Examination Council of Zambia

** In 2016 and 2017, the format of papers changed according to the new syllabus, with paper 1 being physics, paper 2, chemistry and paper 3 is practical (physics and chemistry)*

Table 1.2: Mean performance (%) in Physics (5054) (From 2013 to 2017)

YEAR	**2013**	**2014**	**2015**	**2016**	**2017**
PERFORMANCE (%)	48.28	48.33	48.83	38.59	44.34

Source Examination Council of Zambia

One of the topics which is poorly performed by learners nearly every year in physics is electromagnetic induction (ECZ, 2013, 2014, 2015, 2016, 2017).

The general comment from the Examinations Council of Zambia (ECZ) Examiner's reports on the poor performance on this topic is that learners find it challenging to express their understanding of abstract concepts.

It is worth noting that the vision of the country in the Science and Technology sector is a Zambia where science, technology and innovation are the driving forces in national development and competes globally by 2030 (Republic of Zambia, 2006). From here, it can be seen that one of the many ways such a vision can be attained is by ensuring that the teaching and learning of science is made meaningful and realistic so that learners can easily comprehend concepts and develop interest in science. This will in turn result in improved academic performance.

With the current poor performance in science and physics in particular which has been mentioned earlier, it becomes almost impossible for the nation's vision in the science and technology sector to be realised. A number of researchers have suggested means and ways of improving learner's performance in science subjects, particularly in physics. According to Kapata (2017), rearrangement of topics where candidates performed poorly such as radioactivity, electromagnetic induction and electronics and consideration of their prerequisites might enhance the performance of learners in physics. The findings of this study indicated that science scholars perceive the rearrangement of some physics topics as one of the ways which might enhance the performance of learners. However, in this study, the researcher investigated whether the use of demonstration-guided simulations in teaching topics like electromagnetic induction can help improve the performance of learners in physics.

physics is one of the many fields of science that relates frequently to people's everyday lives. It is considered as the study of matter, energy and their various interactions. Electromagnetic Induction (EMI), which is a component of physics is defined as the process by which an electromotive force is generated across an electrical conductor in a changing magnetic field. The concept behind EMI has fashioned a great revolution in the field of engineering applications which further influenced other fields such as space exploration, industrial applications, medicine to mention but a few. Some of the many applications of EMI at domestic level are found in most electrical appliances which use transformers, appliances such as hair blowers, computers, mobile phone chargers and in agriculture it is used in of soil investigations (Doolittle & Brevik, 2014). Entertainment systems like television sets and radios equally utilize the principles of EMI. At industrial level, EMI equally has a good number of applications such as in power generation where generators produce electricity and at the stage of transmission of power where step-up transformers are deployed (Faraj & Shadhan, 2020). Generators used in industries also work on the principle of EMI as power sources for the operation of other machinery. All these and many other applications stress the incalculable importance of EMI. Its importance even extends to a wider variety of other fields consequently providing a foundation for a number of such fields as electrical, mechanical, civil and computer engineering to mention but a few. It can therefore be seen that EMI is capable of creating essential knowledge required for the future technological advances that will drive the economic engines of countries and the world at large. As such, it becomes imperative to build a sound and competent cadre of learners who will have the passion, drive and interest to study science related fields and physics in particular at advanced levels. That is why it must be emphasised that concepts in physics like those of EMI are presented in an interesting and engaging way for the learners to develop the interest and passion for the subject and have a better understanding of such concepts. One way of doing this is by utilising the power of technology in teaching, specifically the use of computer simulations. It is hoped that once the interest and passion for the subject is inculcated into the learners, it will further improve their performance in the subject.

Most concepts on electromagnetic induction pose a lot of challenges for learners to fully conceptualise mainly because of their nature, complexity and to a greater extent because of how the information is presented to learners. This topic like a few others contains a lot of abstract concepts which must be presented in a way that simplifies them so that learners are able to understand them easily (Dori & Belcher, 2005). When the concepts in such topics are not properly concretised as they are presented by teachers, they will cause alienation to the subject for most learners. Learners usually find it difficult to visualise such abstract concepts and their processes especially that when teaching, most teachers present such topics with limited or no visual aids. In instances where teaching aids are used, they are usually static images which are limited because they do not represent the complete picture of a real-life process being taught and learners are unable to explore and interact with them.

In order to help learners easily comprehend concepts behind such topics and thus improve their performance in science and physics in particular, there is need to adopt teaching methods that are more learner-centred and capable of simplifying these concepts by using more realistic visual aids. One such a method is the incorporation of simulations as a supplementary teaching method to the traditional instruction. It should be noted that this might be one of the many interventions that can be done to solve the problem of poor performance in physics.

A simulation is a mathematical model that describes or creates computationally a system process. Simulations are our best cognitive representation of complex reality, that is, our deepest conception of what reality is (Vallverdú, 2014). From this definition, it becomes easy to note that introducing simulations in teaching may offer learners the opportunity to make more sense out of the concepts being presented to them because they connect reality to what is being presented. Learners in science education often have to deal with complex concepts or processes that are frequently considered difficult to grasp.

Digital technologies can help to facilitate knowledge acquisition and understanding in this context (Moser, Zumbach & Deibl, 2017). Since there are so many simulations which are used for educational purposes, in this study, the researcher used a physics Education Technology (PhET) Simulation titled Faraday's Electromagnetic lab (*v 2.07*). The PhET Project is a suite of online and offline open source simulations for teaching and learning introductory physics, mathematics and other sciences at high school and college levels. One advantage of simulations can be seen in the opportunity to present simplified external visualisations of phenomena that cannot be easily observed in the real sense. Compared to other educational media such as textbooks or animations, opportunities for learners to interactively manipulate different scientific variables and observe the results in graphical representations like graphs or tables are crucial for knowledge acquisition (Moser et al., 2017).

In an ideal situation, students are expected to explore these simulations on their own with minimal guidance from the teacher. But it is worth noting that in a Zambian context, most public schools are not adequately equipped with enough computers to carter for each and every student during the exploration of these simulations (Mwansa, 2022). As a result, demonstration-guided simulations were used in this study, where the teacher used a projector and demonstrated the working of particular simulations while engaging the learners during the exploration.

The motivation to undertake this study was necessitated by the failure by many learners to comprehend the concepts in electromagnetic induction.

1.3 Statement of the problem

The general performance of students in the Zambian Senior Secondary School Certificate in Science and physics in particular has been very poor and a major concern to a number of interested stakeholders in the education sector. As stated earlier, the mean performance of learner's in science keeps falling way below 50% with the highest mean score being 35.28 % in 2017. If this situation is left unattended to, it will become almost impossible for the nation to attain its 2030 vision of having a nation where science, technology and innovation are the driving forces in national development.

While the use of simulations on their own may help solve the problem regarding poor performance of learners in physics, they come with a number of limitations such as inadequate computers for each and every learner especially in most public schools, which limits their exploration to the maximum. Therefore, in the Zambian context, this study used the simulations in a demonstration manner which hasn't been explored that much. This is because using simulations in this manner seems to be more feasible under the circumstances. Hence the term demonstration-guided simulations.

While many educators find it appealing to use simulations in their classroom, very little research has been done to determine if simulations improve a student's understanding of or enthusiasm for science and how simulations can be designed and used most effectively (Adams et al., 2008). It is therefore against this background that this study was designed to investigate the efficacy of demonstration-guided simulations on learners' conceptual understanding of electromagnetic induction.

1.4 Purpose of the study

The main purpose of this study was to investigate the efficacy of demonstration-guided simulations on learners' conceptual understanding of electromagnetic induction in selected schools of Lusaka district.

1.5 Objectives

The objectives of the study were:

1. To compare the performance in electromagnetic induction between learners taught using demonstration-guided simulations as a supplement to traditional instruction and those taught using the traditional method.
2. To compare performance in electromagnetic induction of male and female learners after teaching them using demonstration-guided simulation.
3. To compare performance in electromagnetic induction of female learners taught using simulations and female learners taught using the traditional method.

1.6 Research Questions

The following were the research questions for the study

1. What is the difference in academic performance between learners taught electromagnetic induction using demonstration-guided simulations as a supplement to traditional instruction and those taught using the traditional method?
2. How do male and female learners perform after teaching them electromagnetic induction using demonstration-guided simulations?
3. How do female learners taught electromagnetic induction using simulations perform compared to female learners taught using the traditional method?

1.7 Hypotheses

Emanating from the above research questions were the following Null and Research Hypotheses which were tested at 0.05 level of significance:

Research Question 1 Hypotheses

H_0 1: There is no statistically significant difference in performance between learners taught using demonstration-guided simulations as a supplement to traditional instruction and those taught using the traditional teaching method.

H_A 1 : Learners taught electromagnetic induction using demonstration-guided simulations as a supplement to traditional instruction will perform statistically significantly better than learners taught using the traditional teaching method.

Research Question 2 Hypotheses

H_0 2 : There is no statistically significant difference in performance between male and female learners taught electromagnetic induction using demonstration-guided simulations.

H_A 2 : Male learners will perform statistically significantly better than female learners after teaching them electromagnetic induction using demonstration-guided simulations.

Research Question 3 Hypotheses

H_0 3 : There is no statistically significant difference in performance between female learners taught electromagnetic induction using simulations and female learners taught electromagnetic induction using the traditional method.

H_A 3 : Female learners taught electromagnetic induction using simulations will perform statistically significantly better than female learners taught electromagnetic induction using the traditional method.

1.8 Significance of the study

It is hoped that the findings from this study may provide important information to various stakeholders for the improvement of the education system especially in physics. The following are some of the stakeholders who might benefit from the findings of the study:

- Curriculum Development Centre (CDC): They may possibly incorporate into the curriculum, the use of simulations as supplementary teaching methods/aids.

- National Science Centre (NSC): The research findings may provide some information to the centre for further studies and possibly design and produce more relevant ICT related teaching aids for science subjects and physics in particular.
- Teacher education and specialised services (TESS) may incorporate the use of simulations in its pre-service and in-service teacher training education programs. This is because one of its mandates is to review and formulate policies on teacher education.
- Teachers of physics might also find the information helpful in their lesson delivery on a number of topics so as to improve the performance of learners.
- Researchers may also use findings from this research as a foundation for further research on similar topics.
- The research findings will also contribute to the existing literature on the subject matter for the general public which may include parents and prospective students. This may help to demystify the notion that physics is a difficult subject, and that there are actually better ways of simplifying difficult abstract concept in physics.

1.9 Delimitation

The following are the delimitations of the study.

- It was conducted in Lusaka district of Lusaka province.
- It was confined to only four selected schools.
- It focused on one topic only.
- It did not take into account the technological competencies of the learners and the pedagogical competencies of the teachers.

1.10 Limitations of the study

The following are the limitations of this study.

- The sampled schools were all urban, this is because it was easier to implement the use of these simulations in urban schools where electricity is readily available for the use of computers and projectors. As such, this might make the results not to be generalisable beyond this demographic group of participants.
- The topic which was taught required some prerequisites in electricity and magnetism which they had not yet done by the time data was being collected through teaching. As such this may have presented some challenges to the learners to fully understand new concepts without the needed prerequisites.
- Two different teachers for the two control groups were used. This may have presented a difference in the way they taught and influenced learners' responses to the lessons differently.
- The study was conducted using a quasi-experimental research design which may not make possible the generalisation of the findings beyond its scope. This is why the Solomon four design was included so as to increase its rigour.

1.11 Theoretical framework

This study was informed by the theory of constructivism, specifically the social cultural theory of constructivism by Lev Vygotsky. The constructivism theory of learning states that learners are active in the construction of their knowledge (Vygotsky, 1978). Vygotsky further amplified this point when he stated that social interactions among learners is important in the construction of knowledge.

Isaacs (2013) highlighted five key elements which Vygotsky identified as characteristics of social constructivist learning;

> *(a) a learner can only understand reality through active participation in his environment; learning is therefore not passive; (b) previous experience is coupled with and compared to new experience which leads to reinforcement and or adaptation of that knowledge;*
>
> *(c) learning occurs within a specific cultural context; (d) emphasis is placed on communication as knowledge is constructed through negotiation; and (e) learning takes place within a socio-cultural context.*

The theory therefore places much importance on instructional methods such as inquiry, group work, problem solving, discovery learning and field/project work. All these instructional approaches make an emphasis on the active participation of the learner. Even if collaboration and active participation is a must according to this theory, it ought to be mentioned that at some point, some level of independence is required from the learner, where the teacher only applies some minimum supervision through scaffolding. This is strongly supported by what Vygotsky (1978) suggested in his theory when he talked about the shift by the learner from their actual developmental level (*the can-do stage*) through the zone of proximal development (ZPD) to the level of potential development (*the can't do stage*).

The moment the learner reaches the level of potential development, they should be able to work independently in expressing their understanding of concepts. This is what now becomes their level of actual development. Figure 1.1 shows a diagrammatical representation of the transition by learners through the ZPD.

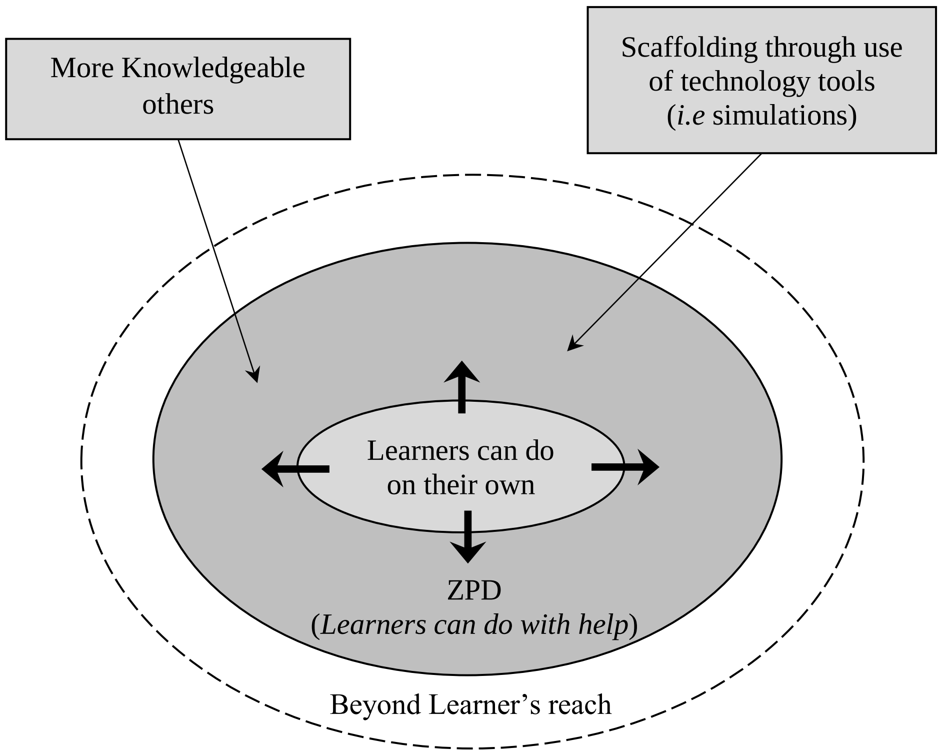

Figure 1.1: Learner's transition through the Zone of Proximal

Social constructivists believe that learner's prior knowledge plays a vital role in their learning because this will act as a reference point for construction of new knowledge through social interactions. Furthermore, they believe that this social interaction always occurs within a socio-cultural context, resulting in knowledge that is bound to a specific time and place (Vygotsky, 1978).

With the use of demonstration-guided simulations, learners will deliberately be accorded an opportunity to create social networks which are seen to develop a supportive learning network that enables collaborative learning so as to support and deepen their learning. This can be done by putting the learners into smaller groups and give them some items on a particular concept to discuss and give their views and understanding. This is done before the simulation is allowed to run. The design of the

PhET simulations, which were used in this study, is such that they are able to bring out learner's preconceptions, which might be correct or incorrect. From here, the teacher will effectively ride on those preconceptions to offer proper guidance to the learners through scaffolding and bringing out the correct conceptions using the simulations. The interesting part is that the simulation will highlight on these concepts in an interactive and engaging way. However, such computer-based learning environments usually include constructivist elements and often require learners to accept a high level of individual responsibility regarding their own learning process (Moser et al., 2017). As learners manage to pass through the ZPD, with the assistance of more knowledgeable others and scaffolding from the instructor, they are capable of attaining a level of potential growth which leads to creation of new knowledge. At this point the learner is now able to explain concepts which they were unable to explain before, leading to conceptual understanding of the topic being presented.

1.12 Conceptual framework

In this study, the use of demonstration-guided simulations as an instructional method has been conceptualised as an independent variable that may affect the conceptual understanding of learners. This may lead to a change in performance on test score results, which is the dependent variable. Interaction of learners through the simulation activities, minimal guidance and scaffolding from the instructor (teacher) are treated as moderating variables which may influence the strength of the relationship between the independent variable (teaching using demonstration-guided simulations) and dependent variable (conceptual understanding, to be determined by test score results).

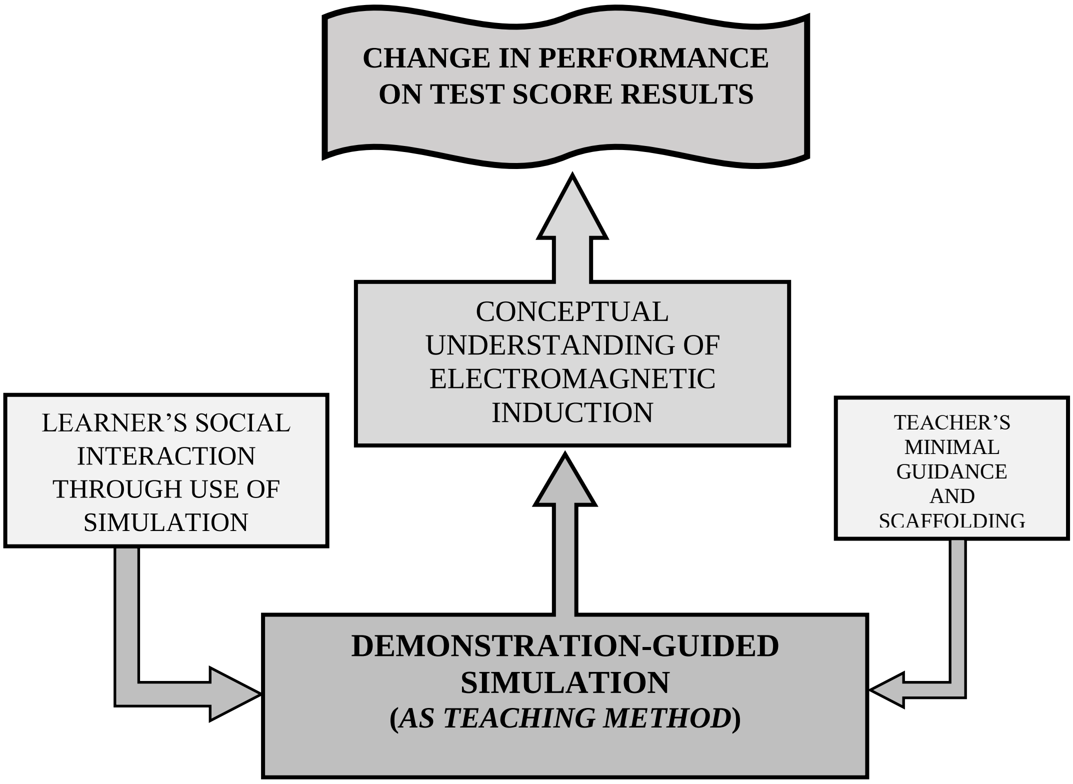

Figure 1.2: Conceptual Framework

1.13 Operational definitions of key terms

Conceptual understanding: Knowledge of abstract ideas determined by test score results

Traditional teaching method: Rote learning, lecture, memorization, drill and practice, educator-centered learning, and teacher-led instruction (Lamb & Annetta, 2010).

Constructivist teaching method: Interactive student-centred method of teaching, where students learn through group participation.

Demonstration-guided simulations**:** Teaching method where the manipulation of simulations is done by the teacher on a projected screen.

1.14 Summary

The chapter looked at an introduction to the study by giving a description of the background information and provided the motivation to the study. It then gave the statement of the problem, the purpose of the study, research objectives, research questions, research hypotheses, significance of the study, delimitation, limitations of the study, theoretical and conceptual framework and finally provided some operational definitions of key terms. The next chapter looks at a review of related literature.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of related literature. It begins with some general thoughts on why simulations offer the best alternative for the understanding of abstract scientific concepts. It then looks at how simulations work in an educational setting and then looks at some findings from other studies on how simulations assist in learning and finally it looks at why the use of demonstration-guided simulations may offer the best realistic alternative for the improvement of learners' conceptual understanding in physics.

2.2 Simulations for better understanding of abstract scientific concepts

The use of computer simulations is beneficial to both the teacher the student as it offers idealised, dynamic and visual representations of physical phenomena and experiments that might be hazardous, stressful, expensive or otherwise not feasible in school laboratories (Oladejo, Nwaboku, Okebukola & Ademola, 2021). A scientist approaches research as an enjoyable opportunity to explore basic concepts, as well as to challenge, correct, and add to his or her understanding of how the world works. Similarly, the student usually finds exploring the simulations fun and, through this exploration, discovers new ideas about the science (Wieman, Adams & Perkins, 2008). This is the more reason why the teaching of science should be done in such a way that it provides learners with a platform and an opportunity to express their scientific ideas in an all embracing and interactive manner. As such, simulations offer an interactive option for learners to fully visualise what each and every concept represents, in a more realistic way with the help of motion pictures and features which can be manipulated and adjusted so as to observe their effects on the processes being learnt. Learners can therefore be made to explore and interact with such simulations. This study however focused on the use of simulations in a demonstration-guided, learner-centred approach. As such, learners did not explore the simulations to the fullest, though they were able to interact in a more learner centred approach of these demonstrations.

Computer simulations are applications of special interest in physics teaching because they can support powerful modelling environments involving physics concepts and processes (Jimoyiannis & Komis, 2001). To the learners, they are able to provide correct mental models on which they can build new knowledge. This is because in the absence of proper visual and/or verbal cues, the brain will create 'mental pictures' which are based upon one's schema so as to add context to what is being learnt. For learners to develop correct schemata, they ought to learn concepts (*topics*) in correct and appropriate ways which are relevant and meaningful to them. That is why simulations offer one of the best instructional alternatives for learners. This is because the presented information will offer learners more realistic imagery of correct concepts being learnt. Simulation games provides opportunities for students to analyse problems, make decision, manage real life situations, control projects and experience the consequences of their actions. They are designed to help students to learn to achieve specific objectives actively rather than passively (Bello, Ibi & Bukar, 2016). These characteristics of simulations make it possible to have a lively classroom environment that is capable of arousing and sustaining learner's interests and attention throughout the lesson time. It equally makes it possible to easily comprehend abstract concepts because each and every aspect that a simulation presents, corresponds to some aspect of a real life situation that is presented in a simplified way. These are elements which cannot be found in other methods of instruction such as the traditional one.

Dori and Belcher (2005) strongly believe that teachers and students need to incorporate visualisations in the teaching and learning of scientific phenomena and processes, especially when dealing with abstract concepts such as electromagnetism.

"While many educators find it appealing to use simulations in their classroom, very little research has been done to determine if simulations improve a student's understanding of or enthusiasm for science and how simulations can be designed and used most effectively" (Adams et al., 2008, p.2). This is the more reason why this area needs to be investigated more, so as to come up with proper research based instructional approaches which will enhance the learning process especially in physics.

2.3 How simulations work in an educational setting

According to Dervić, Glamočić, Gazibegović-Busuladžić and Mešić (2018), external visualisations may facilitate physics learning by: highlighting elements that are most important to understanding the underlying physics concepts, conveying abstract information and providing a vivid context for testing hypotheses and solving problems. This is true because a number of physics concepts are very abstract to be effectively communicated to the learners without use of appropriate models or teaching aids. Simulations in general are able to bring out these external visualisations and make proper connections between concepts being presented and real-world situations or processes. Therefore, in order to effectively communicate concepts, it is important to make sure that these simulations are capable of helping the learners to concentrate on vital features of a particular concept and bridging the gap between real-life and abstract concepts.

One other important feature of simulations is that learners are capable of exploring the simulations and hence establish cause and effect relations of some physics concepts, this helps in the effective construction of appropriate mental models (Dervić et al., 2018). This is made possible because when using simulations, learners are virtually allowed to change parameters of the simulated system or process and visualise the results or consequences of these changes. This gives learners the opportunity to make proper inferences on scientific concepts. In the context of physics instruction, it is particularly important to note that the effectiveness of visualisations largely depends on the extent to which they trigger those cognitive activities that are considered to be of crucial importance for learning of the specific physics topics (Rapp & Kurby, 2008). It must be mentioned that for a simulation to be effective in delivering the intended information to the learner, it must avoid elements that might bring about cognitive overload especially extraneous ones which can be caused by superfluous cognitive activities and features. Superfluous features in a simulation can come about due to too much unnecessary graphics within the simulation. These features typically do not contribute to the construction of knowledge. A simulation must therefore be very simple and capable of offering an opportunity for effective knowledge construction. PhET simulations are some of the best simulations which are designed to reduce cognitive overload (Kaheru & Kriek, 2016). With PhET simulations, learners are able to effectively see the effects on one variable when another is changed in a more realistic manner.

According to Wieman et al. (2008), there are a number of characteristics that make a simulation fun and intellectually engaging, these include;

> *(i) dynamic visual environments that are directly controlled by the user, (ii) challenges that are neither too hard nor too easy, and (iii) enough visual*

complexity to create curiosity without being overwhelming. Items (ii) and (iii) are best developed through iteration and testing with students.

They further argued that most of the learning occurs when the student is able to ask questions that will guide his/her exploration of the simulation and discovery of the answers. This is because students learn better when they are engaged in self-driven explorations. All these characteristics are perfectly embedded in PhET simulations making them one of the best simulations for self-driven explorations by learners.

2.4 Some findings on how simulations assist in learning

Empirical results on the effectiveness of simulations on the performance of learners are quite mixed. According to a research conducted by the PhET project team on the design and use of simulations in a variety of educational settings, students who did a 2-hour exercise using the "Circuit Construction Kit" simulation in one semester course demonstrated higher mastery of the concepts of current and voltage on the final examination than students who did a parallel laboratory exercise with real equipment (Wieman et al., 2008). Their findings showed how effective the simulation was in helping learners understand the concepts in comparison with the traditional laboratory activity. On the other hand, Dervić et al., (2018) compared the conceptual understanding of upper secondary learners taught physics using the teacher-centred simulation and the student-centred simulation approaches. The student-centred method adopted a constructivist approach, keeping in mind that learners must construct their own knowledge as they interact with the simulation, of course with minimal guidance from the teacher. However, contrary to the researcher's predictions, the learners from the teacher-centred group out-performed those in the student-centred group. These finding were in support of the findings of Kirschner, Clark and Sweller (2006) who argued against effectiveness of constructivism in class, but states that there is much empirical evidence that guided instruction is generally more effective compared to minimal guidance approaches. They further stated that the advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide "internal" guidance. This implies that the instructor must not take the prior knowledge of the learners casually as this will be able to guide them on how much of the guidance ought to be provided to the learners so as to allow for some constructivism to still take place. Likewise, Wu and Huang (2007) compared teacher-centred and student-centred use of simulations in teaching ninth grade students. Their findings suggested that both instructional approaches promoted students' conceptual understanding and provided students with different opportunities to engage in science learning. There was no significant difference in the performance of the two groups. On the contrary, when used as a lecture demonstration, the "Wave on a String" simulation resulted in greater conceptual learning than did the standard demonstration (Perkins et al., 2006). All these findings were based on the use of simulations in both groups but using different approaches. And it can be seen that findings from these studies are quite mixed.

In different study conducted in Nigeria, Adegoke and Chukwunenye (2013) compared computer simulated experiments and hands on experiments in improving student's learning outcomes in practical physics. They compared three groups; group one, taught using both computer simulated experiments and hands-on experiment, group two, taught using computer simulated experiments alone and group three, taught using hands-on experiments alone. Their findings showed that, the first group performed significantly better than the other two while the third group performed the worst. This shows that when the use of simulation in teaching is done collectively with other instructional approaches, the resulting effects are significantly maximised.

According to Oladejo, Nwaboku, Okebukola and Ademola (2021), a computer simulation, if carefully explored, should be able to stimulate female students' interest, boost their class participation and enhance their learning irrespective of their individual learning modality or style (visual, aural, read and write and kinesthetic). However, according to Ankiewicz, Rensburg and Myburgh (2001), when it comes to the aspect of gender, findings on the effect of gender on the use of simulations are different with some showing significant differences in performance between male and female learners, while other studies found no significant differences. According to a study by Gamabri and Ikusanu (2014), there was no significant difference in performance between boys and girls when a computer based simulation was used in teaching them physics. His findings were consistent with the research findings of Yusuf and Afolabi (2010) who, in their study, further investigated the influence of gender on the performance of students in biology after being exposed to computer assisted instruction. Their research found no significant difference in the performance of male and female students. However, other studies suggest otherwise on this aspect. Research conducted by Geelan and Mukherjee (2011), yielded contrary results showing huge significant differences between male and female learners with the males still outperforming their female counterparts. They only justified their use in teaching and learning on grounds of other benefits which they offer such as enjoyment of lessons. According to them, their findings warranted further study into the subject matter and specific issues of sex and availability/achievement level.

Almasri (2022) looked at understanding the connection between learners' engagement and satisfaction with simulations for science learning and their learning styles. The results of this study indicated that there was a significant difference between male and female learners in their level of engagement and satisfaction towards simulations in science learning. Female learners reported a significantly higher level of engagement and satisfaction with simulations in science learning than their male counterparts.

With all these mixed findings on use of simulations in the classroom, it remains unclear how impactful simulations are on the performance of learners especially when they are used a demonstration. Hence the need for further investigation in the matter. In this study, the effectiveness of the simulation was compared with the common traditional method, where the lecture method was principally used. It has also been seen clearly from all the antagonistic views that the use of simulations as an instructional approach may not always yield the same results in different contexts.

2.5 Demonstration-guided simulation: The realistic alternative

The idea of using simulations in a demonstration manner is hinged on the premise that in most real situations, not every learner can have access to a computer and effectively manipulate the different parameters in a simulation during a particular lesson. This happens to be the prevailing situation in most public schools due to inadequate resources such as computers and internet connectivity (Mulauzi et al., 2020; Mwansa, 2022; Nkhoma, 2019). At times the teacher may be required to carry out demonstrations while manipulating a number of parameters in the simulation. In such a situation, the whole simulation program is projected on a big screen for every learner to see. According to Wieman et al. (2010), a simulation can be used as a simple animated illustration, in concept tests or in form of interactive classroom demonstrations. As an animated illustration, the simulation shows the process and can be slowed or sped up depending on the concept being shown. This allows effective classroom management by the teacher in the sense that the teacher controls the running of the simulation. To make it more interactive, learners can be engaged in concept test where the teacher asks a question in line with the concept at hand. Learners are then allowed to discuss with their neighbours and vote on the answer. Perhaps the most effective way to use simulations in a lecture is to begin with the teacher posing a scenario and asking students to write down their predictions, after students have written down their predictions, they talk with their neighbours to come up with final prediction for their group. The teacher then asks to hear predictions from the class and then runs the simulation. After students see what the simulation does, they write down what did happen and how it was different from their predictions. Finally, there is a whole class discussion about what they saw and why it makes sense based on physics ideas (Wieman et al., 2010). This happens to be one of the best ways to use simulations in a demonstration manner as it gives the teacher enough control of the classroom situation so as to effectively manage the learning process while actively engaging the learners. It also proves to be effective especially in a situation where the learners are not well acquainted with the proper use of computers.

Using simulations in a demonstration manner has proven to be more effective than using them in a learner centred manner, in certain instances. In a study to compare the teacher-centred approach and the student-centred approach in teaching physics using simulations, Dervić et al., (2018) found that students in the teacher-centred group significantly outperformed their counter parts in the student-centred group on the post test. This can be attributed to the fact that in the teacher-centered approach, the teacher is able to give the appropriate minimal guidance to the learners unlike in a situation where the learners interact with the simulation on their own as is the case for the student-centered approach.

This research was therefore designed to ascertain the efficacy of demonstration-guided simulations on learner’s conceptual understanding of electromagnetic induction in the

Zambian context. It further established how gender influences performance of students when exposed to simulations during teaching and when taught using the traditional method.

2.6 Summary

The chapter reviewed literature of different studies conducted on various aspects to do with the use of simulations as a method of instruction. The chapter looked at why simulations are considered important when used as an instructional method. It then looked at how simulations work in an educational setting and then reviewed some studies on the impact of simulations on learners' performance. From the reviewed studies, scholars who investigated the subject matter employed different approaches on the use of simulations in a classroom environment. Some studies yielding different results while others yielding similar results. Finally, the chapter looked at how and why demonstration-guided simulations can be adopted as the best realistic alternative in a number of situations.

From the reviewed literature, it is evident that there is very little research done on the use of simulation as a demonstration in teaching science and physics in the Zambian context. The next chapter describes the methodology used in this study.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter outlines how the study on the efficacy of demonstration-guided simulations on learner's conceptual understanding of electromagnetic induction was carried out. The outline of the research methodology looks at the research paradigm and design, study area, study sample, sampling techniques, research instruments, data collection procedure, data analysis instruments and procedures and reliability and validity measures and ethical considerations.

3.2 Research paradigm

A quantitative research paradigm was employed in this study. This is because the researcher was investigating the effect of an intervention (*demonstration-guided simulation*) on learners' conceptual understanding of electromagnetic induction. The study looked at a cause and effect relationship which was investigated quantitatively. According to Campbell, Stanley and Gage (1963), an experiment is that portion of research in which variables are manipulated and their effects upon other variables observed.

3.3 Research design

The research design that was adopted for this study was quasi-experimental pre-test/post-test control group design. The adoption of this design was mainly because of the non-randomisation of the sample that was chosen. The other reason is that specific characteristics of schools which were chosen was of paramount importance to the study. These characteristics were; the schools were from urban locations, they were co-education schools, because gender was another variable that was investigated. The other reason for this design was that it relied on pre-existing classes, which were assigned to the groups. The study also adopted the Solomon four design in the arrangement of the groups, because it has higher reputation and represents the first explicit consideration of external validity factors (Campbell et al., 1963).

A summary of the research design and how it was conducted is shown in Table 3.1.

Table 3.1: Summary of the Design

Groups	Pre-test	Independent Variable	Post-test
Experimental group$(\boldsymbol{E_1})$	$\boldsymbol{Y_1}$	$\boldsymbol{X}$	$\boldsymbol{Y_3}$
Control group$(\boldsymbol{C_1})$	$\boldsymbol{Y_2}$	$\boldsymbol{T}$	$\boldsymbol{Y_4}$
Experimental group$(\boldsymbol{E_2})$	$-$	$\boldsymbol{X}$	$\boldsymbol{Y_5}$
Control group$(\boldsymbol{C_2})$	$-$	$\boldsymbol{T}$	$\boldsymbol{Y_6}$

Where,

$\boldsymbol{Y_1}$ refers to the pretest scores of the experimental group (E_1)

$\boldsymbol{Y_2}$ refers to the pretest scores of the control group (C_1)

$\boldsymbol{Y_3}$ refers to the posttest scores of the experimental group (E_1)

$\boldsymbol{Y_4}$ refers to the posttest scores of the control group (C_1)

$\boldsymbol{Y_5}$ refers to the posttest scores of the experimental group (E_2)

$\boldsymbol{Y_6}$ refers to the posttest scores of the control group (C_2)

$\boldsymbol{X}$ refers to the use of demonstration-guided simulations as a supplementary teaching method to the traditional method

$\boldsymbol{T}$ refers to the use of traditional teaching method only

Using this method increased the rigour of the design chosen because in the event that the treatment is effective, its effects can be replicated in four different fashions such as:

$\boldsymbol{Y_3} > \boldsymbol{Y_1}$ $\boldsymbol{Y_3} > \boldsymbol{Y_4}$ $\boldsymbol{Y_5} > \boldsymbol{Y_6}$ $\boldsymbol{Y_5} > \boldsymbol{Y_2}$

In this study, the independent variables were; teaching using demonstration-guided simulations as a supplement to the traditional method while the dependent variable was the achievement scores which learners obtained after the posttests. Gender was a moderating variable.

3.4 Study area

The research was conducted in Lusaka district of Zambia in four co-educational secondary schools.

3.5 Sampling techniques

In this quasi-experimental study, a three-stage sampling technique was carried out. Firstly, a purposive and convenient sampling technique was done to obtain the four secondary schools with similar characteristics such as school type (*i.e. public schools*) and gender arrangement (*i.e. mixed schools*). This was done in such a way that the sampled schools were to be at some reasonable distance apart to avoid contamination. Secondly, a class from each of the selected schools was again purposively sampled and lastly, the four selected, similar groups from the mixed schools were purposively assigned to the four groups. The sampled schools were given pseudo names as follows:

Alpha School, was experimental group 1 ($\boldsymbol{E_1}$)

Beta School, was experimental group 2 ($\boldsymbol{E_2}$)

Gamma School, was control group 1 ($\boldsymbol{C_1}$)

Delta School, was control group ($\boldsymbol{C_2}$)

3.6 Study population

The study population comprised all the grade 12 learners from the four selected secondary schools in Lusaka district.

3.7 Study sample

The study sample for this research consisted of approximately 132 grade 12 learners, of which 37 came from Alpha School, 26 came from Beta School, 33 came from Gamma School and 36 came from Delta School.

3.8 Data collection instruments

3.8.1 The Physics Achievement Test (PAT)

The research instrument that was used to collect primary data in order to determine the efficacy of the simulations is the Physics Achievement Test (PAT). The PAT was subjected to validation and reliability test as described in Section 3.10. It consisted of 21 multiple choice items, ranging from definition of terms and processes, identification of correct abstract concepts and some calculations.

3.8.2 The Physics Education Technology (PhET) Simulation

Figure 3.1 below shows an extract of the simulation that was used in the teaching and learning process for the experimental group.

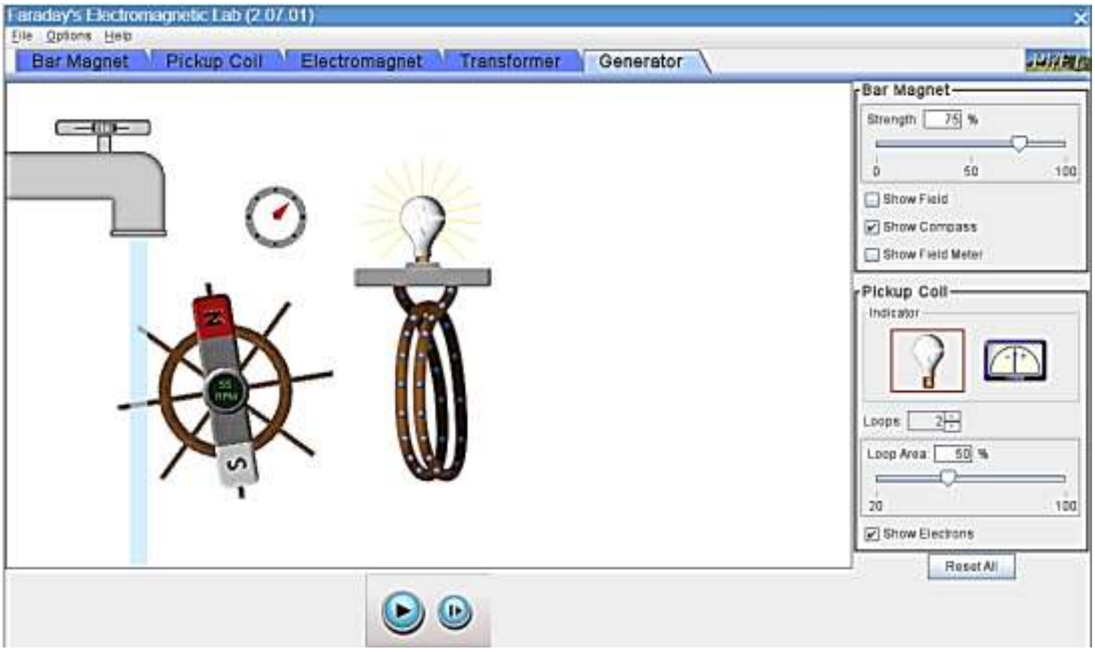

Figure 3.1 Extract of Faraday's Electromagnetic laboratory simulation

The pedagogical structure of the simulation is in such a way that it has five panels; the bar magnet, the pick-up coil, the electromagnet, the transformer and the generator. The panels begin with the basic concepts from the bar magnet and builds up the concepts in terms level of difficulty up to the generator. Each panel is interactive and learners can see what happens whenever parameters are adjusted. For example, in the panel shown in Figure 3.1, the speed of rotation of the magnet can be adjusted by increasing the amount of water flowing, which ends up increasing the induced electromotive force seen by the increase in the intensity (brightness) of the light bulb. The strength of the magnet and the number of coils (loops) can equally be increased or reduced from the side panel. Their effects are equally observed by the brightness of the light bulb or the extent of deflection on the galvanometer.

3.9 Data collection procedures

Data collection involved pretesting, teaching and post testing. It was collected in two phases.

Phase 1 (3 weeks): Data collected from the first two schools.

The researcher collected data in one school where the intervention (treatment) was used, in the experimental group while a research assistant (*a physics teacher*) collected data from the other school were the traditional method of instruction was used.

Phase 2 (3 weeks): Data Collected from the last two schools

Again, the researcher collected data in one other school were the intervention (treatment) was used while a second research assistant (*a physics teacher*) collected data from the other school were the traditional method of instruction was used.

Firstly, pre-tests were administered in the first week to the experimental group (E_1) and control group (C_1) using the (PAT). From the second to the third week, the lessons were taught to the experimental group (E_1) and control group (C_1) with the PhET simulations used as a supplementary teaching method in the experimental group (E_1) and the traditional method used in the control group (C_1). At the end of the third week, the two groups were post-tested. This was done in phase 1.

In phase 2, starting in the fourth week, experimental group (E_2) was taught using the PhET simulations as a supplementary teaching method, without being pretested. Control group (C_2) was also taught but using only the traditional method. This went into the fifth week and at the end of the teaching cycle, these two groups were also post-tested. All the four groups had a time allocation of two periods of 40 minutes each week.

3.10 Data analysis procedures

The collected data was analysed using descriptive and inferential statistics with the help of SPSS version 25.

To compare the mean performance between the experimental and control groups and hence find out if there was a significant difference, independent samples t-tests were conducted.

To compare the mean performance between boys and girls within the experimental group and hence find out any significant difference, an independent samples t-test was carried out.

To compare the mean performance between boys and girls within the control groups and hence find out if any significant difference existed, another independent samples t-test was done. All statistical tests were evaluated at $p < 0.05$ level of confidence.

3.10 Validity and reliability

3.10.1 Validation of Research Instrument and Treatment

(a) Treatment: Faraday's Electromagnetic Laboratory is one of the simulations developed by the University of Colorado under the PhET project. They are open source simulations which are developed from research.

While the simulations are research based and already validated, they were still subjected for further validation by giving them to two expert physics teachers and two expert science education lecturers for content and appropriateness to grade level. Among the items which were assessed included language, typography, legibility, navigation, interface, animations, functionality, packaging, suitability for instruction, simplicity, unity among illustrations, emphasis on key concepts, colour use and text. This ensured that all the contents and learning items are coming from the subject's scope of the curriculum and suitable for grade 12 physics learners.

Faraday's Electromagnetic Lab (*v2.07*) link:

https://phet.colorado.edu/en/simulations/faraday

(b) *Physics Achievement Test (PAT)***:** PAT was given to two lecturers in the Department of Mathematics and Science Education, University of Zambia and two physics teachers from secondary schools. These experts assessed the face and content validity of the instrument in relation to the background of physics for secondary school students in grade 12. They also examined all the items in the test instrument with reference to the appropriateness of the content, and the extent to which the contents will cover the topic electromagnetic induction.

3.10.2 Reliability of the Instrument

PAT was pilot tested in one senior secondary school in Lusaka, which was different from the schools from which the sample was drawn. Forty-two learners took part in the pilot study. A reliability coefficient of 0.75 was obtained from the pilot test using Kuder Richardson (KR-20).

3.11 Ethical consideration

First and foremost, ethical clearance was obtained from the University of Zambia Ethics Committee. Then before data collection was done, permission from head teachers of the sampled schools was sought and granted. Permission from the participants was also sought which enabled them to fully and voluntarily participate in the whole process of data collection. The whole purpose of the study was fully explained to the participants. The names of the schools and that of the participants had been kept confidential and not mentioned in any part of the report. Only pseudo names were used.

3.12 Summary

This chapter presented the methodology of the study by outlining the research paradigm and design used, study area which was chosen, the study sample and sampling techniques used, research instruments and data collection procedure, data analysis instruments and reliability and validity measures. The results obtained will now be presented in the next chapter.

CHAPTER 4

PRESENTATION OF FINDINGS

4.1 Introduction

This chapter presents the findings of the study. The results are reported in three sections according to the objectives of the study. The first one deals with inferential statistics on the first objective which compared post-test performance between learners taught using demonstration-guided simulations as a supplement to traditional instruction and those taught using the traditional method. The second section reports on inferential statistics on the second objective which compared post-test performance between male and female learners after teaching them using demonstration-guided simulations. And the last section reports on inferential statistics on the third objective which compared post-test performance between female learners taught electromagnetic induction using simulations and female learners taught electromagnetic induction using the traditional method.

4.2 Effectiveness of demonstration-guided simulations on learner performance

From the four groups in the design, the Experimental group 1 ($\boldsymbol{E_1}$), from Alpha School and Control group 1 ($\boldsymbol{C_1}$), from Gamma School were both pre-tested and the results show that there was no statistically significant difference between the mean score of $\boldsymbol{E_1}$ ($M = 38.94$, $SD = 12.843$) and $\boldsymbol{C_1}$ ($M = 40.06$, $SD = 16.306$; $t = 0.306, p = 0.760$).

Table 4.1 shows independent samples t test results conducted on the results for $\mathbf{E_1}$ and $\mathbf{C_1}$ given in Table 4.1.

Table 4.1: Independent samples test for E_1 (Alpha School) and C_1 (Gamma School) Pretest

Groups	N	t	CV	Df	$p-value$	Mean difference	Cohen's d
E_1	35	0.306	2	59.765	0.760	0.561	0.036
C_1	33						

The data for these results is extracted from the pre-test scores for alpha school and gamma school which are shown in Appendix 3 Table 5(a) and 5(b).

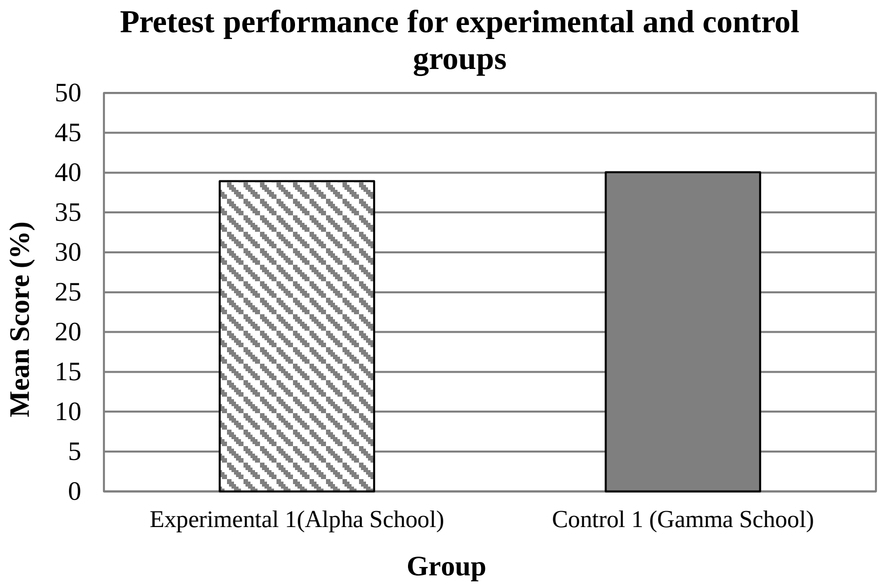

Figure 4.1: Pretest performance for Experimental group and Control group

These results have shown that the groups where at the same level of comprehension on the topic electromagnetic induction.

The major objective of the study was to determine how effective demonstration-guided simulations (DGSs) are on learner's conceptual understanding of electromagnetic induction in comparison with the traditional instructional method. To do this, it was imperative to conduct a number of independent samples t tests.

Table 4.2 shows a summary of descriptive statistics in form of means and standard deviations for pre and post test results of experimental and control groups.

Table 4.2: Summary of descriptive statistics results for pre-and post-test results for all the groups

Group		Pre test		Post test		Mean Difference
		M	***SD***	***M***	***SD***	
Experimental Groups (*Using simulations*)	E_1 **(*Alpha School*)**	38.94	12.843	66.03	15.542	27.09
	E_2 **(*Beta School*)**			69.73	19.023	
Control Groups (*Using Traditional teaching method*)	C_1 **(*Gamma School*)**	40.06	16.856	51.42	16.702	11.36
	C_2 **(*Delta School*)**			57.88	12.652	

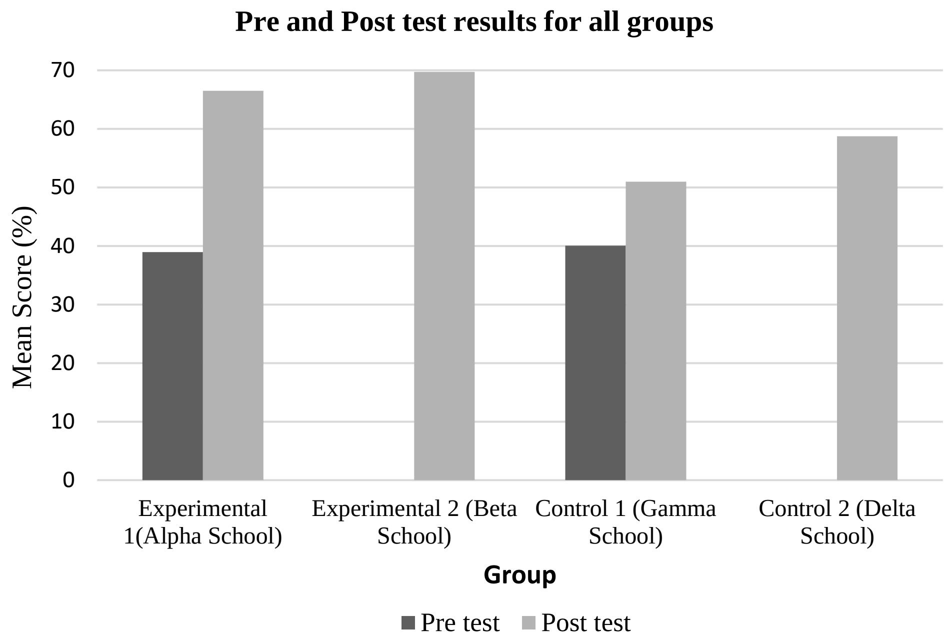

Figure 4.2: Pre and Post-test performance for all the groups

Table 4.3 shows independent samples t-test results to determine whether the post-test means of experimental groups were statistically significantly different from the post-test means of the control groups.

Table 4.3: Independent samples t test results.

GROUPS	*N*	*t*	*CV*	*df*	*p – value*	Mean difference	Cohen's *d*
$\boldsymbol{E_1}$	30	3.466	2.004	54.895	.001*	14.712	.913
$\boldsymbol{C_1}$	28						
$\boldsymbol{E_1}$	30	2.060	2.003	55.780	.044*	7.283	.518
$\boldsymbol{C_2}$	36						
$\boldsymbol{E_2}$	26	3.767	2.009	49.918	0.00043*	18.409	1.031
$\boldsymbol{C_1}$	32						
$\boldsymbol{E_2}$	26	2.562	2.02	40.568	.014*	10.981	.7026
$\boldsymbol{C_2}$	36						

*Significant at $p < .05$

The guide on the interpretation of the effect size according to Cohen (1992), has three levels as given below.

small effect size, $d = 0.2$ to 0.5,

medium effect size, $d = 0.5$ to 0.8 and

large effect size, $d > 0.8$

"An effect size of d = 1.0 indicates an increase of one standard deviation on the outcome, in this case the outcome is improving school achievement." (Hattie, 2009)

The data presented above shows that both experimental groups performed statistically significantly better than the two control groups with a medium to large effect size of the intervention.

$\boldsymbol{E_1}$ $(M = 66.03, SD = 15.54)$ performed better than $\boldsymbol{C_1}$ $(M = 51.32, SD = 16.7;$ $t = 3.466, p = .001, d = .913)$.

$\boldsymbol{E_1}$ $(M = 66.03, SD = 15.54)$ performed better than $\boldsymbol{C_2}$ $(M = 58.75, SD = 12.65;$ $t = 2.06, p = .044, d = .518)$.

$\boldsymbol{E_2}$ $(M = 69.73, SD = 19.02)$ performed better than $\boldsymbol{C_1}$ $(M = 51.32, SD = 16.7;$ $t = 3.767, p = .00043, d = 1.031)$.

$\boldsymbol{E_2}$ $(M = 69.73, SD = 19.02)$ performed better than $\boldsymbol{C_2}$ $(M = 58.75, SD = 12.65;$ $t = 2.562, p = .014, d = .7026)$.

From all these findings, all p values are less than 0.05 and all t values are greater than their corresponding critical values, therefore, learners taught electromagnetic induction with simulations performed statistically significantly better than those taught using the traditional method. Therefore, the first null hypothesis (H_0 1) has been rejected.

The consistence with the post test scores shows that pre-testing had not affected the groups in such a way that they become sensitized or familiarised to the experimental variable and respond differently than the un-pretested groups. This is one of the advantages of the Solomon four design in overcoming the external validity weakness to do with pretesting.

4.3 Influence of gender on learner performance in a DGSs classroom

To show whether gender had an influence on the performance of the experimental group, an independent samples t-test was conducted.

Table 4.4 shows a summary of the independent samples t test results between males and females in the experimental group.

Table 4.4: independent samples t test results between males and females for experimental group

		EXPERIMENTAL GROUP 1	***N***	**Mean**	***t***	***CV***	***df***	***p – value***
E_1	**Pretest**	***M***	18	39.50	.260	2.034	33	.796
		F	17	38.35				
	Posttest	***M***	18	72.33	3.16	2.048	28	.004
		F	12	56.58				

The results from the independent samples t test show that after teaching both of them using simulations, males ($M = 72.33$, $SD = 14.16$) performed significantly better than females ($M = 56.58$, $SD = 12.824$; $t = 3.16$, $p = .004$). Therefore, the second null hypothesis, H_0 2 has been rejected.

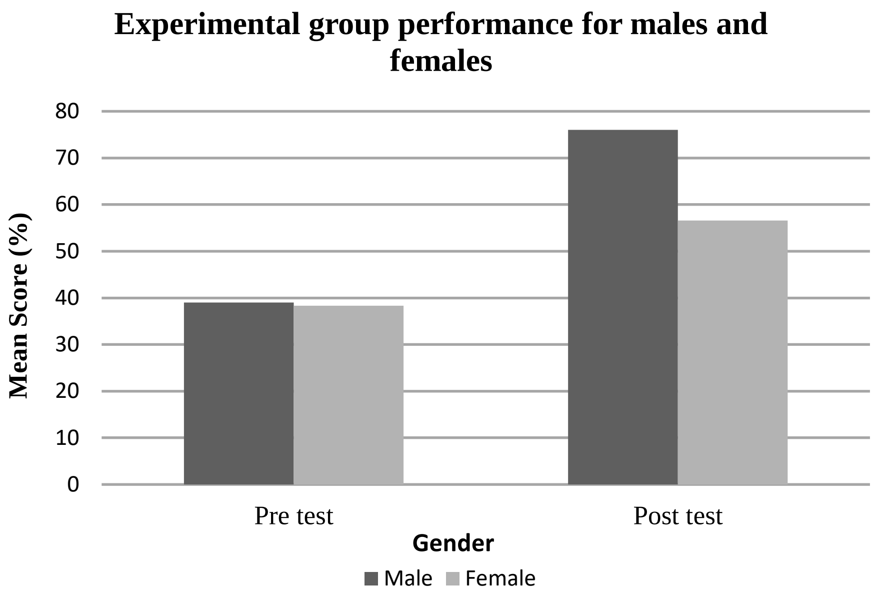

Figure 4.3: Pre and Post-test performance for males and females in Experimental group

4.4 Influence of gender on learner performance in the traditional classroom

To show whether gender had an influence on the performance of the control group, another paired samples t-test was conducted.

Table 4.5 shows paired samples t-test results between males and females in the control group

Table 4.5: Independent samples t-test results between males and females for control group

	CONTROL GROUP 1		*N*	Mean	*t*	*CV*	*Df*	*p – value*
C_1	**Pretest**	***M***	13	51.54	3.693	2.061	24.706	.001
		F	20	32.60				
	Posttest	***M***	13	59.38	2.608	2.061	24.65	.015
		F	15	44.33				

From Table 4.5 above, it can equally be observed that after teaching them using the traditional method only, once again males ($M = 59.38$, $SD = 15.819$) performed significantly better than females ($M = 44.33$, $SD = 14.519$; $t = 2.608$, $p = .015$). Therefore, the third null hypothesis, H_0 3 has equally been rejected.

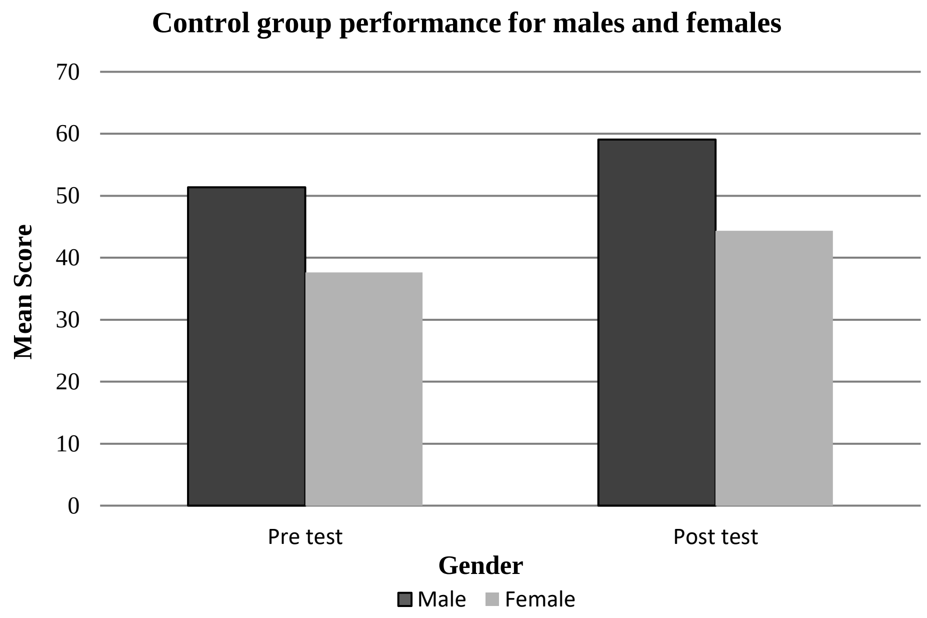

Figure 4.4: Pre and Post-test performance for males and females in Control group

4.5.1 Female performance from the experimental group and the control group

Table 4.6: Independent samples t test results between females in experimental group and females in control group

GROUP	*N*	Mean		SD	*t*	*CV*	*df*	*p – value*
		Pre	Post					
Experimental 1 (Female)	15	38.35	56.58	12.82	2.325	2.061	24.711	.029
Control 1 (Female)	12	37.62	44.33	14.519				

The results from Table 4.6 above reveals that females in the experimental group ($M = 56.58$, $SD = 12.82$) performed significantly better than females in the control group ($M = 44.33$, $SD = 14.519$; $t = 2.325$, $p = .029$, $d = 0.8877$).

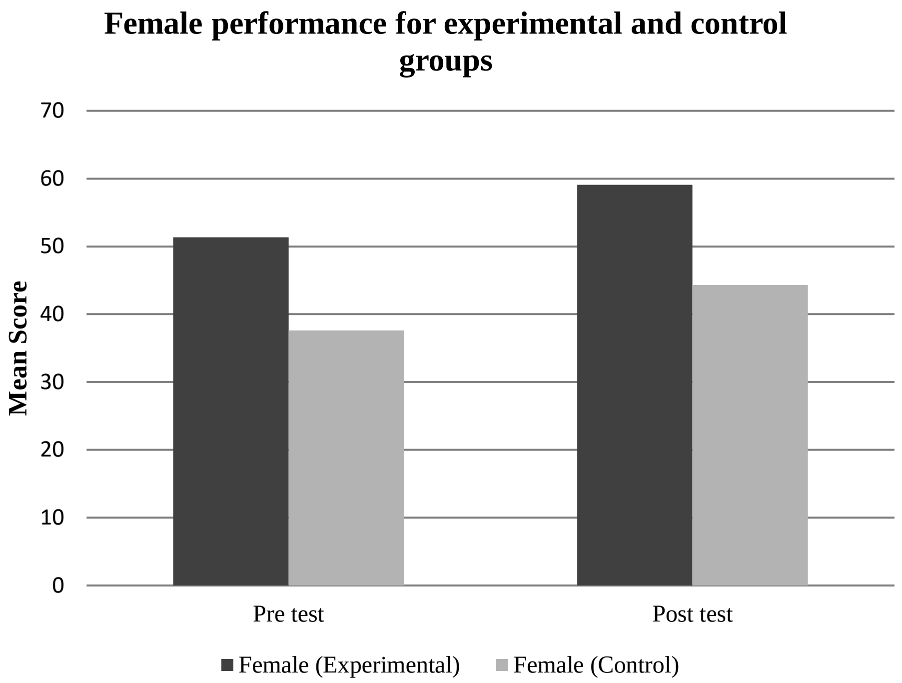

Figure 4.5: Pre and Post test performance of females in Experimental and Control groups

4.7 Summary

This chapter presented the findings of the study. The results were reported in three main segments in line with the objective of the study. The first segment reported on findings from descriptive and inferential statistics on the first objective which compared post-test performance between learners taught using demonstration-guided simulations as a supplement to the traditional instruction and those taught using the traditional method. The second segment reported on findings from inferential statistics on the second objective which compared post-test performance between male and female learners after teaching them using demonstration-guided simulations. And the last segment reported on findings from inferential statistics on the third objective which compared post-test performance between male and female learners after teaching them using the traditional method. The chapter that follows presents discussion of the findings.

CHAPTER 5

DISCUSSION OF FINDINGS

5.1 Introduction

This chapter discusses the findings on the efficacy of demonstration guided simulations on learners' conceptual understanding of electromagnetic induction and the influence of gender on the use of simulations as an instructional method.

5.2 Effectiveness of Demonstration-Guide Simulations (DGSs)

From the analysis of the pre-test scores shown in Table 4.2, it shows that students from all the groups were admitted into the study with comparatively low levels of conceptual understanding of electromagnetic induction. It was also found that there was no significant difference in the performance of the groups at pre-test, $\boldsymbol{E_1}$ ($M = 38.94$, $SD = 12.843$) and $\boldsymbol{C_1}$ ($M = 40.06$, $SD = 16.306$; $t = 0.306, p = 0.760$). After the pupils were pretested, the lessons on electromagnetic induction were introduced to them.

The results of the study revealed that when used as a supplementary teaching method to the conventional traditional method, demonstration-guided simulations (DGSs) where able to enhance learner's performance. This is so because the learners from the groups exposed to DGSs as a supplement to traditional instruction performed statistically significantly better than their counterparts taught only using the traditional method in the control groups. Their good performance can be attributed to the constructivist nature of the lessons which was provided by the simulations. Since all learning is a process of discovery, it is worth mentioning that in a constructivist learning environment, development in cognition and improvement in conceptualization largely depends on the process used to internalize the knowledge.

As such, the use of computer simulations and other multi-dimensional environments are seen to be more powerful than those which are used in conventional learning environments (Gönen, Kocakaya & Inan 2006). Being a social progression, learning involves language, real world situations, and interaction and collaboration among learners. These are some of the elements which computer simulations bring out during the process of learning. The socio-constructivist classroom created by the use of demonstration-guided simulations had substituted the role of the teacher from being an instructor (*as is the case in a traditional method of instruction*) to that of a facilitator and in this case, the learner became the centre of classroom activity. According to Mhlongo, Dlamini and Khoza (2017), the socio-constructivist approach emphasises the active construction of knowledge through the use of technology-based tools merged with social practices.

These findings of this study are seen to be consistent with those of a number of researchers. Kaulu (2011) found that the use of simulations enhanced learner's performance when used as a supplement in the teaching and learning process. His findings showed that the use of the Physics Classroom Computer Software enhanced the performance of learners in Kinematics more than when traditional approaches were used. Similar finding from a good number of other researchers have shown that the use of computer assisted instructions and simulations in particular, always enhance the performance of learners in a number of subjects (Adegoke & Chukwunenye, 2013; Kirschner et al., 2006; Perkins et al., 2006; Wieman et al., 2008; Wu & Huang, 2007). This therefore shows that the use and integration of simulations in teaching as a supplement to the traditional method can address and solve the challenge of learner's poor performance in science and physics in particular. It should be noted that all the researchers used simulations in their studies in different ways but similar results were produced. Some compared conventional experiments and simulated experiments (Adegoke & Chukwunenye, 2013), others compared teacher-centred use of simulations and student-centred use of simulations (Dervić et al., 2018) and others compared teaching using simulations and teaching using standard demonstrations (Perkins et al., 2006).

In this study the comparison was done between the use of simulations in a demonstration manner with the teacher running the simulations and the use of the conventional traditional method of teaching. As stated earlier in all these instances, simulations did enhance the performance of learners to a significant extent.

5.3 Impact of gender on the use of simulations

Lastly, the study tried to investigate whether gender differences had an impact of the use of Demonstration-Guided Simulations (DGSs). The study revealed that there was a significant difference in performance between male and female learners. It was found that male learners performed statistically significantly better than their female counterparts in the two experimental groups where demonstration-guided simulations were used. The results are in accord with those of Gambari, Obielodan and Kawu (2017), who found that there was a significant difference in the mean achievement scores of male and female students with males performing better than females when they were all taught chemistry using the virtual laboratory simulation in an individualized setting. In another study by Gamabri, Kawu and Falode (2018), male students performed statistically significantly better than their female counterparts in both homogenous and heterogeneous groups where virtual labs where used in collaborative environments. A study by Geelan, Ebner, Bastiaens and Mukherjee (2011), equally showed huge significant differences between male and female learners with the males outperforming their female counterparts when simulations when were used in teaching physics and chemistry.

The findings of this study are equally consistent with the Examination Council of Zambia (ECZ) report on general performance in science and physics which indicates that the performance of male learners in science and physics is better than that of female learners (ECZ, 2013, 2014, 2015, 2016, 2017).

On the contrary, other researchers have found the use of simulations to be gender friendly. Gambari, Shittu, Falode and Adegunna (2016) found that the use of Computer Self-Interactive Package (CSIP) in mathematics was gender friendly. In their study, there was no significant difference in terms of performance between male and female learners when the CSI Package was used. On average, the female learners performed as good as their male counterparts. Similarly, Falode, Falode, Usman, Sobowale and Saliu (2015) who investigated effectiveness of Computer Simulation Instructional Package on secondary school Geography students' achievement in map reading found that there was no significant difference in performance between male and female learners.

While the performance of the females in this study was statistically significantly lower than that of males within the experimental group, the females from the experimental group performed statistically significantly better than the females from the control group. This therefore shows that the use of demonstration-guided simulations in teaching still remains gender friendly as it enhanced the general performance of the female learners in the experimental group.

5.4 Summary

This chapter presented a discussion of the findings on the efficacy of demonstration-guided simulations on learners conceptual understanding of electromagnetic induction it further discussed the influence of gender on the use of demonstration- guided simulations in teaching.

CHAPTER 6
CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter presents the conclusion of the main research on the efficacy of demonstration-guided simulations (DGSs) on learner's conceptual understanding of electromagnetic induction.

6.2 Conclusion

The main objective of the study was to establish the efficacy of DGSs on learner's conceptual understanding of Electromagnetic Induction. The study established that learners from experimental groups who were exposed to the use of DGSs performed significantly better than those in the control groups taught using the traditional method only where the lecture method was predominantly used. Based on these findings, it can be concluded that the use of DGSs in teaching Electromagnetic Induction is able to produce conceptual understanding and can therefore lead to enhanced learner performance. When it comes to gender differences, the use of simulations was still considered to be gender friendly even though statistically, male learners performed better than female learners. This is because the female learners in the experimental group managed to perform statistically significantly better than their counterparts in the control group. These findings therefore made it possible to still uphold the supremacy of DGSs over the traditional method of instruction where the lecture method is mostly used.

With all these findings, it can also be concluded that the use of the traditional method of instruction alone is one of the contributing factors to learner's poor performance in science and physics in particular. As such, teachers ought to begin to apply instructional strategies that are more learners centred and interactive such as the use of simulations when teaching, and depending on the availability of resources, this can be done either as a demonstration or allowing learner to explore simulations on their own with some minimal guidance from the teacher.

It is important to remember that the complex nature of most topics in science and physics in particular such as Electromagnetic Induction makes it impossible to conduct such demonstrations in the laboratory. With the use of simulations however, students are helped to a greater extent to improve their ability to perform such experiments and demonstrations virtually and hence understanding of fundamental concepts being learnt. This is mainly because simulations are capable of perfectly representing and simplifying some of reality's complex processes, they can be considered to be equivalent epistemologically and ontologically to other types of cognitive models which represent reality. It is therefore high time that teachers started thinking outside the box whenever it comes to presenting such topics. Where possible and appropriate, the traditional method of instruction should be supplemented by the use of DGSs for improved performance of learners when teaching them Science and physics in particular.

6.3 Recommendations

Based on the findings of this study, the following recommendations have been made;

- CDC should incorporate in the curriculum the use of PhET simulations, specifically Faraday's electromagnetic lab on Electromagnetic Induction, as a supplementary teaching method to the traditional method especially using them as demonstration due to the fact that a good number of public schools are not adequately equipped with computers and internet connectivity. This will compel teachers to start acquainting themselves with the use of simulations
- NSC should conduct more research on the use of simulations and their impact on learning and possibly recommend the use of such innovative learning approaches in teaching and learning of science.
- MoGE through TESS should include in teacher training programs, the use of PhET simulations, specifically Faraday's electromagnetic lab, as a teaching method/aid so as to adequately prepare would-be science teachers on the skills and knowledge on how to use simulations.
- Schools and district administrators should develop regular CPD programs in form of seminars, conferences and workshops on the integration of simulations in the teaching process. This will equip teachers with inadequate skills and knowledge on the use of simulations.

6.4 Proposed areas for future research

The following are some proposed areas for future research on the use of simulations in the teaching and learning process.

- In future, it can be of paramount importance to investigate the various factors which influence the effective use of simulations in teaching so as to maximise on their effectiveness.
- Since performance in a particular subject is linked to attitude towards that subject, it can equally be interesting to look at the impact of simulations on learner’s attitude to science.
- Future areas of study may equally address specific qualitative factors which cause gender effect outcomes linked to the use of technology specifically simulations in teaching and learning.

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APPENDICES

APPENDIX 1: PHYSICS ACHIEVEMENT TEST (PAT)

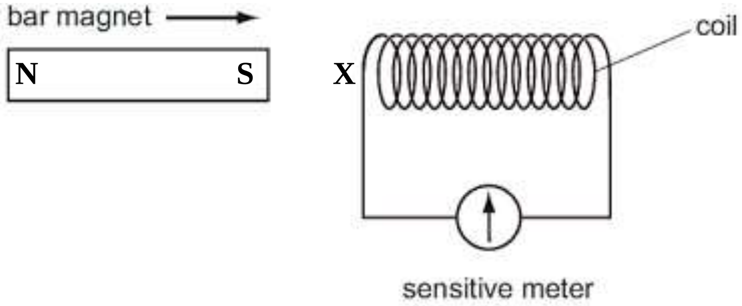
Indicate the correct answer in the answer grid provided at the bottom of each page

1. Electromagnetic induction produces …
   A. Permanent magnetism
   B. An induced emf
   C. A magnetic force
   D. Temporal magnetism
2. Which one of the following does not produce a change in the magnetic field?
   A. Pulling a coil away from the magnet
   B. Pushing the coil and a magnet in the same direction with the same speed
   C. Pushing the magnet towards the coil
   D. Pulling the magnet from the coil
3. When the magnet in the coil is not moving, there is no induced emf, this is because …
   A. The magnet loses all its magnetism
   B. The magnetic strength in the coil is maximum
   C. The magnetic strength in the coil is not changing
   D. The magnetic strength in coil is zero
4. The direction of induced current is such that it opposes the change producing it. This law is called…
   A. Magnetism law
   B. Lenz's law
   C. Faraday's law
   D. Charles' law
5. Which one of the following will **not** increase the voltage output of a simple generator?
   A. Increase the number of turns on coil
   B. Using a stronger magnet
   C. Increasing the speed of the rotation
   D. Increasing the distance between the poles of the magnet
6. A magnet is moved towards a coil of insulated wire. A voltmeter connected across the coil shows a positive reading. What produces a higher reading on the voltmeter?
   A. moving the magnet away from the coil at the same speed
   B. moving the magnet away from the coil at a slower speed
   C. moving the magnet towards the coil at a faster speed
   D. moving the magnet towards the coil at a slower speed
7. By reducing the speed of the magnet inside coil, current in it
   A. increases
   B. decreases
   C. remains constant
   D. reverses

Answer grid

1	2	3	4	5	6	7
A	A	A	A	A	A	A
B	B	B	B	B	B	B
C	C	C	C	C	C	C
D	D	D	D	D	D	D

Answer question 8 to 11 with reference to the diagram below showing a south pole of a magnet being pushed inside a coil through point X. causing the pointer to



8. What will be the size and direction of deflection of the sensitive meter when the same magnet is pulled away from the coil?

	Size	***Direction of deflection***
A.	The same	To the left
B.	Greater	To the right
C.	Zero	No deflection
D.	The same	To the left

9. Which of the following will affect the **magnitude** of the deflection?
   A. Direction in which coil is wound
   B. Speed with which the magnet enters the coil
   C. Which end of the coil is used
   D. Which pole of magnet enters first

10. According to Lenz's law, a magnetic pole is induced at point X as the magnet is moved into the coil. Which pole will be induced at X when the south pole moves in and out of the coil?

	Magnet moved into the coil	***Magnet moved out of the coil.***
A.	North	North
B.	North	South
C.	South	North
D.	South	South

11. What will happen if an iron rod is pushed inside the coil instead of a magnet?
   A. The deflection will increase
   B. The deflection will reduce
   C. There will be no deflection
   D. None of the above

Answer grid

8	9	10	11
A	A	A	A
B	B	B	B
C	C	C	C
D	D	D	D

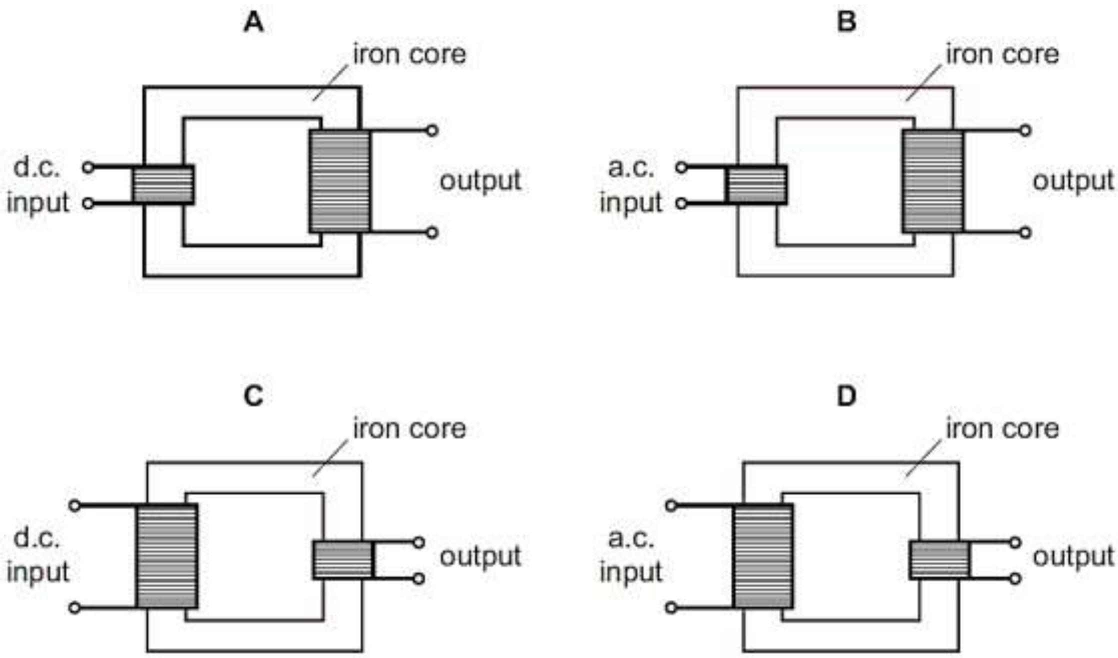
12. The induced current in a conductor will depend upon
    A. the speed of movement of conductor
    B. the length of wire
    C. the thickness of the wire
    D. all of above
13. Which law states that the magnitude of an induced e.m.f. is proportional to the rate of change of magnetic flux.
    A. Charles' law
    B. Faraday's law
    C. Lenz's law
    D. Boyle's law
14. What is the main energy change in a simple generator?
    A. Potential energy to kinetic energy
    B. Kinetic energy to electrical energy
    C. Electrical energy to potential energy
    D. Electrical energy to kinetic energy
15. Two of the following are the main ways of generating electricity using faraday's law of electromagnetism.
    A. Leaving the magnet stationary inside the coil
    B. Pushing the magnet into the coil
    C. Moving the coil towards the magnet
    D. Pulling the magnet out of the coil
16. The following are ways of increasing the strength of the induced emf except …
    A. Using a stronger magnet
    B. Moving the magnet faster
    C. Having more turns on the coil
    D. Moving the magnet inside the coil using a north pole
17. Which statement about the action of a transformer is correct?
    A. An e.m.f. is induced in the secondary coil when an alternating voltage is applied to the primary coil.
    B. An e.m.f. is induced in the secondary coil when there is a steady direct current in the primary coil.
    C. The current in the secondary coil is always larger than the current in the primary coil.
    D. The voltage in the secondary coil is always larger than the voltage in the primary coil.
18. There are 2000 turns in the secondary coil of a transformer and 500 turns in the primary coil. An alternating voltage of 240 V is applied across the primary coil. What is the voltage across the secondary coil?
    A. 60 V
    B. 500 V
    C. 960 V
    D. 2000 V
19. What is the main function of a transformer?
    A. to change d.c. to a.c.
    B. to change to a higher or a lower a.c. voltage
    C. to provide a constant voltage source
    D. to store electrical energy

Answer grid

12	13	14	15	16	17	18	19
A	A	A	A	A	A	A	A
B	B	B	B	B	B	B	B
C	C	C	C	C	C	C	C
D	D	D	D	D	D	D	D

20. A step-down transformer changes 240 V a.c. to 12 V a.c. There are 600 turns on the primary coil.
How many turns are on the secondary coil?
A 20 B 30 C 600 D 12 000

21. Which transformer arrangement produces an output voltage that is larger than the input voltage?



Answer grid

20	21
A	A
B	B
C	C
D	D

APPENDIX 2: RAW RESULTS

Table: 5 (a) and (b): Pretest results for alpha school and gamma school

(a)ALPHA SCHOOL-PRETEST RESULTS

S/N	NAME	GENDER	SCORE (%)
1	A 1	F	57
2	A 2	F	19
3	A 3	F	38
4	A 4	F	33
5	A 5	F	24
6	A 6	F	24
7	A 7	F	29
8	A 8	F	52
9	A 9	F	48
10	A 10	F	52
11	A 11	F	33
12	A 12	F	43
13	A 13	F	38
14	A 14	F	38
15	A 15	F	62
16	A 16	F	48
17	A 17	F	14
18	A 18	M	57
19	A 19	M	24
20	A 20	M	48
21	A 21	M	19
22	A 22	M	52
23	A 23	M	52
24	A 24	M	19
25	A 25	M	29
26	A 26	M	48
27	A 27	M	29
28	A 28	M	38
29	A 29	M	43
30	A 30	M	57
31	A 31	M	38
32	A 32	M	29
33	A 33	M	43
34	A 34	M	38
35	A 35	M	48

(b) GAMMA SCHOOL-PRETEST RESULTS

S/N	NAME	GENDER	SCORE (%)
1	C 1	F	57
2	C 2	F	19
3	C 3	F	19
4	C 4	F	24
5	C 5	F	52
6	C 6	F	24
7	C 7	F	29
8	C 8	F	62
9	C 9	F	47
10	C 10	F	47
11	C 11	F	38
12	C 12	F	38
13	C 13	F	33
14	C 14	F	29
15	C 15	F	29
16	C 16	F	29
17	C 17	F	24
18	C 18	F	19
19	C 19	F	19
20	C 20	F	14
21	C 21	M	71
22	C 22	M	57
23	C 23	M	57
24	C 24	M	57
25	C 25	M	71
26	C 26	M	67
27	C 27	M	62
28	C 28	M	52
29	C 29	M	38
30	C 30	M	38
31	C 31	M	38
32	C 32	M	33
33	C 33	M	29

Table 6 (a) and (b): Post test results for alpha and beta schools

(a)ALPHA SCHOOL-POST TEST RESULTS

S/N	NAME	GENDER	SCORE (%)
1	A 1	F	51
2	A 2	F	48
3	A 3	F	38
4	A 4	F	67
5	A 5	F	52
6	A 6	F	52
7	A 7	F	76
8	A 8	F	57
9	A 9	F	43
10	A 10	F	62
11	A 11	F	52
12	A 12	F	81
14	A 14	M	81
15	A 15	M	71
16	A 16	M	62
17	A 17	M	86
18	A 18	M	71
19	A 19	M	86
20	A 20	M	90
21	A 21	M	48
22	A 22	M	76
23	A 23	M	95
24	A 24	M	76
25	A 25	M	67
26	A 26	M	52
27	A 27	M	71
28	A 28	M	52
29	A 29	M	90
30	A 30	M	71
31	A 31	M	57

(b)BETA SCHOOL - POST TEST RESULTS

S/N	NAME	GENDER	SCORE (%)
1	B 1	F	81
2	B 2	F	71
3	B 3	F	48
4	B 4	F	71
5	B 5	F	19
6	B 6	F	76
7	B 7	F	81
8	B 8	M	95
9	B 9	M	90
10	B 10	M	95
11	B 11	M	67
12	B 12	M	33
13	B 13	M	62
14	B 14	M	90
15	B 15	M	67
16	B 16	M	81
17	B 17	M	67
18	B 18	M	67
19	B 19	M	48
20	B 20	M	57
21	B 21	M	71
22	B 22	M	67
23	B 23	M	52
24	B 24	M	81
25	B 25	M	76
26	B 26	M	100

(c)GAMMA SCHOOL - POST TEST RESULTS

S/N	NAME	GENDER	SCORE (%)
1	C 1	F	71
2	C 2	F	67
3	C 3	F	31
4	C 4	F	48
5	C 5	F	29
6	C 6	F	33
7	C 7	F	48
8	C 8	F	33
9	C 9	F	29
10	C 10	F	67
11	C 11	F	38
12	C 12	F	33
13	C 13	F	38
14	C 14	F	48
15	C 15	F	52
16	C 16	M	52
17	C 17	M	38
18	C 18	M	57
19	C 19	M	81
20	C 20	M	86
21	C 21	M	81
22	C 22	M	52
23	C 23	M	48
24	C 24	M	62
25	C 25	M	67
26	C 26	M	48
27	C 27	M	62
28	C 28	M	38

(d)DELTA SCHOOL - POST TEST RESULTS

S/N	NAME	GENDER	SCORE (%)
1	D 1	F	71
2	D 2	F	52
3	D 3	F	67
4	D 4	F	61
5	D 5	F	48
6	D 6	F	61
7	D 7	F	62
8	D 8	F	62
9	D 9	F	67
10	D 10	F	67
11	D 11	F	57
12	D 12	F	52
13	D 13	F	76
14	D 14	F	48
15	D 15	F	62
16	D 16	F	62
17	D 17	F	33
18	D 18	M	57
19	D 19	M	57
20	D 20	M	62
21	D 21	M	21
22	D 22	M	71
23	D 23	M	62
24	D 24	M	43
25	D 25	M	48
26	D 26	M	76
27	D 27	M	76
28	D 28	M	48
29	D 29	M	57
30	D 30	M	67
31	D 31	M	76
32	D 32	M	43
33	D 33	M	81
34	D 34	M	48
35	D 35	M	57
36	D 36	M	57