DECLARATION

I Aggrey Sichone declare that this dissertation is my own work and that it has not been submitted previously for a degree at this or any other university.

Date ……………………………………. Signature …………………………….

APPROVAL

This dissertation by Aggrey Sichone is approved as a partial fulfilment of the requirement for the award of the degree of Master of Education in Science Education of the University of Zambia.

Examiner 1…………………….. Signature…………………… Date ………………

Examiner 2…………………….. Signature…………………… Date ………………

Examiner 3…………………….. Signature…………………… Date ………………

Chairperson, Board of Examiners…………………………..… Signature…………

Date ………………………

Supervisor…………………….. Signature…………………… Date ………………

ABSTRACT

This study investigated the efficacy of improvised apparatus in the teaching of selected Physics topics when they were used as supplements to the conventional ones. It also investigated the need for improvisation as well as the frequency at which teachers used improvised apparatus. The objectives were to: establish the need for improvisation in Physics at Mukamambo II Girls' Secondary School; establish how often teachers used improvised apparatus in the teaching of physics at Mukamambo II Girls' Secondary School and finally determine the efficacy of the improvised apparatus in teaching some Physics topics, when they were used as a supplement to conventional ones. A total of 100 grade 11 pupils and 4 teachers of physics, constituted the study sample. The study used the pre-test post-test control group experimental design. Both quantitative as well as qualitative data were collected using the following instruments: Pupils' Tests, Observation Schedule, Focus Group Discussion, Pupils' and Teachers' Questionnaires. Quantitative data were analysed in MS Excel, by comparing the means generated, and the calculated t-value to the appropriate table value at p=0.05 level of confidence, while qualitative data were analysed using themes. The findings of the study revealed that there was great need for improvisation at Mukamambo II Girls' Secondary School since the school had inadequate apparatus. Furthermore, 96.0% of the participants suggested that teachers used improvised apparatus most frequently. The findings of the study revealed that when improvised apparatus were used in teaching some selected topics in Physics, results of learners improved by 11.8%. This increase in performance by the experimental group was an indication of the efficacy of improvised apparatus. From the study, the following recommendations were made: Firstly, even if improvised apparatus showed high efficacy, they should always be used together with conventional ones in the teaching of physics. Secondly, we recommend that this approach be adopted for teaching of Physics in schools which do not have enough apparatus in Zambia. We also recommend the method be tried in other science subjects.

Keywords: Efficacy, Improvised apparatus

DEDICATION

I dedicate this study to my late parents, Godwell and Grace Sichone for the support they gave me while we were living at Nakalume Farms in Musyani Village. Lastly, I dedicate this piece of work to my children Njavwa, Vwambanji, Twalumba and Lumba for the support and encouragement they unknowingly gave me.

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ACRONYMS

FGD	Focus Group Discussion
GM Tube	Geiger Muller Tube
HOD	Head of Department
ILE	Improvised Laboratory Experimentation
IQR	Inter Quartile Range
JETS	Junior Engineers Technicians Scientists
MoE	Ministry of Education
MMA	Mixed Method Approach
MS	Microsoft
Q	Quartile
Q1	First Quartile
Q2	Second Quartile
Q3	Third Quartile
SPSS	Statistical Package for Social Science

CHAPTER ONE

INTRODUCTION

1.1 Preamble

This chapter introduces the study. It is presented in the following order: Background to the Study, Statement of the Problem, Purpose of the Study, Objectives of the Study, Research Questions, Significance of the Study, Theoretical framework, Conceptual framework, Limitations of the Study and lastly Operational definitions of key terms.

1.2 Background

According to the Ministry of Education (1996), Science and technology have had a radical impact on Zambia's economy and on the way of life of almost every Zambian. For this reason, science is not an optional subject in Zambian Secondary Schools. According to Kaulu (2009), all pupils in high schools are expected to take at least a science subject. This is important so that they prepare to face the world in a scientific manner. Kothari (2004), contends that the ability to think scientifically and to understand scientific processes is becoming a condition for survival. This entails that the methods of teaching science should improve so that learners can find science to be meaningful and it can only be so when the necessary apparatus are available. Unfortunately, laboratories in most of schools in Zambia do not have enough science apparatus (MoE, 1996). Hence, the need for improvisation in Physics and other sciences because science only makes sense to learners when teachers make it concrete using some form of apparatus.

According to Mohammed (2016), improvisation had been a concept that had attracted the attention of many science educators in recent years. Mohammed (2016), defines improvisation as the provision of a substitute made from locally or readily available raw materials for producing real or original equipment or materials. On the other hand, Gaka (2012), defines improvisation as a process whereby some sophisticated and expensive science materials are replaced by those made by the teacher or which he caused to be made by some other individuals in order to achieve the objectives of his science lessons. Furthermore, Utibe-Abasi (2015), defines improvisation with respect to science teaching as the sourcing, selection and deployment of relevant instructional element of the teaching and learning processes in the absence or shortage of standard or accredited teaching and learning elements for a meaningful realization of specified educational goals and objectives. This is important because many secondary schools in Zambia today including the newly upgraded ones, do not have science laboratories and apparatus to perform experiments, but science has to be taught and learnt despite the unavailability of the laboratories and inadequacy of apparatus. Therefore, if physics is to be taught properly in these schools, not only competent teachers will be needed, but also schools that are adequately supplied with equipment and apparatus.

In the science class, teaching aids, whether, accredited or locally made, are needed to supplement the teacher's oral explanation with the students' visible experiences. According to Mboto et al, (2011), these scientific materials used in teaching enable the students to become actively involved intellectually, perceptually and physically in the learning process. However, it is not easy for any government to provide all the needs of each and every school effectively. Balogun (1982), claims that no matter how generous and rich an education authority might be, they are generally not always in a position to provide their schools with all they need. Therefore, there is need to use improvised apparatus as a supplement to the conventional ones as is the case in many secondary schools in Zambia. However, the efficacy of these improvised apparatus is not known in the Zambian context. It is for this reason that this study investigated the efficacy of improvised apparatus when they are used as a supplement to conventional ones in the teaching of selected topics in Physics at Mukamambo II Girls' Secondary School.

According to Jocelyn (2010), Physics, is no longer an isolated subject. Therefore, Physics teachers have an important task of making their students realize that Physics is everywhere. This means Physics can be learnt and taught anywhere, with or without conventional apparatus. For this reason, the duties and responsibilities of an average teacher of Physics are more challenging now than before. This calls for the teachers of Physics to be more innovative and creative. Good teachers of Physics should be equipped with necessary science skills and concepts. This is important because a good teacher of Physics must be familiar with the latest teaching strategies and techniques.
Jocelyn (2010) further suggests that science teaching may not be efficient and successful unless it is done in a laboratory. A good laboratory has available equipment and apparatus to be used by the students in performing experiments. However, it has to be understood that these equipment and apparatus are not necessarily the conventional ones only, but they can even be the improvised ones as long as they serve the purpose of making pupils understand the basic principles of physics. Jocelyn (2010) suggests that the difference in performance between the pupils being taught using improvised apparatus and those taught with the sophisticated ones is not that great.

As already stated, most public secondary schools in Zambia have inadequate laboratory equipment. The rural secondary schools generally have a limited range of equipment. In case there is any, it is insufficient to serve the student population. According to Kapting'ei and Kimeli (2014), science simply belongs to the laboratory, just as cooking belongs to the kitchen. From this, it is evident that without a laboratory it is difficult for teachers to engage students in practical activities, impacting negatively on instruction. However, it has to be noted that even without a kitchen, food has to be prepared. In the same way, without a laboratory, physics must be taught and learnt without any excuses, possibly using improvised apparatus whose effectiveness is not known, in the Zambian context.

1.3 Statement of the Problem

Kira and Nchunga (2016) indicate that the reasons for the poor quality of teaching and academic performance of learners in science are the inadequacy and lack of teaching and learning materials for demonstration and the abstract nature of most of the concepts in Physics. This makes the learners to perceive the concepts as difficult, hence, the need for improvisation. There are several other studies that support these views (Aina 2013; Jocelyn 2010; Millar 2004, Muhammed 2016; Olufunke 2012). While improvisation is required in the teaching of science, studies do not show the efficacy of improvised apparatus in the Zambian context. It is in view of this problem that this study investigated the efficacy of improvised apparatus when they were used as a supplement to conventional ones, in teaching of selected topics in physics at Mukamambo II Girls' Secondary School of Chongwe District, in Zambia.

1.4 Purpose of the Study

The purpose of the study was to investigate the need for improvised apparatus, how often they were used and their efficacy, when they were used as a supplement to conventional ones, in teaching selected topics in Physics at Mukamambo II Girls' Secondary School.

1.5 Research Objectives

The objectives of the study were to:

(i) establish the need for improvisation of the apparatus in the teaching of Physics at Mukamambo II Girls' Secondary School,

(ii) establish how often teachers use improvised apparatus in the teaching of physics at Mukamambo II Girls' Secondary School, and

(iii) determine how effective improvised apparatus are in teaching Physics when they are used as a supplement to conventional ones.

1.6 Research Questions

The research questions for the study were as follows:

(i) Is there need for improvisation of apparatus for teaching Physics at Mukamambo II Girls' Secondary School?

(ii) How often do teachers use improvised apparatus in the teaching of Physics at Mukamambo II Girls' Secondary School?

(iii) How effective are improvised apparatus in teaching Physics, when they are used as a supplement to conventional ones?

1.7 Research Hypothesis

The following null hypothesis was formulated and tested at an alpha level of 0.05:

H_0: There is no statistically significant difference in the mean performance in science 5124 (Physics) between pupils taught with improvised materials as a supplement to conventional ones and those taught with conventional materials only if they are available.

1.8 Significance of the Study

The findings of this study might be beneficial to the learners, teachers, administrators, educational policy makers as well as curriculum developers.

This study might benefit learners of Physics because they will be exposed to relevant practical skills such as manipulative and observational skills, which are necessary for problem solving. According to Ministry of Education (2009), all topics in science can be taught with a practical lesson. Therefore, this study might help teachers of Physics at Mukamambo II Girls' Secondary School and other schools in the country, to become creative where improvisation is concerned. The outcomes of this study might as well provide school administrators with some useful information or ways on possible causes and solutions to learner under achievement in Physics and other Sciences in general.

If Policy makers and curriculum developers can have access to the findings of this study, they may design the Science Curriculum in such a way that improvisation becomes part of the syllabus. This, on the other hand, would also enhance pupil performance in Integrated Science at Junior Level since improvisation can be done anywhere regardless of the location of the school. Finally, it is hoped that the findings of this study might add to the existing literature on the efficacy of improvised apparatus in teaching Physics Worldwide.

1.9 Delimitation

The study was conducted at Mukamambo II Girls' Secondary School.

1.10 Limitation

Being a student, the researcher had limited time in which this research was to be done and so were unable to cover all the lessons in more than one school. Therefore, since the study was done in only one school, the findings may not be generalised.

1.11 Theoretical Framework

This study was informed by the Sensory Learning Theory by Laird (1985), who suggested that learning occurs most effectively when the senses of sight, hearing, touch, smell and taste are stimulated. This is easy and possible in the teaching of science subjects as opposed to theoretical subjects where some of the senses remain dormant. This theory is relevant as it encourages linking theory to practice, and the use of practical activities based around the subject and the areas of interest of the learners. The teacher is supposed to arouse learners' interest in the lesson by making each lesson as fun as possible while achieving specific objectives. If the teacher is able to make his or her teaching session fun and interesting, relating to all the senses, it will help his or her learners remember the topics better. In science, this can only be achieved by conducting practical.

This theory is relevant to the study in the sense that it emphasises the stimulation of certain senses for learning to take place. Since Physics is a practical subject, it implies that learners should be taught Physics by giving them an opportunity to manipulate certain apparatus. As learners manipulate these apparatus, certain senses are activated as the theory suggests.

1.12 Conceptual Framework

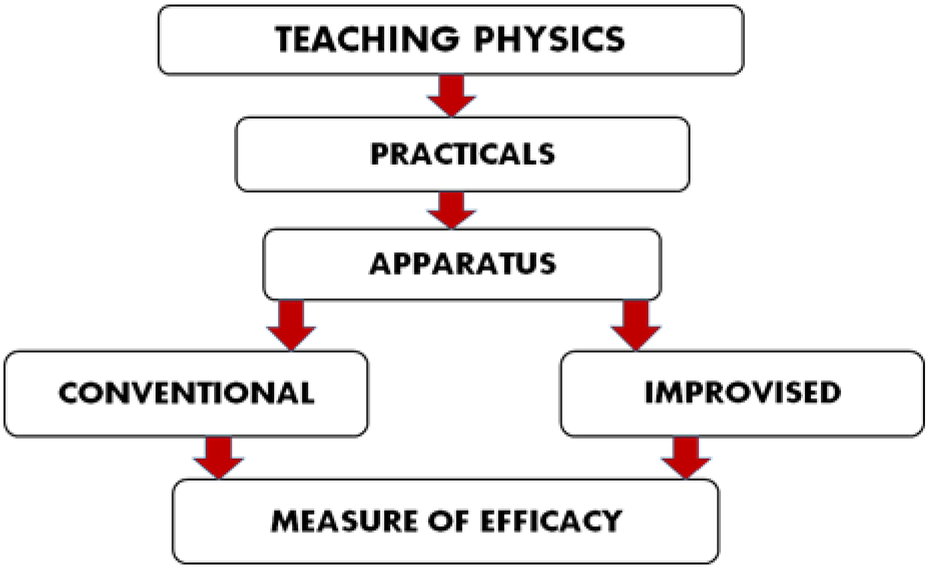

Figure 1.1 Conceptual Framework

The successful teaching of Physics requires conducting of practicals. Figure 1.1 illustrates that practicals can only be done when apparatus are available. It further suggests that apparatus can either be conventional or improvised. Therefore, the teacher may choose to use either conventional apparatus only or conventional and improvised apparatus. In this case, practical is a dependent variable since it can only be done when the apparatus are available. On the other hand, apparatus are independent variables.

1.13 Operational Definition of Key Terms

In this study, the word "Efficacy" meant effectiveness of improvised apparatus when they were used as a supplement to conventional ones in teaching of selected topics in Physics. "Effectiveness" referred to the ability of each improvised apparatus to enhance performance in O-Level Physics and it was expressed as a percentage. On the other hand, "Improvised Apparatus" meant substitutes for conventional apparatus which were made out of the materials that happened to be available at that time. Lastly, the word “Apparatus” referred to sets of equipment to be used for a particular purpose.

1.14 Ethical Considerations

Creswell (2011) suggest that it is important to respect the site in which the research takes place. There are several reasons why it is important to adhere to ethical norms in research. Ethical norms promote the aims of research and the values that are essentially to collaborative work. According to David & Resnik, (2015), ethical norms make researchers to be held accountable to the public, build public support for research and promote a variety of other important moral and social values. For this reason, participation in this study was voluntary. Consent forms were provided to the participants that were willing to participate in the study. Anonymity was respected by the researcher. All the instruments were administered and collected by the researcher. Additionally, all the instruments used were approved by the University of Zambia Humanities and Social Sciences Research Ethics Committee.

1.15 Chapter Summary

According to the Examinations Council of Zambia (2016), performance of students in Physics and other science subjects has often been poor. There are many factors that make pupils perform poorly. According to Sileshi (2012), poor performance is partly blamed on the increasing school enrolment without a corresponding increase in teaching equipment due to high cost and lack of improvisation by most Teachers of Science. In most cases, it is not possible to procure adequate equipment for teaching and learning, hence the need for improvisation. However, the efficacy of these improvised apparatus is not known in the Zambian context.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature was reviewed under the following headings: Need for improvisation in Physics at Mukamambo II Girls' Secondary School, frequency of teachers' use of improvised apparatus in the teaching of Physics and lastly effectiveness of improvised apparatus in teaching selected topics in Physics.

2.2 Need for improvisation in Physics

Science can play many different roles in someone's life. According to Millar (2004), school science has two distinct purposes; firstly to develop the 'scientific literacy' of all students as a preparation for active citizenship; and secondly to provide the foundation for further study of science for those students who may wish to follow careers that require this. It is clear that for both purposes, developing students' scientific knowledge is a necessary aim. The two purposes according to Millar (2004) may lead to different choices about the areas of knowledge which should have priority, and the depth of treatment required. For these aims to be achieved, science has to be taught practically using necessary instructional materials.

Instructional materials are materials used to impact knowledge into the mind of learners, Millar, (2004). These materials can either be audio, visual or audio-visual. According to Johnson, (1994), improvised instructional materials are those teaching and learning materials produced using locally available resources with the help of experts. Experts in this case can be the teachers, learners and any other person who is given clear instructions on how to make such materials.

According to Sileshi (2012), Physics is an experimental, observational and laboratory oriented field of study, therefore, Physics lessons must be formulated to reflect this. Currently there is an urgent need everywhere in the world to have low-cost instruments and low-cost experiments for teaching Sciences. This situation is especially serious in developing countries such as Zambia where most schools have insufficient apparatus. Sileshi (2012), further indicates that despite the various efforts, shortage of school laboratory apparatus continues to be a major problem which should be of serious future concern. This is so because learners acquire more information when they do hands-on activities which are possible through conventional and improvised materials.

According to Zacharia (2007), students have difficulties in understanding scientific concepts across all ages and levels. This is confirmed by the Examinations Council of Zambia (2016), which suggests that Physics is one of the science subjects that many students usually find challenging and this is why students usually have low achievement in the subject. Challenges associated with low achievement do range from the way it is taught to the way it is learnt. Aina (2013), suggests that the teaching of Physics in schools has not been encouraging due to its abstract nature and that is why the use of instructional materials is needed to facilitate students' learning. The abstract nature of Physics suggests that it must be taught practically even though there are inadequate apparatus in most of the schools.

Whilst real experimentation with conventional laboratory apparatus and equipment is desired, many schools in developing countries face challenges of limited resources particularly financial resources for acquiring apparatus and materials for imparting effective and efficient science education, Zacharia (2007). Despite these challenges of shortage of materials and apparatus, science has to be taught in these schools. Improvised Laboratory Experimentation (ILE) has been used as a remedy to the situation at hand, Zacharia (2007). Improvisation, therefore, is a pedagogical intervention strategy that teachers may use to address similar situations by being resourceful in the manufacture and use of locally available materials where conventional equipment and or apparatus may be inadequate or not available at all, Inyenga & Tompson, (2002). Low-cost materials produced through improvisation are not an attempt to provide a watered down science education, but low cost in the mentioned sense is highly creative and highly productive, provides opportunities for creativity and development of manipulative abilities and concepts are learnt and internalized by concrete and unspectacular work than proceeding with chalk and teacher talk in teaching science, Pimpro, (2005). Since learners may also be involved in the production of these improvised apparatus, retention of knowledge is likely to be higher. According to Zarewa, (1991), improvisation helps to change students' attitudes towards science. This portrays that if we can encourage students to partake in the improvisation exercise, they stand a better chance of having a positive attitudinal change towards sciences. Therefore, students should be engaged in the collection, assembling and fixing of some basic and non-injurious items for improvisation.

While it is necessary to engage pupils in the production of improvised apparatus, it has to be noted that not all apparatus can be improvised not even by the teacher as well as any expert. For example, a good teacher can improvise a circuit board, simple pendulum, bimetallic strips and many other apparatus that can work perfectly well. However, it might be impossible for a teacher of science to improvise apparatus such as a voltmeter, ammeter, Geiger Muller Tube and many other complicated apparatus which can work as well as the conventional ones. Hence the need for combining the improvised apparatus with the conventional ones.

Improvisation is vital because it tends to remove abstraction in learning theories as the products of improvisation are tangible, real, handy and concrete. In most cases, improvised apparatus are safe to use during demonstrations and experiments. The product must not be capable of inflicting injuries on the user or person operating it. Improvised instructional materials should be used effectively in teaching Physics and other science subjects, not only at Secondary School level, but at all levels of education.

Ministry of Education (2009), puts it clear that Zambia's national curriculum requires learners to develop inquiry and problem solving skills. It further suggests that in order to develop the skills, an emphasis is being placed not only on minds, but also hands-on activities. However due to inadequate and in some cases a complete lack of conventional apparatus and materials worsened by large class sizes, improvisation is employed. According to Kapting'ei and Kimeli (2014), Physics and other teachers of science should strive to improvise apparatus which are not available in their laboratories since improvisation makes learners appreciate the relationship between classroom instruction and their day to day encounters due to the fact that improvised apparatus are mainly adopted from the learner's local environment. However, it must be noted that improvised apparatus are made by human hands, therefore, it is practically impossible to improvise the apparatus for the entire class of about sixty to seventy learners as it is today in most Government Schools. Therefore, for large classes, improvisation can be difficult if pupils are to be put in small groups for effective teaching and learning

While it is true that improvisation makes learners appreciate the relationship between classroom instruction and their day to day encounters, the need for improvisation, as well as which pieces of apparatus were lacking, in most Zambian schools is not known. Hence leaving a gap which this research sought to bridge.

2.3 Frequency of teachers' use of improvised apparatus in the teaching of Physics

The teaching approach that a teacher adopts and the available materials he or she teaches with are factors that may affect students' achievement, Mills (1991). Consequently, the use of appropriate teaching materials and teaching methodology is critical to the successful teaching and learning of Physics. According to Kibett & Kathuri (2005), students that are taught using project based learning out perform their counterparts in regular teaching approach, for example lecture method, demonstration method and many other methods. Project based learning is the type of learning where hands on activities are encouraged.

In spite of many studies being conducted in examining different teaching methodologies adopted in Physics class for example, Bello (2011) found out that using small group cooperative teaching method facilitated students' learning in Physics. Not only does cooperative teaching facilitate learning, but this method also increases students' motivation to learn Physics. Bello (2011) further suggests that below average students' were found to improve on their achievements far more than those in regular teaching method class. However, cooperative teaching in countries like Zambia may not work effectively in all schools because of several factors such as over-enrolment, inadequate teaching and learning materials and lack of infrastructure. These factors have made teachers' efforts of improvisation very difficult.

Since practical work is the basis of teaching in all science subjects, it implies that science subjects can only be effectively taught under conditions where there is an adequate provision of teaching and learning materials. The Ministry of Education

(MoE) realised the need for adequate provision of science teaching and learning materials as early as 1992 when it indicated that the priority in resource allocation, in secondary school be given to the rehabilitation of science laboratories and specialist rooms, provision of text books and other miscellaneous science teaching aids, and re-equipping science laboratories and providing consumables, MoE (1992). This implies that teaching science with necessary teaching aids is cardinal to learners' understanding of the concepts. According to Mboto et al (2011), teaching aids in the science class, are needed to supplement the teacher's oral explanation with the students' visible experiences. Kulik (1992), noted that for Physics and other sciences to be understood better by all, there is need to emphasise its instruction in secondary schools through practical approach. However, for various reasons, teaching aids may not be available when they are needed and as a result, teachers may end up teaching using some methods of teaching such as lecture method, which results in low retention of knowledge by the learner, Muzumara (2000)

> *"Additionally, Martin et al, (1997) explains that rather than putting fully formed knowledge into the learners' minds, the teacher should guide them in constructing knowledge through scientifically valid approaches. Thus a teacher of physics with a constructivist instructional philosophy, would not encourage learners to memorise rote information, but give them opportunities to meaningfully construct knowledge through active participation and interaction."*

This entails that all physics lessons must be taught with a practical if meaningful learning is to be achieved. Therefore, teachers of Physics have an important task of making their students realise that Physics can be taught and learnt anywhere. And as such, each and every lesson must have a practical. This means that the teacher should always use practical in teaching, by either using improvised, conventional or a mixture of both the improvised and conventional apparatus. This broadening scope and nature of teaching Physics has made the duties and responsibilities of an average Physics teacher more challenging than before, Jocelyn (2010). Thus, a teacher of Physics must be innovative and creative. This means that a teacher of Physics must be equipped with science skills and concepts and must be familiar with the latest teaching strategies and techniques. Most of these strategies and techniques can be successfully verified in a well-stocked science laboratory. Unfortunately, most public secondary and high schools have inadequate laboratory equipment. Ministry of Education (1996) puts it clear that rural high schools are generally considered to have a very limited range of equipment. However, Ministry of Education (2000), encourages teachers of science never to resort to the "chalk-talk" method where the learners are asked to read books or simply listen to lectures and write the results of normal experiments in situations where there are no or limited apparatus. This means that teachers of science must perform practicals as often as possible. Teachers of science may want to teach each and every lesson with a practical, but because they have to improvise in most cases, and because they have the heaviest teaching loads, it might be very difficult because of inadequate time to prepare.

To overcome this situation where Hands-On activities are avoided, teachers of Physics need to use their resourcefulness to make equipment from low-cost, local and discarded materials. Sileshi (2012), further suggests that by using locally available materials, most school experimental lessons can be performed in a very short time, often with no or low financial input and without long sessions of preparation. For this to be possible, teachers of Physics must use any available resources and encourage their learners to participate in the making of the apparatus. According to Jocelyn (2010), if the improvised apparatus are properly constructed, they can perform as effectively as the conventional ones. For this reason, all Physics lessons regardless of the topic being taught, are supposed to be taught using an experiment. Martin et al., (1997) claims that if we base our teaching of science with locally available materials, it will make learning by doing possible, even when the conditions for teaching are not conducive. This is likely to increase the teachers' frequency of teaching science with improvised apparatus and hence making the teaching of science more enjoyable. Despite the importance of conducting practicals and the fact that all science lessons have practical components, the frequency of teachers' use of improvised apparatus is not known. It is not known how often teachers of physics at Mukamambo II Girls' Secondary School use these improvised apparatus if at all they do.

2.4 Effectiveness of improvised apparatus in teaching certain topics in Physics.

Improvisation is always a better option in the absence or inadequacy of conventional teaching and learning apparatus. However, Mboto et al, (2011) suggests that, for an improvised apparatus to be valid, it should provide the desired results expected, improve the lesson effectiveness and reduce to minimum the risks associated with the usage of the apparatus. Therefore, the efficacy of improvised teaching apparatus is measured by the results it produces as well as its safety when in use.

> *"Kira and Nchunga (2016) suggest that the use of improvised instructional materials to run practical lessons had refined and broadened teachers' knowledge on designing and the use*

of such local materials to carry out Physics experiments in Community Secondary Schools."

This can be true because before you improvise, you need to read the theory on what you need to improvise, hence broadening the knowledge base of the teacher. Additionally, Kaulu (2008), suggests that locally made teaching aids have the potential of motivating learners into liking a particular subject or topic, improve punctuality of learners as well as increasing the desire to share ideas when it comes to problem solving. This is so because learners will pay maximum attention to observe how a particular piece of improvised apparatus works.

Mboto et. al, (2011), provides the qualities of a good improvised apparatus, while Kira and Nchunga (2016), discuss how improvised apparatus could refine and broaden teachers' knowledge. On the other hand, Owolabi and Oginni (2012), discuss the importance of accuracy and precision in the science experiment. However, none of the researchers above have stated the efficacy of the improvised apparatus in the teaching and learning of Physics, when they are used as a supplement to the conventional ones. In short, little if any, is known about the efficacy of the improvised materials on teaching and learning of science, therefore, leaving a gap in knowledge that could be bridged by this research.

With the lack or inadequacy of conventional teaching and learning materials in most schools, hands–on activities have been scanty in most classrooms. According to the Ministry of Education (2009), the idea of improvisation has not been well managed. The implementers of the curriculum, who are, in most cases, the teachers, claim that they have very little time to prepare the low cost material for their lessons. This is true because according to the Ministry of General Education (2016), every teacher should have a minimum of thirty two (32) teaching periods per week, with each period having (40) forty minutes. This translates to One Thousand, Two Hundred and Eighty (1,280) minutes per week. This means that a teacher of science will be teaching for slightly more than twenty one (21) hours per week. This teaching load is too high if the teacher is required to make teaching aids for each and every lesson. Now, since the idea of improvisation is not well managed in Zambia by teachers of science, the efficacy of improvised materials, when used as a supplement in the teaching of Physics and Science in general, needs to be investigated.

2.5 Chapter Summary

Literature has pointed out that in many schools, some pieces of apparatus are not available. However, literature does not reveal exactly which types of apparatus are not available in the laboratories in the teaching of Physics. This leaves a gap which this research investigated.

Additionally, literature reveals the importance of improvisations of apparatus in the teaching of Physics and other science subjects. Literature indicates that improvisation of apparatus improves creativity in the learners if they are involved in the making of the improvised apparatus. Improvisation also broadens the teachers' knowledge base since the teacher needs to read the theory behind the working of the apparatus to be improvised. Improvised apparatus makes learning exciting and above all, improvisation of apparatus makes planning of the work easy as minimal resources are required. However, little if any, is known about how often the teachers of science in the Zambian context use the improvised apparatus as a supplement to conventional ones. This therefore, leaves another gap which this research addressed.

Furthermore, literature reveals some of the qualities of improvised materials and reasons why improvised materials are necessary, but no literature reviewed specifies how effective and safe the improvised materials are when used in the teaching of Physics, hence leaving a gap to investigate the efficacy of these improvised apparatus when they are used as a supplement to conventional ones.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview

The chapter discusses the research approach, research design, research study area or site, study population, study sample, sampling techniques, instruments used for data collection, procedure for data collection and data analysis.

3.2 Research Approach

There are two main approaches to a research problem. These are quantitative and qualitative approaches. The approaches can be used independently or as a combination of both quantitative and qualitative. According to Creswell (2003), quantitative approach is one in which the investigator primarily uses post-positivist claims for developing knowledge, that is, cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories, employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data. The last but not the least approach is the Mixed Method Approach (MMA). MMA involves having both a quantitative design and qualitative design, Kothari (2004).

This study employed a MMA. It was mostly quantitative but with some qualitative aspects to address specific problems. According to Creswell (2012), MMA is suitable if you are conducting an evaluation research. In this research, the researcher wanted to evaluate the efficacy of improvised apparatus when they were used as a supplement to conventional ones in the teaching of selected Physics topics at Mukamambo II Girls' Secondary School, hence, MMA became the most appropriate method.

The quality of MMA can be enhanced, defended and judged based on a concept called legitimation, Onwuegbuzie & Johnson (2006). Brown (2014) defined legitimation as "the degree to which MMA of integration of qualitative and quantitative research strengthens and provides legitimacy, fidelity, authority, weight, soundness, credibility, trustworthiness and even standing to the results and interpretations in MMA.

3.3 Design

According to Creswell (2009), research designs are plans and the procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis. Therefore, in order to answer different research questions, experimental design was used. It involved conducting pre-test and post-test of both the control and experimental groups and most of the data that was collected was quantitative in nature. Therefore, Experimental Design was the most appropriate research design for this research because the researcher wanted examine in depth, the efficacy of improvised apparatus when they were used as a supplement to conventional ones in the teaching of selected physics topics at Mukamambo II Girls' Secondary School.

3.4 Study Area

This study was done in Chongwe District of Lusaka Province in Chalimbana area at Mukamambo II Girls' Secondary School. This school is situated close to Chalimbana University. The School is about 8 kilometers away from the Palace of Chieftness Nkomeshya Mukamambo II, after which the school was named. It is about 1 kilometer off Chalimbana Road.

3.5 Study Population

Mukamambo II Girls' Secondary School has 3 Grade 11 Classes. Each of the classes has approximately 60 pupils. Therefore, the study population was about 180 pupils.

3.6 Sample Size

According to White (2005), a sample refers to a group of subjects or situations selected from a larger population. Cresswell (2011) suggests that when selecting participants for a study, it is important to determine the size of the sample you will need. Cresswell (2011) further indicates that it is important to select as large a sample as possible from the population. The larger the sample, the less the potential error is that the sample will be different from the population. Gay (1996), recommends a minimum number of 30 participants if the results are to be meaningful. However, the sample size for this particular research comprised of 100 Grade 11 pupils at Mukamambo II Girls' Secondary School and 4 teachers of Physics from the same school, a total of 104 participants. The sample size used was slightly more than three times the minimum recommended sample size, an indication that the results that were obtained were meaningful.

3.7 Sampling Procedure/Techniques

The researcher used Simple Random Sampling technique to select the 100 pupils that took part in the study. According to Kasonde (2013), Simple Random Sampling provides each participant in a population an equal chance to be selected as a study sample. Additionally, Saunders, et al (2012), suggests that there are two popular approaches that are aimed to minimise the relevance of bias in the process of random sampling selection: method of lottery and the use of random numbers. In this research, the researcher used the method of Lottery.

In this study, only Grade 11 pupils were used because they had been at Mukamambo II Girls' Secondary School for fairly a long period of time. Additionally, Grade 11 pupils were not very busy during the time when the research was being conducted. However, the best pupils to be used would have been the Grade 12s, but during the time the research was being conducted, they were very busy with their final examinations preparations. Grades 8 and 10 were not suitable because they were still new at the school, while Grade 9s were also preparing for their final examinations, just like the case with Grade 12s.

The researcher typed the names of all the Grade 11 pupils that were willing to take part in the study. Those that were willing had filled in the consent form. Thereafter, names on pieces of paper were cut and folded. These pieces of folded papers were put in a carton box for selection. Lastly, folded papers were picked randomly from the carton box by choosing folded pieces of papers in a random manner. After one name was picked, it was announced and written down, and then the carton box was shaken in readiness for picking of the next name. This continued until all the 100 participants were chosen. These 100 participants were divided into Experimental and Control Groups.

To allocate the participants into classes, the researcher wrote fifty **E's** and fifty **C's** on bottle tops. The 100 bottle tops were mixed in a carton box. The one hundred (100) participants were allowed to pick the bottle tops at random. Those that picked bottle tops labelled **E**, were put in the Experimental Group, while those that picked bottle tops labelled **C** were put in the Control Group.

When the researcher presented the list of the randomly selected participants to the Head of Department, (HOD), it was discovered that slightly over 80% of the selected 100 participants were also members of JETS Club. When these girls heard the announcement for free Physics lessons, they turned out in numbers to have their names registered so that they could start learning. The researcher, however, never knew which of the participants, were members of JETS Club. Members of JETS are usually advised to read far beyond what they learn in class because of the nature of questions that they encounter during quizzes and Olympiads at District, Provincial and National JETS fares. For this reason, random allocation of the 100 participants to the control and experimental groups was necessary.

3.8 Research Instruments

The following instruments were used for data collection:

- A Physics test on topics that the researcher had taught.

  A physics test was administered in order to compare the achievements between the control and the experimental groups. Quantitative data was collected.
- Pupils' questionnaire.

  Pupils answered different questions about how Physics was taught by their teachers. Quantitative data was collected
- Teachers' questionnaire.

  Teachers answered different questions about how they taught Physics to their learners. Qualitative data was collected
- Observation schedule.

  The researcher had observe how the teachers were teaching Physics to the leaners as well as observing how well stocked the Department of Science was. Qualitative data was collected.
- Focus Group Discussion Guide

Participants were asked a lot of questions about improvised apparatus and how their teachers put into use of improvised apparatus. Qualitative data was collected.

3.9 Validity and Reliability of an Instrument

According to Kasonde (2014), an instrument is reliable if it consistently gives the same results when administered to the same people under the same conditions.

> *"Reliability and validity are bound together in complex ways. These two terms sometimes overlap and at other times are mutually exclusive. Reliability is generally easier to understand as it is a measure of consistency. If scores are not reliable, they are not valid; scores need to be stable and consistent first before they can be meaningful. In addition, the more reliable the scores from an instrument, the more valid the scores will be", Creswell, (2011)*

Therefore, to ensure that the instruments were valid and reliable, they were piloted at Lusaka Girls' Secondary School, in Lusaka District. Five pupils were administered with a Physics test which was used as a Pre-test and Post-test for the Experimental and Control Groups. The pupils in the pilot study were identified as P1, P2, P3, P4 and P5. Table 3.1 shows the results from the Pilot tests

Table 3.1: Results from Test retest of Instruments for validity and reliability

Participant	**Tests marks in**	
	Test 1 Score (%)	Test 2 Score (%)
P1	23	25
P2	20	29
P3	50	55
P4	26	25
P5	21	30
Mean Marks	**28**	**33**

On the other hand, questionnaires were administered to two teachers of Physics that were selected purposively.

3.10 Negotiating Access to Research Sites

The researcher got permission from the Dean of the School of Education to go and research in Chongwe District. When the Researcher went to the research site, he first went to the Head teacher before meeting the Head of Department for Natural Sciences.

3.11 Data Collection Procedure

The researcher had two classes, namely Experimental Group and Control Group and the members of the two classes were randomly allocated. After the learners were divided into these classes, a Pre-test was administered to both classes. The researcher taught the two classes the same topics in Physics. The only difference was that the Experimental Group was taught using conventional apparatus, with improvised apparatus as a supplement, while the Control Group was taught using conventional apparatus only. In situations where conventional apparatus were not available for certain topics, improvised apparatus were used for the Experimental Group as a supplement to discussion and lecture method of teaching while the Control Group used the same teaching strategies but without any improvised apparatus. Five topics in Physics were taught to each of the two classes in a period of 4 weeks. Each class learnt 3 times in 1 week, with a duration of 1 hour 20 minutes per day. The topics that were taught were those that learners had not yet learnt in class. These were:

i. Energy

ii. Simple Machines

iii. Thermal Physics

iv. Waves

v. Electricity

Thereafter, the researcher administered the same test to both classes on the same day at the same time, but in different rooms. This was followed by administering pupils' questionnaires. Finally, the researcher administered questionnaires to the teachers of Physics.

Data was collected using questionnaires. Questionnaires come in many different forms. They range from factual to opinion based and from tick boxes to free text responses. According to Milne (2009), questionnaires are often viewed as quick and easy to do in addition to the fact that responses from questionnaires can be gathered in a standardised way. Questionnaires are often more objective as compared to interviews. This mode of data collection was therefore, preferred by the researcher.

Milne (2009) further suggests that it is generally quicker to collect information using a questionnaire, even though in some situations they can take a long time not only to design but also to apply and analyse

Since questionnaires were used to obtain numerical data, the researcher wished to get the views of individual participants on the use of improvised apparatus as a supplement to conventional ones. For this reason, the researcher decided to use another method of data collection so that learners' views could be captured. Focus Group Discussion, (FGD) method was therefore used.

According to Morgan (1997), the method of interviewing participants in focus groups comes largely from marketing research but has been widely adapted to include social science and applied research. The groups are generally composed of 7 to 10 participants, although groups range from as small as 4 to as large as 12 participants who are unfamiliar with one another and have been selected because they share certain characteristics relevant to the study's questions. Witkin and Altschuld (1995), suggests that FGD as a method of data collection, is frequently used to collect in-depth qualitative data in various descriptive studies such as case studies, phenomenological and naturalistic studies. FGD provides a chance for the participants to talk to one another about a specific problem which is being studied. The researcher guided the discussion to make sure that only relevant issues were discussed.

The researcher chose to incorporate FGD because the method is socially oriented, good for studying participants in an atmosphere more natural than artificial experimental circumstances and more relaxed than a one-to-one interview. According to Morgan, (1997), FGD when used together with participant observation, both become more useful for gaining access, focusing site selection and sampling, and even for checking tentative conclusions. Morgan (1997), further suggests that FGD allows the facilitator the flexibility to explore unanticipated issues as they arise in the discussion and as a result, the validity of the results become high.

According to Riessman, (2002), FGD as a method of data collection assumes that an individual's attitudes and beliefs do not form in a vacuum. People often need to listen to others' opinions and understandings to form their own. In most cases, the questions in a FGD are relatively simple; the trick is to promote the participants' expression of their views through the creation of a supportive environment.

3.12 Data Analysis

Data Analysis is a process of examining what has been collected in a research and making deductions and interferences. According to Kombo & Tromp (2006), data analysis involves uncovering underlying structures, extracting important variables, detecting any anomalies and testing any underlying assumptions. Since this research employed a MMA, data was analysed both qualitatively and quantitatively.

Qualitative data were collected from FGD, Observation Schedules and Interview Guides and was analysed thematically. On the other hand, quantitative data were collected from questionnaires and the pre and post-tests given to both the Experimental and Control Groups and were analysed by comparing the means generated in MS Excel, and the calculated t-value to the appropriate table value at p=0.05 level of significance as illustrated in Figures 4.1, 4.2, 4.4 and 4.5, as well as in Tables 4.5, 4.7, 4.9 and 4.11. Additionally, data from questionnaires was analysed by SPSS version 20 and the results are shown in Table 4.2 to Table 4.3.

CHAPTER FOUR

FINDINGS

4.1 Introduction

This chapter is divided into four main parts. The first part gives the characteristics of the respondents that took part in the study. The second part has findings from the teachers' questionnaires and what the researcher observed in the Department of Natural Sciences at Mukamambo II Girls' Secondary School. This information was used to answer the first question of the study. The third part has findings from both teachers' and pupils' questionnaires and observations that the researcher made through the observation schedule. These findings were used to answer the second question of the study. The fourth part presents the test performance of the experimental and control groups in the pre-test and the post-test. It also contains findings from the FGD between the researcher and the pupils. This information was used to answer the third question of the study.

4.2 Characteristics of Respondents:

Mukamambo II Girls' Secondary School has three (3) Grade 11 classes, these are 11 Yellow, 11 White and 11 Violet. After random selection of the experimental and control groups, the following numbers were selected as shown in Table 4.2 and Table 4.3 respectively. The tables were obtained from SPSS.

Table 4.1 Characteristics by Class for Experimental Group

Class	Frequency	Percent
11 Violet	6	12.0
11 Yellow	17	34.0
11 White	27	54.0
Total	50	100.0

Table 4.1 above reveals that the highest number (27), 54.0% of participants for the experimental group in this study were from Grade 11 White, followed by 11 Yellow which had (17) participants translating to 34.0%. The least number of participants (6) were from Grade 11 Violet. This translated to only 12.0%. After consultation as to why most of the participants came from one class, i.e. 11 White, it was revealed that 11 White was in an Academic Pathway of the Curriculum. Another reason why more participants came from 11 White could have been that it is the class with the highest number of JETS Club members. This could have motivated them to come and learn for free.

Table 4.2 Characteristics by Class for Control Group

Class	Frequency	Percent
Yellow	8	16.0
White	31	62.0
Violet	11	22.0
Total	50	100.0

Table 4.2 shows that 8 (16%) of the participants came from 11 Yellow, while 31 (62%) of the participants came from 11 White. 11 Violet contributed 11 participants,

translating into 22% of the participants. As shown in the table above, the majority (62%) of the respondents came from one class (11W). The two main reasons for this could be that the class is in an Academic Pathway. Secondly, the majority of the members of this class were JETS members, so immediately they heard of free lessons, a large number of them expressed interest as compared to the other two classes.

Table 4.3 Characteristics by number of years at Mukamambo II Girls' Secondary School for Experimental Group

No. Years	Frequency	Percent
1	12	24.0
2	29	58.0
3	2	4.0
4	7	14.0
Total	50	100.0

Table 4.3 shows that 12 (24%) of the participants had spent only one (1) year at Mukamambo II Girls' Secondary School, while 29 (58%) of the participants had been at Mukamambo for 2 years. Additionally, only 2 (4%) of the participants had been at Mukamambo II Girls' Secondary School for 3 years. Those that had been at Mukamambo II Girls' Secondary School for four (4) years were seven (7), constituting 14%. This shows that more of the Grade 11 pupils (86%) at Mukamambo II Girls' Secondary School did their grades 8 and 9 from other schools.

Table 4.4 Characteristics by number of years at Mukamambo II Girls' Secondary School for Control Group

No. of years	Frequency	Percent
1	2	4.0
2	34	68.0
3	6	12.0
4	8	16.0
Total	50	100.0

Table 4.4 shows that 2 (4%) of the participants had spent only one (1) year at Mukamambo II Girls' Secondary School, while 34 (68%) of the participants had been at Mukamambo for 2 years. Additionally, only 6 (12%) of the participants had been at Mukamambo II Girls' Secondary School for 3 years. Those that had been at Mukamambo II Girls' Secondary School for four (4) years were seven (8), constituting 16%.

4.3 Qualitative Research Findings

Qualitative data was collected from FGD and Observation Schedule. The researcher had enough time to discuss with the participants on how Physics was taught at Mukamambo II Girls' Secondary School. Additionally, the researcher observed how the Department of Natural Sciences was stocked with physics apparatus. Generally, the findings from the quantitative correlated well with the qualitative findings. All the discussions and observations tend to back the statistical findings. In the following section findings from the qualitative data which agrees with the statistical inferences are presented.

4.4. Research Question Number 1: Is there need for improvisation of apparatus for teaching Physics at Mukamambo II Girls' Secondary School?

4.4.1. Findings from observations made by the researcher

Mukamambo II Girls' Secondary School was opened by Chalimbana University, so that its students could practice teaching at this school. For this reason, Mukamambo II Girls' Secondary School depended on Chalimbana University for the supply of teaching aids in most of the subjects ranging from textbooks, chemicals and apparatus. Because of this dependence on Chalimbana University for the supply of Chemicals and apparatus, Mukamambo II Girls' Secondary School has very few pieces of apparatus for the teaching of Physics as shown in Appendix G. Table 4.5 shows the name of apparatus that are needed in the teaching of science, but are not available in the departmental store room.

Table 4.5 Nonfunctional and lacking pieces of apparatus at Mukamambo II Girls' Secondary School

S/N	Apparatus	Quantity	Functional	Non-Functional
1	Micrometer screw gauges	3	0	3
2	Beam balances	2	0	2
3	Ticker tape timers	0	0	0
4	Pulley wheels	0	0	0
5	Gears	0	0	0
6	Bicycle Pumps	0	0	0
7	Demonstration Chimneys	0	0	0
8	Clinical thermometer	0	0	0
9	Bimetallic strips	0	0	0
10	Water baths	1	0	1

11	Thermos flasks	0	0	0
12	Tuning folks	0	0	0
13	Concave lenses	0	0	0
14	Prisms	0	0	0
15	Optical fibres	0	0	0
16	Rheostats	0	0	0
17	Power packs	0	0	0
18	Car batteries	0	0	0
19	3 Pin Plugs	0	0	0
20	Thermionic tubes	0	0	0
21	Cathode Ray Oscilloscopes	0	0	0
22	GM Tubes	0	0	0

Physics apparatus that do not appear in Table 4.5 are available, but in very small quantities such that using them without improvisation will prove to be very difficult.

On the other hand, all the four teachers of physics that took part in the study suggested that they did more improvisation in Thermal Physics than any other topics in Grade 11.

4.4.2 Findings from Focus Group Discussion (FGD)

In order to establish the need for improvisation of apparatus in teaching Physics at Mukamambo II Girls' Secondary School, participants during FGD, were asked to mention some of the apparatus from the topics that they had covered with their teachers in class, but had no opportunity of seeing such apparatus. In short, participants were asked the questions, "What Physics apparatus are lacking at this school?" Several answers came up as indicated below:

During the FGD, participant number A031 said she wanted to see how a micrometer screw gauge is used to measure the diameter of a ball bearing. When asked how the teacher taught her, the participant said the teacher just drew the diagram of the micrometer screw gauge on a flip chart. When asked whether she understood, the participant said she understood the theory part, but never understood the practical part because she was not able to use a real micrometer screw gauge.

Another participant, number A022, claimed that she had not seen many of the real apparatus physically. She said that she only sees the apparatus in the books as well as those that teachers try to make.

When asked what exactly were the pieces of apparatus that were lacking in the department of science at Mukamambo II Girls' Secondary School, there was a loud laughter among the participants as some were heard saying "There was nothing in the department". Participant number A041 volunteered to mention the apparatus that she wished she could see and use: this was a bimetallic strip. She said this was important because the teacher mentioned that it was used in making of thermostats used in electric pressing irons, electric kettles, stoves, heaters and many more other appliances.

Another participant, number A008 said she would have loved to use a ticker-tape timer. The participant claimed that she did not even know where in life a ticker-tape timer is used. Actually she wondered why the teacher spent a lot of time trying to explain it. Most participants supported her argument saying to be taught how the ticker tape timer works was not necessary at all.

Participant number A038 indicated that she used to learn in one of the schools in Ndola. She strongly agreed with participant number A008 that despite the school where she came from having a very good laboratory, she had never seen a ticker-tape timer being used by any teacher. She wondered whether such apparatus existed in real life.

Participant number A022 wondered whether a Water Bath was merely a container of hot water being used to heat something. She said she got confused when her teacher of Biology got a pot of hot water from the Department of Home Economics and said it was a Water Bath. Meanwhile, her teacher of Physics used a beaker with a source of heat under it and said it was a Water Bath. She said she wished she had seen the real Water Bath.

Participant number A003 said that she did not know exactly what pieces of apparatus were missing because when teachers go to teach, they always carry some apparatus. So, as pupils, they did not know whether teachers make improvised apparatus for teaching because they are not there in the department or they make those apparatus to show that Physics is easy. Others shouted that there were no apparatus at the school and that is why teachers laboured to make us understand.

Each time one participant said anything about some pieces of apparatus that were lacking at Mukamambo II Girls' Secondary School, they received an overwhelming support from other participants, a sign that many pieces of apparatus were lacking at the school, confirming a greater need for improvisation.

4.5. Research Question Number 2: How often do teachers use improvised apparatus in the teaching of Physics at Mukamambo II Girls' Secondary School?

In order to determine how often teachers use improvised apparatus in the teaching of Physics at Mukamambo II Girls' Secondary School, the researcher used teachers' questionnaires, pupils' questionnaires and observation schedules.

4.5.1 Findings from teachers' questionnaires

All the four teachers of Physics that participated in the study agreed that they use improvised apparatus when teaching physics. The four teachers confirmed that they used improvised apparatus as a supplement to conventional ones. The four teachers agreed that improvised apparatus could add value to improve academic achievement of their learners. In order to ensure safety for the pupils, all the four teachers that took part in this study suggested that they always tried their improvised apparatus before using them in the presence of pupils.

Table 4.6 Frequency of use of improvised apparatus

	Frequency	Percent
Always	1	25.0
Sometimes	3	75.0
Total	4	100.0

Table 4.6 shows that one teacher always used improvised apparatus when teaching physics while three teachers said they sometimes use improvised apparatus when teaching.

Table 4.7 Experience of teaching of physics using a mixture of conventional and improvised materials

	Frequency	Percent	Percent
Interesting	1	25.0	25.0
Very Interesting	3	75.0	75.0
Total	4	100.0	100.0

Table 4.7 shows that of the four teachers that took part in the study, one teacher found the use of improvised apparatus as interesting while three teachers found the use of improvised apparatus as very interesting.

4.5.2 Findings from pupils' questionnaires

Table 4.8 Teachers' use of improvised apparatus

	Frequency	Percent
Yes	48	96.0
No	2	4.0
Total	50	100.0

Table 4.8 shows that 96% of the participants agreed that teachers used improvised apparatus when teaching physics.

Table 4.9 Frequency of teachers' use improvised apparatus

	Frequency	Percent
Always	4	8.0
Most Often	46	92.0
Total	50	100.0

Table 4.9 indicates that 8.0% of the participants agreed that teachers always use improvised apparatus while 92.0% of the participants indicated that teachers used improvised apparatus most often.

4.5.3 Findings from the Observation Schedule

According to the observations made by the researcher, it was revealed that teachers of physics at Mukamambo II Girls' Secondary School used improvised apparatus and they did so most often. Additionally, it was revealed that teachers of Physics at this school used improvised apparatus as a supplement to conventional ones. In most cases, it was practically impossible to use improvised apparatus alone as it was almost impossible to improvise all the apparatus.

The figures below show some of the improvised apparatus that were used in this stud**y.**

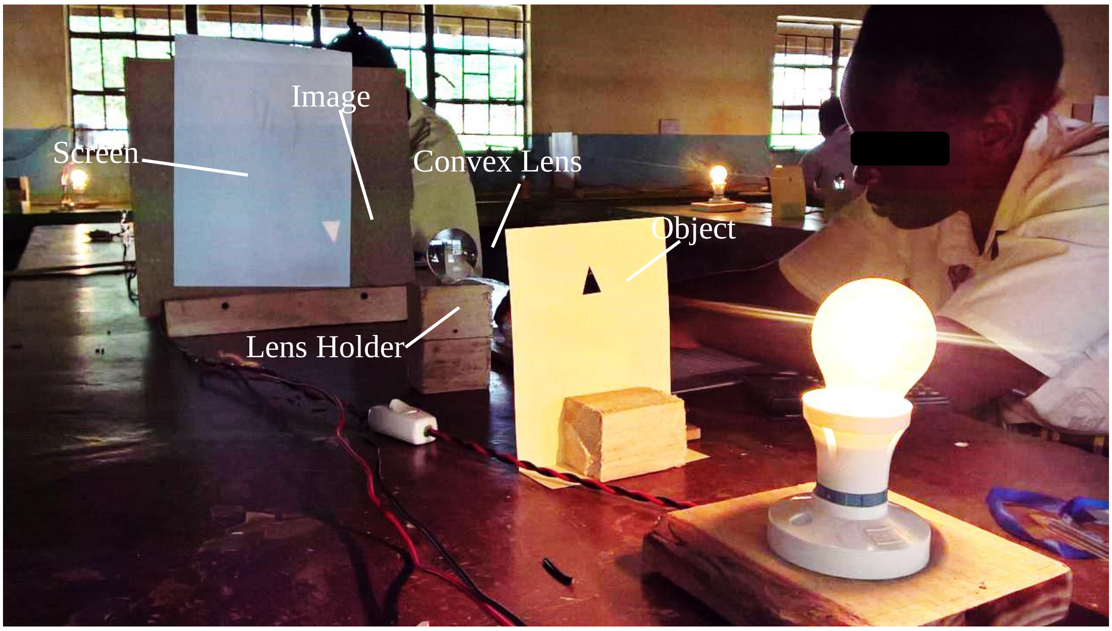

Figure 4.1: Screen, Object and lens holder

Figure 4.1 shows an improvised screen and a lens holder. However, it was practically impossible to improvise a convex lens, hence the need to use improvised apparatus in conjunction with the conventional ones.

Figure 4.2 Circuit Board

Figure 4.2 shows a participant using a voltmeter and an improvised circuit board. An original circuit board costs slightly more that K1,500.00, but this one in Figure 4.3 and Figure 4.4 were made at a cost of less than K5.00.

Figure 4.3 Circuit Board

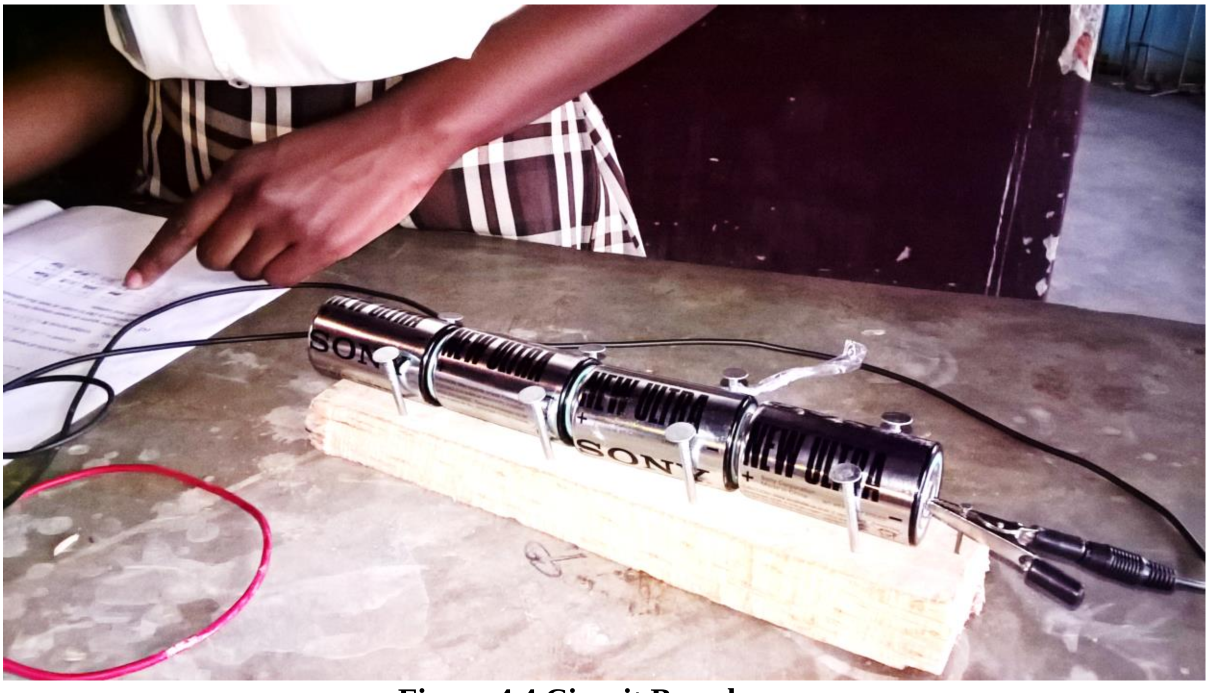

Figure 4.4 Circuit Board

4.6 Quantitative Research Findings

Quantitative data was collected from pupils' questionnaires and the pre and post-tests that were administered to the participants. For each of the results that were obtained, outliers were determined using the Box Plot. According to Abebe et al, (2001), Outliers are points of the data set that do not seem to belong to the rest of the data as they differ by a substantial amount from the rest of the data set. They can either be too low, or too high. Outliers are often points worthy of investigation in order to understand why they differ.

4.6.1 Results from Pre-test for Experimental Group

Table 4.1 shows that most participants (15) in the experimental group got marks between 41% and 50%

Table 4.10 Frequency Table of the Pre-test Results for Experimental Group

Marks	Frequency
0 – 10	1
11 – 20	2
21 – 30	5
31 – 40	8
41 – 50	15
51 – 60	13
61 – 70	6
71 – 80	0
81 – 90	0
91 – 100	0

Figure 4.5 shows the same results in Table 4.10 now plotted on a bar chart.

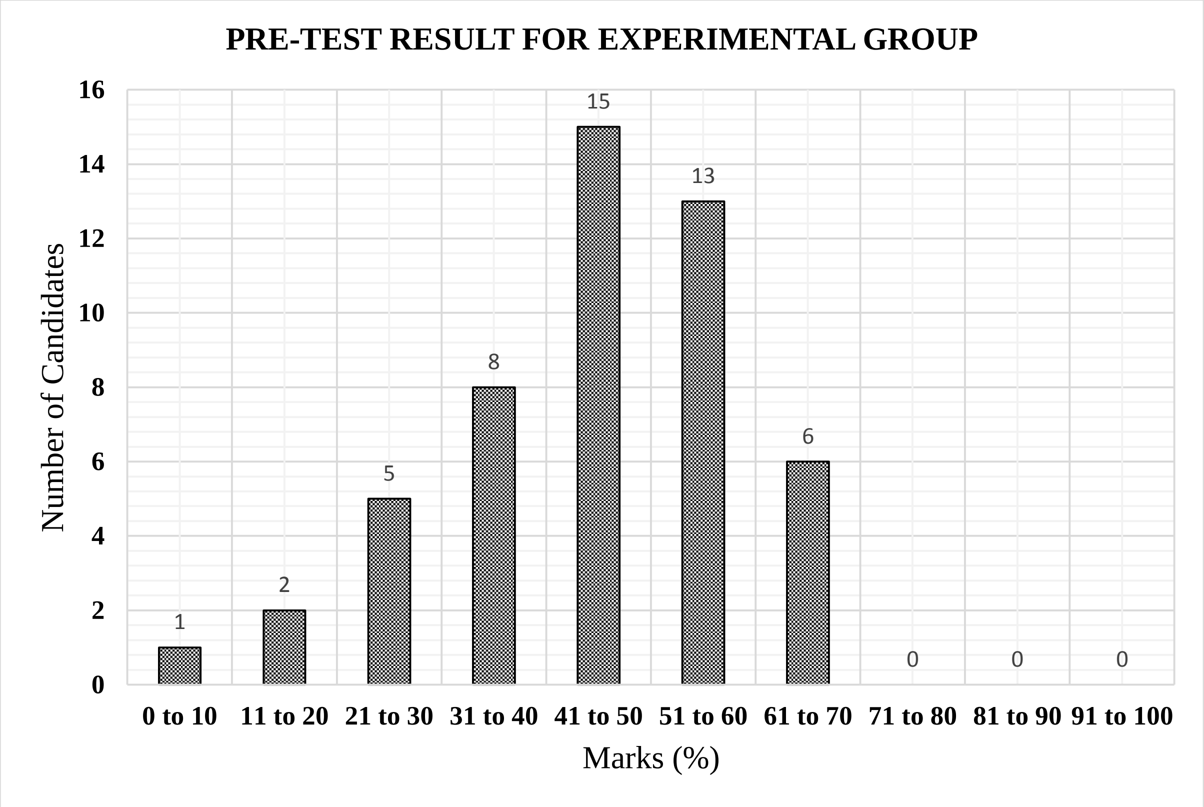

Figure 4.5: Bar Chart for the Pre-test Results for Experimental Group

4.6.2 Pre-test Outlier Determination Using Box Plot for Experimental Group

The following were the results from the Pre-test of the Experimental Group, arranged from the lowest mark to the highest mark:

8, 14, 16, 22, 22, 26, 28, 28, 32, 36, 36, 38, 38, 38, 40, 40, 42, 42, 42, 42, 42, 44, 44, 44, 44, 44, 46, 46, 48, 48, 50, 52, 52, 52, 52, 52, 54, 54, 54, 56, 58, 58, 60, 60, 62, 62, 62, 62, 66, 68

The lower quartile, Q1 is 38, while the median Q2 is $\frac{44+44}{2}=\frac{88}{2}=44$. The upper quartile, Q3 is 54

Q1=38 Q2=44 Q3=54

Minimum Value = 8

Maximum Value = 68

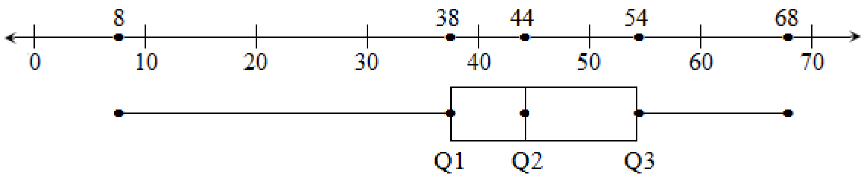

Figure 4.6 Pre-test Box Plot for Experimental Group

$$\begin{aligned}
&\text{IQR} = \text{Q3} - \text{Q1} = 54 - 38 = 16\\
&\text{IQR} \times 1.5 = 16 \times 1.5 = 24\\
&\text{Lower inner fence} = \text{Q1} - (\text{IQR} \times 1.5)\\
&\text{Lower inner fence} = 38 - 24\\
&\text{Lower inner fence} = 14
\end{aligned}$$

This means that any mark in the data set that is lower than 14, is an outlier. Since 8 is lower than 14, but it is not very far from 14, it is called a Mild Outlier.

$\text{Upper inner fence} = Q3 + (\text{IQR} \times 1.5)$
$\text{Upper inner fence} = 54 + 24$
$\text{Upper inner fence} = 78$

This means that any mark in the data set that is higher than 78, is an outlier. From the data set, no one got more than 78, hence, there were no outliers.

Table 4.11 shows that most participants (13) in the experimental group of the post-test got marks between 71% and 80%

Table 4.11 Frequency Table of the Post-test Results for Experimental Group

Marks	Frequency
0 – 10	0
11 – 20	0
21 – 30	1
31 – 40	2
41 – 50	5
51 – 60	8
61 – 70	11
71 – 80	13
81 – 90	9
91 – 100	1

When the results in Table 4.11 were plotted on the bar chart, Figure 4.7 was produced.

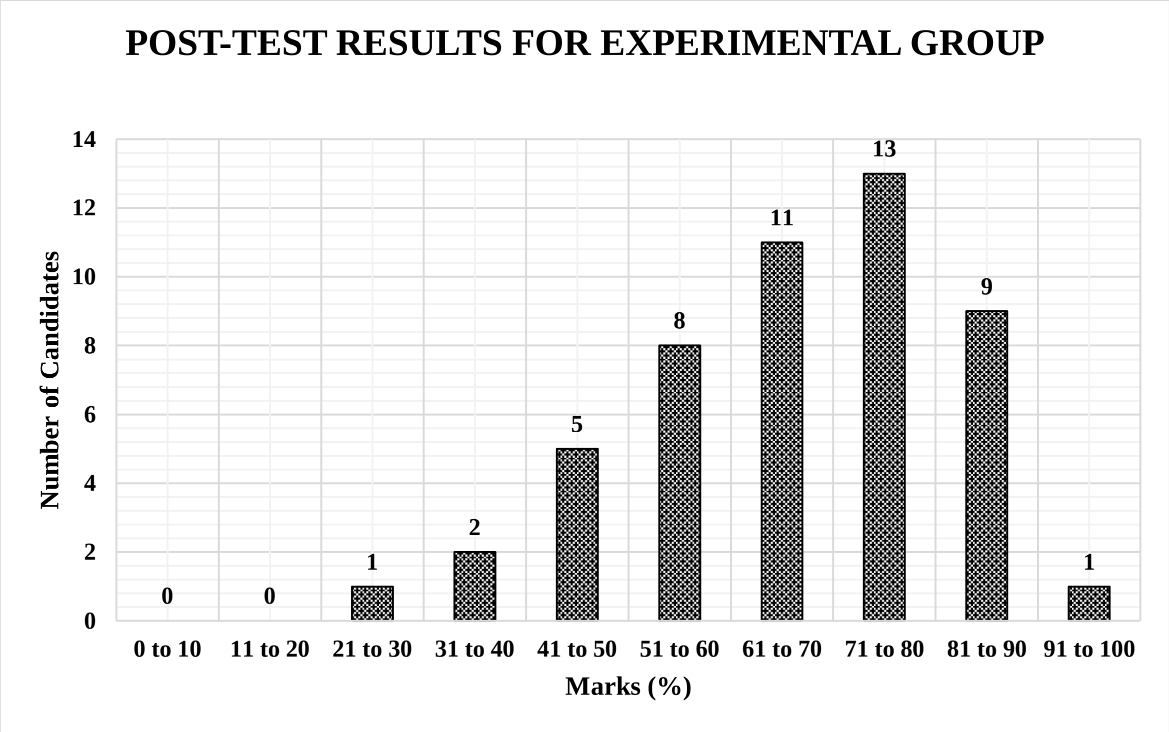

Figure 4.7: Bar Chart for the Post-test Results for Experimental Group

4.6.3 Post-test Outlier Determination Using Box Plot for Experimental Group

The following were the results from the Post-test of the Experimental Group, arranged from the lowest mark to the highest mark:

28, 38, 40, 42, 44, 50, 50, 50, 52, 54, 56, 58, 58, 60, 60, 60, 62, 64, 64, 64, 66, 66, 68, 68, 68, 70, 70, 72, 72, 72, 72, 72, 72, 74, 74, 76, 78, 78, 80, 80, 82, 82, 84, 84, 86, 86, 88, 90, 90, 92

The lower quartile, Q1 is 58, while the median Q2 is $\frac{68+70}{2}=\frac{138}{2}=69$. The upper quartile, Q3 is 78

Q1=58 Q2=69 Q3=78

Minimum Value = 28

Maximum Value = 92

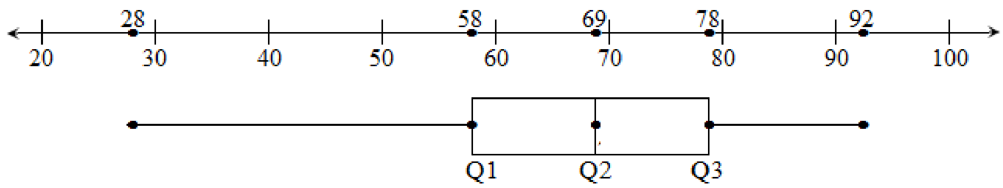

Figure 4.8 Post-test Box Plot for Experimental Group

$$\text{IQR} = \text{Q3} - \text{Q1} = 78 - 58 = 20$$
$$\text{IQR} \times 1.5 = 20 \times 1.5 = 30$$
$$\text{Lower inner fence} = \text{Q1} - (\text{IQR} \times 1.5)$$
$$\text{Lower inner fence} = 58 - 30$$
$$\text{Lower inner fence} = 28$$

This means that any mark in the data set that is lower than 28, is an outlier. In this case, there were no Outliers.

$$\text{Upper inner fence} = \text{Q3} + (\text{IQR} \times 1.5)$$
$$\text{Upper inner fence} = 78 + 30$$
$$\text{Upper inner fence} = 108$$

This means that any mark in the data set that is higher than 108, is an outlier. In this case, there were no outliers

Table 4.3 shows a summary of the results of the pre and posttests of the Experimental and Control Groups.

Table 4.13 Summary of Experimental Group Pre and Post-test Results

Test	Number of Participants	Mean	Outliers
Pre-Test	50	44.5%	1
Post-Test	50	67.3%	0

As shown in Table 4.13, the mean score for the Experimental Group was 44.5% in the pre-test. After teaching these participants with Improvised apparatus as a supplement to the conventional apparatus, the post-test mean score increased to 67.3%. The pass increase between the pre-test and post-test was 22.8%. One outlier was recorded in the pre-test. However, this outlier could easily be ignored as it was a Mild Outlier.

4.7 Results from Pre-test for Control Group

Table 4.14 Frequency Table of the Pre-test Results for Control Group

Marks	Frequency
0 – 10	4
11 – 20	2
21 – 30	3
31 – 40	9
41 – 50	17
51 – 60	12
61 – 70	3
71 – 80	0
81 – 90	0
91 – 100	0

Table 4.14 shows that before any lesson was given to the Control Group, the majority (17) of the participants got between 41% and 50%.

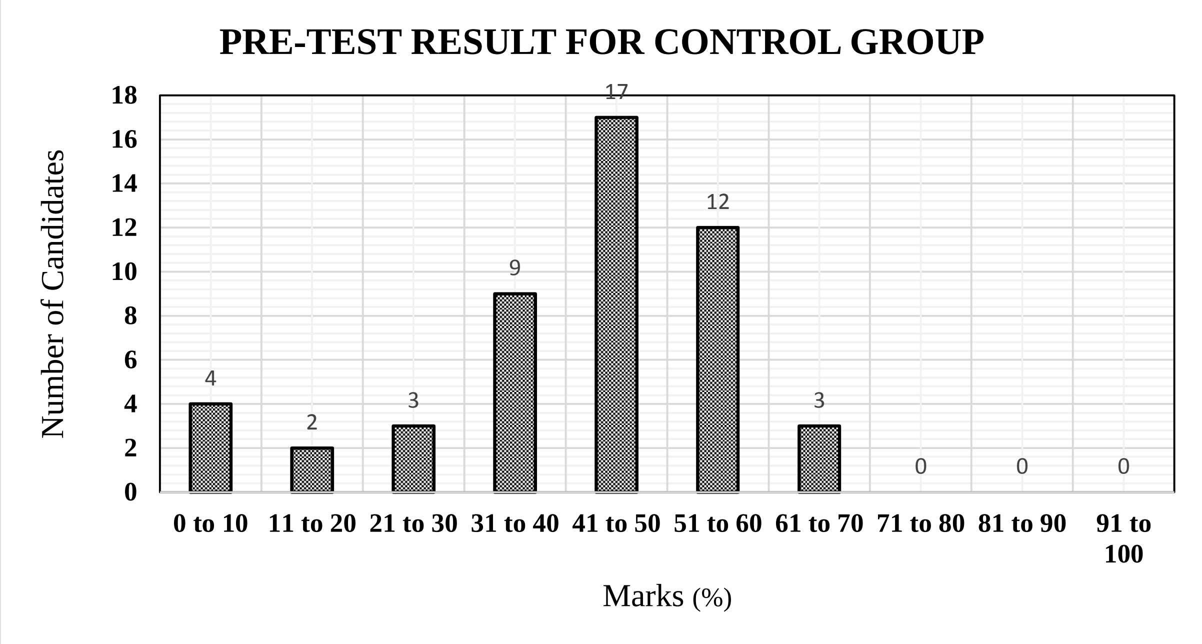

Figure 4.9: Bar Chart for the Pre-test Results for Control Group

4.8 Pre-test Outlier Determination Using Box Plot for Control Group

The following were the results from the Pre-test of the Control Group, arranged from the lowest mark to the highest mark:

2, 2, 8, 10, 12, 18, 24, 28, 30, 32, 32, 34, 34, 36, 38, 40, 40, 40, 42, 42, 44, 44, 44, 44, 44, 46, 46, 48, 48, 50, 50, 50, 50, 50, 50, 52, 52, 52, 52, 54, 56, 56, 56, 58, 58, 60, 60, 62, 68, 68

The lower quartile, Q1 is 34, while the median Q2 is $\frac{46+46}{2}=\frac{92}{2}=46$. The upper quartile, Q3 is 52

Q1=34 Q2=46 Q3=52

Minimum Value = 2

Maximum Value = 68

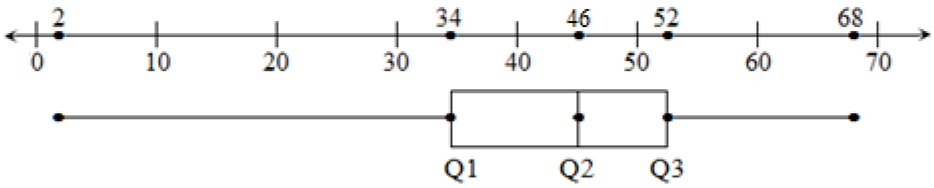

Figure 4.10 Pre-test Box Plot for Control Group

$$\text{IQR} = \text{Q3 - Q1} = 52 - 34 = 18$$
$$\text{IQR} \times 1.5 = 18 \times 1.5 = 27$$
$$\text{Lower inner fence} = \text{Q1} - (\text{IQR} \times 1.5)$$
$$\text{Lower inner fence} = 34 - 27$$
$$\text{Lower inner fence} = 7$$

This means that any mark in the data set that is lower than 7, is an outlier. In this case, two values are lower than 7, but they are not very far from 7, therefore, they are called a Mild Outliers.

$$\text{Upper inner fence} = \text{Q3} + (\text{IQR} \times 1.5)$$
$$\text{Lower inner fence} = 52 + 27$$
$$\text{Lower inner fence} = 79$$

This means that any mark in the data set that is higher than 79, is an outlier. From the data set, no one got more than 79, hence, there were no outliers

Table 4.15 Frequency Table of the Post-test Results for Control Group

Marks	Frequency
0 – 10	0
11 – 20	1
21 – 30	3
31 – 40	6
41 – 50	9
51 – 60	13
61 – 70	8
71 – 80	7
81 – 90	3
91 – 100	0

Table 4.15 indicates that after participants were taught Physics using only the available conventional apparatus, the largest number (13) of participants got marks between 51% and 60%. This improvement could be due to the fact that learning had taken place.

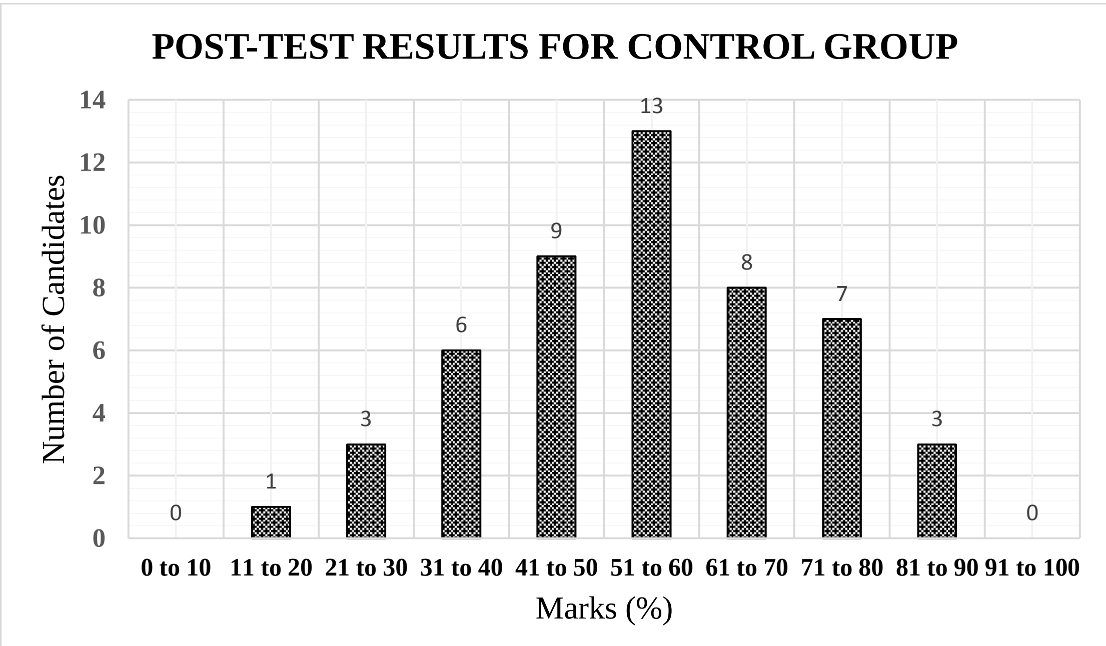

Figure 4.11: Bar Chart for the Post-test Results for Control Group

4.9 Post-test Outlier Determination Using Box Plot for Control Group

The following were the results from the Pre-test of the Control Group, arranged from the lowest mark to the highest mark:

20, 22, 22, 28, 32, 32, 32, 36, 40, 40, 44, 44, 46, 46, 48, 48, 48, 48, 50, 54, 54, 54, 54, 56, 58, 58, 58, 58, 58, 60, 60, 60, 62, 62, 62, 64, 64, 68, 68, 70, 72, 74, 74, 78, 80, 80, 80, 82, 82, 84

The lower quartile, Q1 is 46, while the median Q2 is $\frac{58+58}{2}=\frac{116}{2}=58$. The upper quartile, Q3 is 68

Q1=46 Q2=58 Q3=68

Minimum Value = 20

Maximum Value = 84

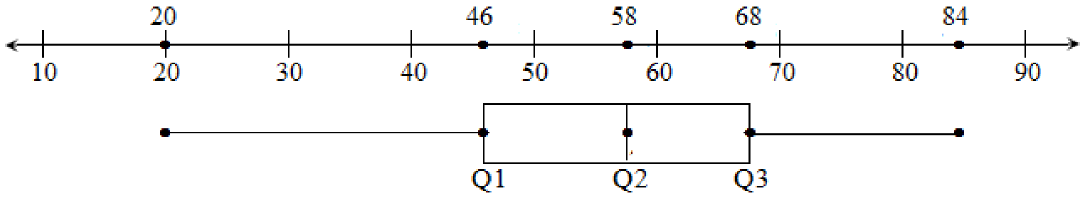

Figure 4.12 Post-test Box Plot for Control Group

$$\text{IQR} = \text{Q3} - \text{Q1} = 68 - 46 = 22$$
$$\text{IQR} \times 1.5 = 22 \times 1.5 = 33$$
$$\text{Lower inner fence} = \text{Q1} - (\text{IQR} \times 1.5)$$
$$\text{Lower inner fence} = 46 - 33$$
$$\text{Lower inner fence} = 13$$

This means that any mark in the data set that is lower than 13, is an outlier. In this case, there were no Outliers.

$$\text{Upper inner fence} = Q3 + (IQR \times 1.5)$$
$$\text{Upper inner fence} = 68 + 33$$
$$\text{Upper inner fence} = 101$$

This means that any mark in the data set that is higher than 101, is an outlier. In this case, there were no Outliers.

Table 4.16: Summary of Control Group of Pre and Post-test Results

Test	Number of Participants	Mean	Outliers
Pre-Test	50	42.3%	1
Post-Test	50	55.5%	0

As shown in Table 4.16, the mean score for the Control Group was 42.3% in the pre-test. After teaching these participants with the available conventional apparatus, the post-test mean score increased to 55.5%. The pass increase between the pre-test and post-test was 13.2%. This increase could have been brought about by the fact that participants had learnt something. One outlier was recorded in the pre-test. However, this outlier could easily be ignored as it was a Mild Outlier.

Table 4.17 Pre-test Results: Comparison between the Experimental and the Control Group

Group	Number of Participants	Mean	Standard Deviation
Experimental	50	44.5%	13.8
Control	50	42.3%	15.9
Difference		2.2%	

Before any lesson was taught to the two groups, there was a very minimal difference (2.2%) in performance in the pre-test as shown in Table 4.17. The experimental group was higher by only 2.2%. This difference is acceptable since the participants were selected at random. It is practically impossible to have the same average mark in the two classes even when the participants are selected purposively. The fact the difference between the experimental and control groups was minimal, suggests that the two groups were well balanced in terms of intellectual achievement.

Table 4.18 Post-test Results: Comparison between the Experimental and the Control Group

Group	Number of Participants	Mean	Standard Deviation
Experimental	50	67.3%	14.8
Control	50	55.5%	16.8

After teaching both classes the same topics, but different apparatus, it was observed that the mean pass rate for the Experimental group was 67.3% as shown in Table 4.18. On the other hand, the mean pass rate for the Control Group was 55.5%, representing an 11.8% difference between the two groups. This difference in the pass rate between the two groups can be attributed to the use of the improvised apparatus as a supplement to the conventional ones for the Experimental Group.

4.10 Comparison of the pre and post-tests results of the Experimental and Control Groups using t-test

Table 4.19 shows the results of the pre and post-tests of the Experimental and Control Groups when they were being compared using t-test

4.1.1: Pre-test t-test calculations

Table 4.19 Pre-test results

Experimental Score (%)	Control Score (%)
62	50
42	40
52	30
44	40
26	40
38	50
66	50
60	58
46	56
48	24
54	28
8	38
32	50
38	36
40	46
36	44
40	50
42	10
48	42
44	48
58	46
54	52
62	8
52	18
68	34
22	34
28	44
36	44
54	44
52	68

	62	32
	46	44
	44	52
	42	52
	52	56
	58	68
	60	2
	62	32
	14	50
	42	42
	28	54
	22	60
	38	60
	42	58
	44	62
	44	48
	52	52
	16	56
	56	2
	50	12
Mean ($\overline{x}$)	45	42
st. dev	14	16
Variance (S)	190	254
N	50	50

Formula 4.7.1 – Calculations of the t-value of the Pre-test Results

$$t = \frac{\overline{x}_e - \overline{x}_c}{\sqrt{\frac{S_e^2}{N_e} + \frac{S_c^2}{N_c}}}$$

Where $\overline{x}_e$ and $\overline{x}_c$ are the two means of the experimental and control groups respectively. S_e^2 and S_c^2 are the two variances of the experimental and control groups respectively.

$$t = \frac{45 - 42}{\sqrt{\frac{190}{50} + \frac{254}{50}}}$$

$$t = \frac{3}{\sqrt{4 + 5}}$$

$$t = \frac{3}{\sqrt{9}}$$

$$t = \frac{3}{3}$$

$$t = 1$$

$$\therefore \text{t - value} = 1$$

p=0.05

Degree of freedom, df=(50+50) – 2=100 – 2=98

$\therefore$ df=98

Hence critical value = 1.99

Since the critical value (1.99) is greater than the t-value (1), suggests that there was nothing that influenced the results in the pre-test of both the experimental and control groups. The difference between the experimental and control group in the pre-test was therefore insignificant.

4.12 Comparison of the pre and post-tests results of the Experimental and Control Groups using t-test

Table 4.10 shows the results of the pre and post-tests of the Experimental and Control Groups when they were being compared using t-test

4.13 Post-test t-test calculations

Table 4.20 Pre-test results

Experimental Score (%)	Control Score (%)
86	48
72	40
72	32
64	44
42	44
54	54
82	54
84	64
64	62
66	32
72	36
28	46
52	58
58	46
60	56
56	54
60	60
62	22
68	54
64	60
78	58
74	64
88	22
72	32
92	48

	44	48
	50	58
	58	58
	80	58
	74	82
	84	48
	70	60
	68	68
	66	68
	76	72
	82	84
	90	20
	86	50
	40	62
	68	62
	38	74
	50	80
	60	80
	70	78
	72	82
	72	70
	80	74
	50	80
	90	28
	78	40
Mean ($\overline{x}$)	67	55
st dev	15	17
Variance (S)	220	283
N	50	50

Formula 4.7.2 – Calculations of the t-value of the Post-test Results

$$t = \frac{\bar{x}_e - \bar{x}_c}{\sqrt{\frac{S_e^2}{N_e} + \frac{S_c^2}{N_c}}}$$

Where $\bar{x}_e$ and $\bar{x}_c$ are the two means of the experimental and control groups respectively. S_e^2 and S_c^2 are the two variances of the experimental and control groups respectively.

$$t = \frac{67 - 55}{\sqrt{\frac{220}{50} + \frac{283}{50}}}$$
$$t = \frac{12}{\sqrt{4 + 6}}$$
$$t = \frac{12}{\sqrt{10}}$$
$$t = \frac{12}{3}$$
$$t = 4$$
$$\therefore \text{t - value} = 4$$

P=0.05

Degree of freedom, df=(50+50) – 2=100 – 2=98

$\therefore$ df=98

Hence critical value = 1.99

The critical value (1.99) is less than the t-value (4). This suggests that there was something that influenced the results.

4.14 Chapter Summary

The just ended chapter outlined the findings of the study from each of the three research questions. It was discovered that Mukamambo II Girls' Secondary School lacks many essential apparatus necessary for the teaching and learning of Physics, hence a greater need for improvisation. It was also observed that all the teachers of physics at least use improvised apparatus in one way or another when teaching. Additionally, it was discovered that in the pre-test, the mean score for the experimental group was 44.5% while for the same test, the mean score for the control group was 42.3%. These two scores are very close to each other, showing that the two groups were almost the same in terms of their academic achievement. In the post-test, the experimental group mean score was 67.3% representing an increase of 22.8% from the results in the pre-test, while in the same test, the control group mean score was 55.5%, representing an increase of 13.2% from the results in the pre-test. In the next chapter, these findings are discussed in detail.

CHAPTER FIVE

DISCUSSION OF FINDINGS

5.1 Overview

This chapter discusses the findings of the investigation of the efficacy of improvised apparatus in teaching of selected topics in Physics at Mukamambo II Girls' Secondary School. The discussion is presented according to the objectives of the study which were to; establish the need for improvisation in Physics at Mukamambo II Girls' Secondary School, establish how often teachers use improvised apparatus in the teaching of Physics at Mukamambo II Girls' Secondary School, and finally to determine how effective improvised apparatus were in teaching Physics, when they were used as a supplement to conventional ones.

5.2 Need for improvisation of apparatus in teaching of Physics at Mukamambo II Girls' Secondary School

5.2.1 Discussion on observations made by the researcher

According to the Ministry of Education (1996), many secondary schools do not have science apparatus, and if they do have, then they are not enough to cater for the ever increasing enrolments in most of the schools. Mukamambo II Girls' Secondary School is one of the many secondary schools which do not have adequate teaching and learning apparatus. Many studies: Ministry of Education (1996), Khawla & Abdul (1999), Oloyede (2007), Ministry of Education (2009), Adeyemo (2010), Olufunke (2012), Aina (2013), Mohammed and Titus (2016), all indicate that many schools lack pieces of apparatus in sciences and therefore, encourage teachers to improvise during their teaching.

According to Table 4.5.1 (a) it was established that Mukamambo II Girls' Secondary School faces challenges with apparatus where teaching and learning of Physics is concerned. This is so because the school lacks many essential apparatus required for the teaching and learning of Physics. Some of the available apparatus are few in number. Additionally, most of the available apparatus were non-functional. For example the department had only three (3) Micrometer Screw Gauges, two (2) beam balances and only one (1) water bath which were all non-functional. This shortage and in most cases non availability of essential apparatus suggests that there is greater need for improvisation of apparatus if Physics is to be taught effectively at this school.

5.2.2 Discussion on findings from FGD

From the findings on FGD, it was clear that pupils at Mukamambo II Girls' Secondary School had not used many of the conventional Physics apparatus. Pupils only used to hear about certain apparatus. For certain apparatus like vernier calipers and micrometer screw gauges, pupils knew how to take readings from the diagrams even though they did not know how to use the actual instrument. For this reason, there is need to sensitise teachers of science to increase and develop improvisational skills. Additionally, schools should purchase at least a few conventional apparatus so that the pupils can be able to connect ideas when they see the improvised apparatus. For example, a bimetallic strip can be improvised by attaching aluminium foil and paper with the help of glue. After being heated, the improvised bimetallic strip bends in the same way that the conventional one does. Hence, there is need to show learners the actual instrument so that they can easily make reference to the improvised.

5.2.3 How often teachers use improvised apparatus in the teaching of Physics at Mukamambo II Girls' Secondary School.

When observed how often teachers of Physics at Mukamambo II Girls' Secondary School used improvised apparatus, it was discovered that teachers at the school use a lot of improvised apparatus. This is contrary to Ministry of Education (2000) which claimed that teachers of science lacked improvisational skills. For teachers at this school, improvisation is the order of the day. Maybe, teachers from other schools are the ones that could have lacked improvisational skills. Teachers at the school were able to make their own apparatus in almost all the sciences as they believe that they may not be able to wait for government funding to buy the much needed apparatus. They also believe that the type of apparatus does not matter, what matters are the results produced at the end of the year. The frequency at which teachers at the school use improvised apparatus clearly indicates that they believe that science can be learnt effectively by involving practical work. These findings are similar to studies by many researchers such as Kulik (1992), Black (1993), Hickey et al. (2001), Gauvain (2001) Kaulu (2008), who assert that sciences (Physics inclusive) are practical subjects hence best learnt through experiments, observations, analysis and generalization of conclusion. Kulik (1992) notes that for Physics and other sciences to be understood better by all, there is need to emphasise its instruction in secondary schools through practical approach. For this reason, teachers of science are supposed to possess skills such as improvisational skills if they are to teach their subjects effectively. It should be made clear that the type of apparatus used does not matter, what matters much is the level of understanding by the learners.

From the results on the questionnaires, all the four teachers who took part in this study agreed that the use of improvised apparatus could add value to the academic achievement of their learners. Their agreement was in line with the academic achievement of pupils of Mukamambo II Girls' Secondary School in National Examinations. Examinations analysis from 2009 to 2016, which are shown in Table 5.1 indicate that the school had been doing well in science (5124) in the previous years. These good results could have been achieved as a result of the use of improvised apparatus.

Table 5.1: Final Examinations Pass rate in Science

Year	2009	2010	2011	2012	2013	2014	2015	2016
Pass rate (%)	93	85	89	97	92	90	96	93

Despite the good results shown in the table for the years from 2009 to 2016, the department of science at Mukamambo II Girls' Secondary School is poorly equipped with conventional apparatus. These results can be attributed to teachers' innovativeness.

Therefore, the researcher strongly feels that improvisation should be part of the training program for any teacher of science to graduate from the teachers training colleges and universities. For teachers already in service, the researcher feels that Government through the Ministry of Education (MoE) in Zambia, should introduce training programs where teachers of science can learn how to improvise certain apparatus. As claimed by the Ministry of Education (2000), that most teachers lack improvisational skills, MoE should also take measures that could make teachers possess improvisational skills so that they are able to teach even when there are no conventional apparatus.

5.2.4 Effectiveness of improvised apparatus in teaching Physics, when they are used as a supplement to conventional ones.

The data collected under this objective was purely quantitative in nature. Therefore, the data was analysed quantitatively in terms of descriptive statistics i.e. means, modes, frequencies.

5.2.5 Discussion of Results from Pre and Post-test of Experimental and Control Groups

In the pre-test of the experimental group, the mean score was 44.5% with an outlier of 1. In the post-test, the mean score for the experimental group was 67.3% without any outlier scores. There was an increase of 22.8% between the mean score in the pre-test and the mean score of the post-test. This increase can be attributed to the fact that improvised apparatus were used in the teaching of Physics to the experimental group.

In the pre-test of the control group, the mean score was 42.3% without any outlier score. In the post-test, the mean score for the control group was 55.5%. There was an increase of 13.2% between the mean score in the pre-test and the mean score of the post-test. This increase can be attributed to the fact that learning took place even though improvised apparatus were not used in the teaching of Physics to the control group. Outliers were calculated and it was found that in the post-test, there was no outlier score. Even if learning took place in the control group, the pass percentage was lower than that of the experimental group in the post-test.

In the pre-test, experimental group mean score was 44.5%, while the mean score for the control group in the pre-test was 42.3%. There was a 2.2% difference between these scores. This difference could not be avoided as the participants were selected at random. However, the two mean results were very close to each other. This shows that both the experimental and control groups were well balanced in terms of participant intelligence.

In the post-test, experimental group mean score was 67.3%, while the mean score for the control group in the post-test was 55.5%. There was an 11.8% difference between these scores. This difference in the mean score between the experimental and control groups could be attributed to the use of improvised apparatus in the case of the experimental group, and the non-use of improvised apparatus in the control group. Therefore, it can be assumed that improvised apparatus are effective in the teaching of physics. These findings are in line with other researchers such as Mboto et al (2011), Osuolale (2014) and Sileshi (2012) who found that improvised apparatus are effective in the teaching of science, more especially when they are used in conjunction with modern apparatus. Findings from these researchers that improvised apparatus are better used in conjunction with modern ones are valid. This is because it is almost impossible to use improvised apparatus only without any conventional apparatus in most of the lessons, for example, when you wish to verify Ohm's law, you may improvise a circuit board and cheap discarded wires. However, you may not be able to improvise an ammeter and a voltmeter, hence the need to supplement the conventional apparatus with improvised ones.

5.2.6 Discussion of the Null Hypothesis:

Null Hypothesis: *There is no statistically significant difference in the mean performance in science 5124/1 between pupils taught with improvised materials as a supplement to conventional ones and those taught with only the available conventional materials*

Since the critical value (1.99) was less than the t-value (4), the use of improvised apparatus as a supplement to conventional ones, influenced the results in the post-test of the experimental group. This entails that the Null Hypothesis which suggests that there is no statistically significant difference in the mean performance in science 5124 between pupils taught with improvised apparatus as a supplement to conventional ones and those taught with conventional materials only if they are available can be rejected. In this case, an alternative can be accepted. The alternative suggests that there is statistically significant difference in the mean performance in science 5124 between pupils taught with improvised materials as a supplement to conventional ones and those taught with only the available conventional materials.

The findings of this study are in line with the theoretical framework which guided this study. As observed with the learners in the experimental group, their senses were stimulated at all times during their learning process since each lesson had a practical. Because of this, learning occurred most effectively as compared to the control group which only did practicals with the available conventional apparatus. This made the experimental group to perform better than the control group in the post-test.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Overview

This chapter has two main parts. The first part is the conclusion of the study based on the results obtained, while the second part of the chapter are the recommendations based on the findings.

6.2 Conclusion

The results of the study revealed that Mukamambo II Girls' Secondary School lacked essential apparatus for the teaching and learning of Physics. However, 96% of the pupils agreed that teachers used improvised apparatus when teaching and 92% of the pupils indicated that teachers used improvised apparatus most often. These findings are in line with the observations that the researcher made. On the other hand, after analysing the results in the pre-tests and post-tests for the experimental and control groups, it was revealed that the experimental group performed better than the Control Group by only 2.2% in the pre-test. However, after a series of lessons, the experimental group outperformed their control group counterparts by a wider margin of 11.8%.

Therefore, based on the results obtained in this study, it can be concluded that when improvised apparatus are used as a supplement to the conventional ones, they are of high efficacy as they greatly improve pupil performance in physics at Mukamambo II Girls' Secondary School.

6.3 Recommendations

Based on the findings of the study, the following recommendations were made:

The fact that learners who were taught using a mixture of improvised and conventional apparatus outperformed their counterparts who were taught by the available conventional apparatus does not mean that the improvised apparatus are effective on their own. It is therefore recommended that teachers of Physics should always use improvised apparatus in conjunction with the conventional ones.

Additionally, it is recommended that this approach be adopted for teaching of Physics in schools which do not have enough apparatus in Zambia. This will greatly improve the learning of science in Zambia.

We also recommend that the method of improvisation be tried in other science subjects. This is important because even other sciences apart from Physics could be having shortages of apparatus

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APPENDICES

APPENDIX A

LABORATORY OBSERVATION SCHEDULE

1. AVAILABILITY OF APPARATUS

1.1 Follow up questions

(i) What Physics apparatus are lacking in the Department of Science at Mukamambo II Girls' Secondary School?

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(ii) What improvised apparatus in Physics are there?

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(iii) Which of the five sciences (Agricultural Science, Biology, Chemistry, Physics and Integrated Science) has more improvised apparatus?

Subject Name:___________________________

2. TABLE 2.1: USE OF IMPROVISED APPARATUS

S/N	Descriptors	Use			
		Never	Rarely	Sometimes	Most often
1	Do teachers use improvised apparatus when teaching Physics?				
2	How often do teachers use improvised apparatus when teaching?				
3	How often do teachers use improvised apparatus in conjunction with conventional ones?				
4	Do improvised apparatus help in achieving teacher's set objectives?				
5	Are improvised apparatus safe for the teacher and learners?				
6	Do the teachers allow learners to these improvised apparatus?				
7	Are the learners motivated by the use of the improvised apparatus in their learning?				
8	How often do teachers assess the performance of learners in physics?				

2.1 Comments

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…………………………………………………………………………………………

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3. TABLE 2.2: MAKING OF IMPROVISED MATERIALS

S/N	Descriptors	Making		
		Never	**Rarely**	**Most often**
1	Do pupils participate in making improvised apparatus?			
2	Are there any challenges faced when making these improvised materials?			
3	Does the Department receive any support from the school management regarding the making of improvised apparatus?			

3.1 Follow up questions

(i) What factors could be hindering the production of improvised apparatus?

(ii) What type of support can teachers receive from administration with regard to making improvised apparatus?

APPENDIX B

PHYSICS TEACHERS' RESEARCH QUESTIONNAIRE

PARTICIPANT ID:…………………………………………..

GENDER:……………………………………………………..

INSTRUCTIONS

- Do not write your name anywhere on this questionnaire.
- Answer all questions by placing a tick where possible. You may be required to write short statements where necessary.
- Do not expose your answers to your colleagues.

1. Which of the Grade 11 Classes do you teach?

11 Violet ☐

11 Yellow ☐

11 White ☐

2. How long have you been in service as a teacher of Physics?

0 - 5 years ☐

6 - 10 years ☐

11 - 15 years ☐

16 years and above ☐

3. For how long have you been teaching Physics at Mukamambo II Girls' Secondary School?

0 - 5 years ☐

6 - 10 years ☐

11 - 15 years ☐

16 years and above ☐

4. In your opinion, which relevant pieces of apparatus are lacking in Physics (if any)?

……………………………………………………………………………………

……………………………………………………………………………………

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5. During Physics lessons, do you teach using improvised apparatus?

Yes ☐

No ☐

6. If your answer to question 5 is yes, how often do you teach using improvised apparatus?

Always ☐

Sometimes ☐

N/A ☐

7. How do your pupils receive the idea of being taught using improvised apparatus?

Positive ☐

Neutral ☐

Negative ☐

8. For how long have you been improvising apparatus for teaching of Physics?

0 - 5 years ☐

6 - 10 years ☐

11 - 15 years ☐

16 years and above ☐

9. How do you use improvised apparatus when teaching Physics?

As a supplement to the conventional ones ☐

Improvised apparatus alone ☐

10. When you use improvised apparatus, how is the performance of your pupils during the lesson?

Very good ☐

Good ☐

Not good ☐

11. On which of the following Grade 11 topics do you improvise more?

Thermal Physics ☐

Wave Motion ☐

Sound ☐

Light ☐

Magnetism ☐

12. Do you involve your pupils in making improvised apparatus?

Always ☐

Sometimes ☐

Never ☐

13. Do you encounter any challenges when it comes to improvisation?

Yes ☐

No ☐

If you do, mention some of them.

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

14. Do you think the use of Improvised apparatus can add value to improve academic achievement of your learners?

Yes ☐

No ☐

15. In what ways do you think improvised apparatus can be improved?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

16. How do you find teaching of Physics using a mixture of conventional and improvised materials?

Boring ☐

Less interesting ☐

Interesting ☐

Very interesting ☐

17. Are the improvised apparatus safe for the teachers and learners use?

Very safe ☐

Safe ☐

Somehow risky ☐

18. If your answer to question 17, how do you improve the safety of these improvised apparatus?

Trying them before using them with pupils ☐

Using of demonstration only ☐

Thank you for your participation

APPENDIX C

FOCUS GROUP DISCUSSION GUIDE

Instructions

My names are **Sichone Aggrey**. I am currently studying for my Master of Education in Science Education, MEd.Sc.Ed, at the University of Zambia. Currently, I am conducting research in Science Education, which is one of the major requirements for my completion of the studies.

I am therefore, encouraging you to participate fully in this discussion. However, I have to mention that participation in this group discussion is purely voluntary. On the other hand, I must assure you that what we shall discuss here is purely for academic purposes only. Therefore, feel free to express your opinions or views. Please take note that during this discussion, there is no wrong answer at all.

I also have to mention that if, for any reason, you feel that you cannot continue with this discussion, you are free to leave. No questions will be asked as to why you would not want to continue with the discussion.

---

1. Do you understand what the term improvisation mean?
2. What Physics apparatus are lacking at this school?
3. Do you think improvised apparatus can help you, as a learner, to learn science effectively? Defend your answer.
4. How often do your teachers of Physics use improvised apparatus when teaching you?
5. What are the advantages and disadvantages of using improvised materials in learning Physics?

6. Whom do you think, should make the improvised apparatus that you use when learning Physics?
7. Do you have any problems regarding the use of these improvised apparatus?

APPENDIX D

PUPILS' RESEARCH QUESTIONNAIRE

PARTICIPANT ID:……………………………………

This questionnaire is meant for academic purposes only. The information that you will give will be treated with the highest level of confidentiality.

6.1 Meaning of an important term

INSTRUCTIONS

✧ Do not write your name anywhere on this questionnaire.

✧ Answer all questions by placing a tick where appropriate. You may be required to write short statements where necessary.

INFORMATION

- The word, "Improvise" means to make a substitute for something out of the materials that are available at that time so that the teaching of Physics proceeds without any difficulty. These improvised apparatus can be locally made by your teachers.
- Do not expose your answers to your friends.

1. Which Class do you belong to?

11 Violet ☐

11 Yellow ☐

11 White ☐

2. Are you a boarder or a day scholar?

Boarder ☐

Day Scholar ☐

3. Do you belong to the JETS Club or not?

Yes ☐

No ☐

4. If your answer is “Yes” to question 3, for how long have you been a member?

Less than 1 year ☐

1 to 2 Years ☐

2 to 4 years ☐

More than 4 years ☐

5. If you are a JETS member, what category are you interested in?

Projects ☐

Quizzes ☐

Olympiads ☐

6. How have you been acquiring materials needed for JETS activities?

Schools supply ☐

Buying my own ☐

Making my own ☐

7. For how long have you been at Mukamambo II Girls' Secondary School?

1 Year ☐

2 Years ☐

3 Years ☐

4 Years ☐

8. During Physics lessons, do your teachers teach using improvised apparatus?

Yes ☐

No ☐

9. If the answer to question 8 is yes, how often do they teach you with improvised apparatus?

Always ☐

Most often ☐

Rarely ☐

Never ☐

10. When teachers use improvised apparatus, do you how do you perform during the lessons?

Very good ☐

Good ☐

Poorly ☐

11. In case there were no apparatus in the laboratory to teach a certain topic, would you encourage your teacher to improvise?

Yes ☐

No ☐

12. Do you think the use of improvised apparatus can add value to your academic performance?

Yes ☐

No ☐

13. On which of the following Grade 11 topics did your teacher use more improvised apparatus?

Thermal Physics ☐

Wave Motion ☐

Sound ☐

Light ☐

Magnetism ☐

14. Would you like the improvisation of apparatus be extended to other science subjects?

Yes ☐

No ☐

15. Do you feel improvised apparatus should be continued to be used in the teaching of science at this school?

Yes ☐

No ☐

Not Certain ☐

16. In terms of teaching, what has been your experience of learning Physics with improvised apparatus as compared to other lessons?

Bad ☐

Good ☐

Very good ☐

17. How did you find the 4 weeks learning of Physics using a mixture of conventional and improvised materials?

Boring ☐

Less Interesting ☐

Interesting ☐

Very Interesting ☐

APPENDIX E

PRE-TEST

MUKAMAMBO II GIRLS' SECONDARY SCHOOL

GRADE 11 PHYSICS TEST

PRE-TEST

Name:…………………………………………………………… Duration: 1 hr 30 Min

INSTRUCTIONS:

- Answer **ALL** questions in this question paper.
- Write your answers on the spaces provided on this question paper.

---

1. A stone of mass 500 g fell freely from a 10 m tall building. Assuming that g=10 N/kg or (m/s^2)

(a) Calculate,

(i) the weight of the stone. [1]

(ii) the energy of the stone before it started falling. [2]

(iii) What kind of energy does the stone possess on impact with the ground?[1]

……………………………………………………………………………………

(iv) How much energy does the stone possess on impact with the ground? [1]

………………………………………………………………………………………

(v) With what speed does the stone hit the ground with? [2]

(b) State the **Law of Conservation** of energy. [2]

……………………………………………………………………………………

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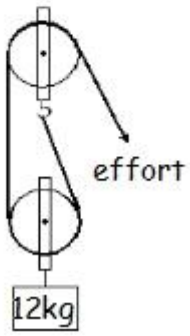
2. The diagram below shows a pulley being used to lift a 12 kg load.



Assuming that g=10 N/kg, or (m/s^2) calculate

(a) the weight being lifted [1]

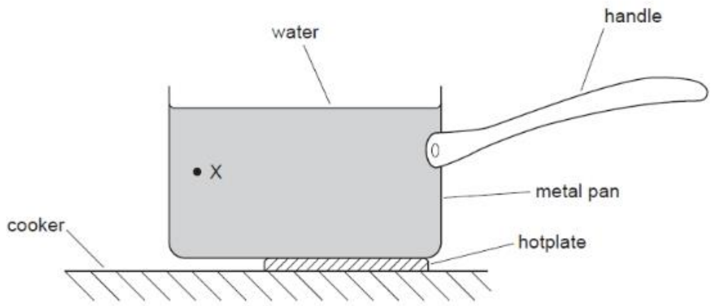
(b) the velocity ratio of the pulley? [1]

(c) the mechanical advantage if the efficiency of the system is 75%. [3]

(d) the size of the effort needed to lift the load? [2]

(e) how much work is done by the effort if the load is lifted 0.5 m? [2]

3. The figure below shows a metal pan containing water on a cooker. The hotplate heats the water.



(a) (i) State the method of heat transfer through the metal pan from the hot plate.

....[1]

(ii) Describe how the molecules transfer heat through the metal pan.

....

....

....[1]

(b) (i) On the figure above, draw an arrow to show the direction of movement of the water at point X. [1]

(ii) Explain why the water moves in this direction.

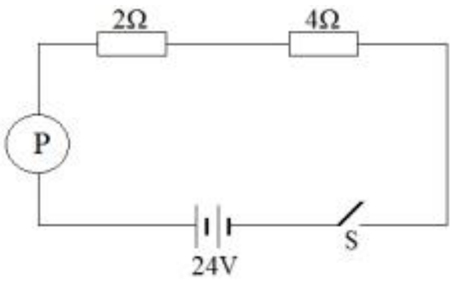
....

....

....

....[3]

4. The diagram below shows a circuit containing two resistors of 2 Ohms and 4 Ohms connected with an instrument P, a 24V power supply and a switch S.



From the diagram above,

(a) state if the two resistors are in parallel or series. [1]

…………………………………………………………………………………

(b) what does instrument P measure? [1]

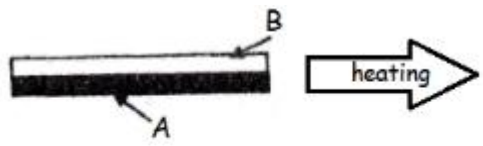
……………………………………………………………………………………

(c) calculate the total resistance in the circuit. [2]

(d) what is the reading on instrument P, when the switch S is closed. [2]

(e) at what rate is energy being transferred in the circuit? [1]

5. The diagram below shows a bimetallic strip made from two metals A and B, being used to make a thermostat.

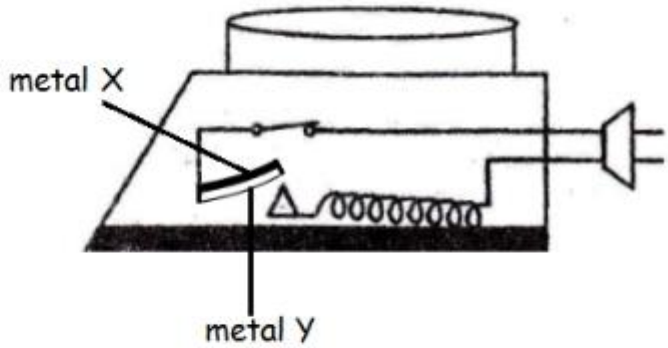


(a) Name the method of heat transfer through solids. [1]

………………………………………………………………………………………

Assuming that metal A expands more than metal B, draw another diagram, next to the diagram above, to show how it will appear after it has been heated. [2]

(b) The figure below shows the bimetallic strip being used in a thermostat of an electric pressing iron.



a) Which metal, X or Y, expands more than the other? [1]

………………………………………………………………………………………

b) With reference to the metals X and Y, explain how the thermostat works in the electric pressing iron shown above. [4]

……………………………………………………………………………………

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……………………………………………………………………………………

6. (a) Water waves are transverse waves. Sound is a longitudinal wave.

(i) Describe the difference between transverse waves and longitudinal waves. In your account, draw a diagram of each type of wave. [4]

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

(ii) Sound contains regions of **compressions** and **rarefactions**. Describe what is meant by a compression and by a rarefaction. [2]

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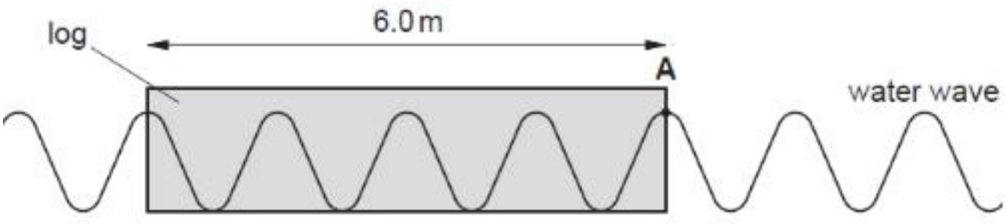
(b) The figure below shows a water wave passing a floating log. The log is stationary.



The log is 6.0 m long and 5 complete waves take 10 seconds to pass point A.

Determine

(i) the wavelength of the water waves, [1]

(ii) the frequency of the water waves, [2]

(iii) the speed of the water waves. [2]

END OF TEST

APPENDIX F

POST-TEST

MUKAMAMBO II GIRLS' SECONDARY SCHOOL

GRADE 11 PHYSICS TEST

POST-TEST

Name:………………………………………………………… Duration: 1 hr 30 Min

INSTRUCTIONS:

- Answer **ALL** questions in this question paper.
- Write your answers on the spaces provided on this question paper.

---

7. A stone of mass 500 g fell freely from a 10 m tall building. Assuming that g=10 N/kg or (m/s^2)

   (c) Calculate,

   (i) the weight of the stone. [1]

   (ii) the energy of the stone before it started falling. [2]

   (iii) What kind of energy does the stone possess on impact with the ground?[1]

…………………………………………………………………………………

(iv) How much energy does the stone possess on impact with the ground? [1]

…………………………………………………………………………………

(v) With what speed does the stone hit the ground with? [2]

(d) State the **Law of Conservation** of energy. [2]

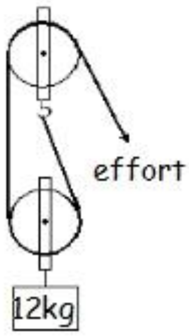
…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

8. The diagram below shows a pulley being used to lift a 12 kg load.



Assuming that g=10 N/kg, or (m/s^2) calculate

(f) the weight being lifted [1]

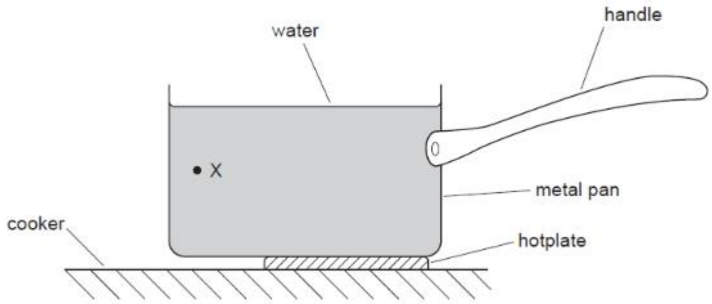
(g) the velocity ratio of the pulley? [1]

(h) the mechanical advantage if the efficiency of the system is 75%. [3]

(i) the size of the effort needed to lift the load? [2]

(j) how much work is done by the effort if the load is lifted 0.5 m? [2]

9. The figure below shows a metal pan containing water on a cooker. The hotplate heats the water.



(a) (i) State the method of heat transfer through the metal pan from the hot plate.

....[1]

(ii) Describe how the molecules transfer heat through the metal pan.

....

....

....[1]

(b) (i) On the figure above, draw an arrow to show the direction of movement of the water at point X. [1]

(ii) Explain why the water moves in this direction.

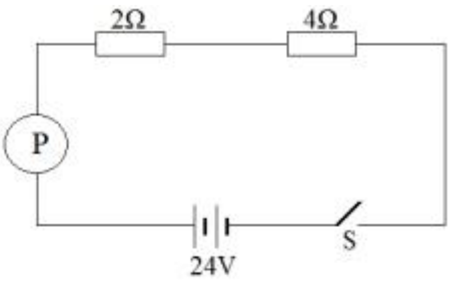
....

....

....

....[3]

10. The diagram below shows a circuit containing two resistors of 2 Ohms and 4 Ohms connected with an instrument P, a 24V power supply and a switch S.



From the diagram above,

(f) state if the two resistors are in parallel or series. [1]

…………………………………………………………………………………

(g) what does instrument P measure? [1]

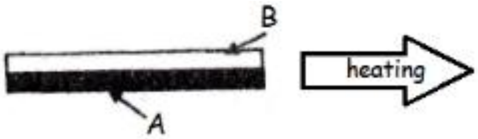
……………………………………………………………………………………

(h) calculate the total resistance in the circuit. [2]

(i) what is the reading on instrument P, when the switch S is closed. [2]

(j) at what rate is energy being transferred in the circuit? [1]

11. The diagram below shows a bimetallic strip made from two metals A and B, being used to make a thermostat.

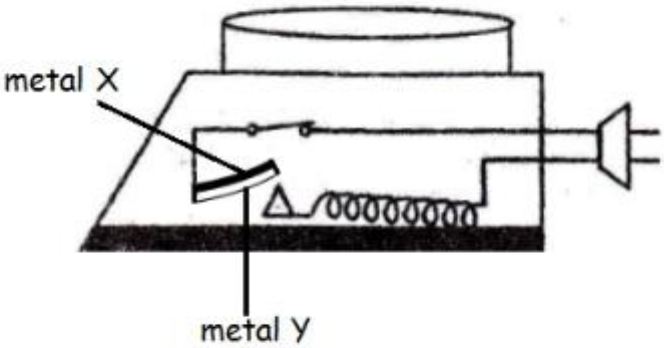


(c) Name the method of heat transfer through solids. [1]

…………………………………………………………………………………………

Assuming that metal A expands more than metal B, draw another diagram, next to the diagram above, to show how it will appear after it has been heated. [2]

(d) The figure below shows the bimetallic strip being used in a thermostat of an electric pressing iron.



c) Which metal, X or Y, expands more than the other? [1]

…………………………………………………………………………………………

d) With reference to the metals X and Y, explain how the thermostat works in the electric pressing iron shown above. [4]

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12. (a) Water waves are transverse waves. Sound is a longitudinal wave.

(i) Describe the difference between transverse waves and longitudinal waves. In your account, draw a diagram of each type of wave. [4]

………………………………………………………………………………………

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(ii) Sound contains regions of **compressions** and **rarefactions**. Describe what is meant by a compression and by a rarefaction. [2]

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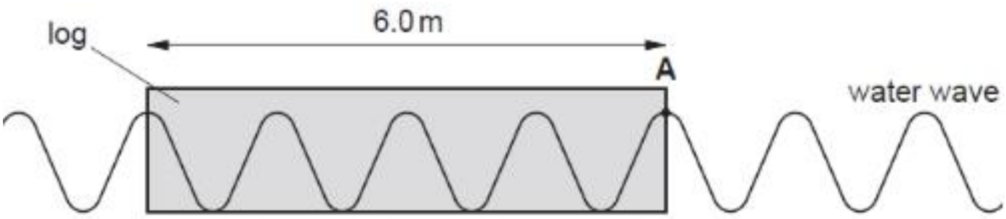
(b) The figure below shows a water wave passing a floating log. The log is stationary.



The log is 6.0 m long and 5 complete waves take 10 seconds to pass point A.

Determine

(i) the wavelength of the water waves, [1]

(ii) the frequency of the water waves, [2]

(iii) the speed of the water waves. [2]

END OF TEST

APPENDIX G

AVAILABLE APPARATUS IN THE LABORATORY

S/N	Apparatus	Quantity	Functional	Non-Functional
1	Vernier calipers	3	1	2
2	Micrometer screw gauges	3	0	3
3	Stop watches	50	45	5
4	Standard masses			
5	10 g	20	20	0
	20 g	20	20	0
	50 g	15	15	0
6	Electronic balances	40	20	20
7	Spring balances	30	28	2
8	Beam balances	2	0	2
9	Springs	20	12	8
10	Clamps and stands	50	45	5
11	Measuring cylinders			
	25 ml	50	50	0
	50 ml	60	60	0
	100 ml	50	50	0
	500 ml	3	3	0
	1000 ml	1	1	0
12	Metre rules	20	20	0
13	Ticker tape timers	0	0	0
14	Pulley wheels	0	0	0
15	Gears	0	0	0
16	Pumps	0	0	0
17	Microscopes	2	2	0

18	Chimneys	0	0	0
19	Thermometers	0		
	Laboratory thermometer	25	22	3
	Clinical thermometer	0	0	0
20	Bimetallic strips	0	0	0
21	Water baths	1	0	1
22	Thermos flasks	0	0	0
23	Wave springs	2	2	0
24	Tuning folks	0	0	0
25	Glass blocks	10	10	0
26	Convex lenses	25	25	0
27	Concave lenses	0	0	0
28	Prisms	0	0	0
29	Mirrors	10	10	0
30	Optical fibres	0	0	0
31	Magnets	7	5	2
32	Iron fillings (in grams)	1000	1000	0
33	Magnetic compasses	1	1	0
34	Electroscopes	2	2	0
35	Ammeters	23	15	8
36	Voltmeters	30	26	4
37	Galvanometers	10	8	2
38	Rheostats	0	0	0
39	Power packs	0	0	0
40	Car batteries	0	0	0
41	Plugs	0	0	0
42	Resistors	20	12	8
43	Electric bells	1	1	0
44	Thermionic tubes	0	0	0

45	Cathode Ray Oscilloscopes	0	0	0
46	GM Tubes	0	0	0
	Totals	**1611**	**1535**	**76**

APPENDIX H

RESULTS FROM PRE AND POST TESTS (EXPERIMENTAL GROUP)

S/N	Participant ID	Pre-test (%)	Post-test (%)	Change
1	A001	62	86	24
2	A002	42	72	30
3	A003	52	72	20
4	A004	44	64	20
5	A005	26	42	16
6	A006	38	54	16
7	A007	66	82	16
8	A008	60	84	24
9	A009	46	64	18
10	A010	48	66	18
11	A011	54	72	18
12	A012	8	28	20
13	A013	32	52	20
14	A014	38	58	20
15	A015	40	60	20
16	A016	36	56	20
17	A017	40	60	20
18	A018	42	62	20
19	A019	48	68	20
20	A020	44	64	20
21	A021	58	78	20
22	A022	54	74	20
23	A023	62	88	26
24	A024	52	72	20

25	A025	68	92	24
26	A026	22	44	22
27	A027	28	50	22
28	A028	36	58	22
29	A029	54	80	26
30	A030	52	74	22
31	A031	62	84	22
32	A032	46	70	24
33	A033	44	68	24
34	A034	42	66	24
35	A035	52	76	24
36	A036	58	82	24
37	A037	60	90	30
38	A038	62	86	24
39	A039	14	40	26
40	A040	42	68	26
41	A041	28	38	10
42	A042	22	50	28
43	A043	38	60	22
44	A044	42	70	28
45	A045	44	72	28
46	A046	44	72	28
47	A047	52	80	28
48	A048	16	50	34
49	A049	56	90	34
50	A050	50	78	28
		44.52	67.32	22.8

APPENDIX I

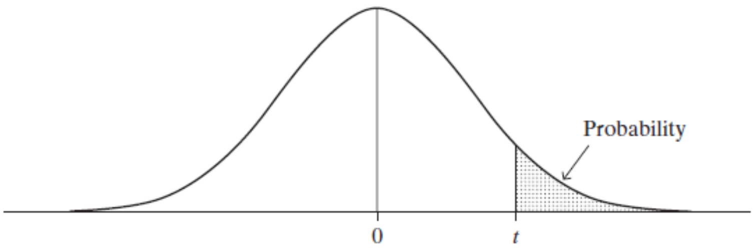
RESULTS FROM PRE AND POST TESTS (CONTROL GROUP)

S/N	Participant ID	Pre-test (%)	Post-test (%)	Change
1	B051	50	48	-2
2	B052	40	40	0
3	B053	30	32	2
4	B054	40	44	4
5	B055	40	44	4
6	B056	50	54	4
7	B057	50	54	4
8	B058	58	64	6
9	B059	56	62	6
10	B060	24	32	8
11	B061	28	36	8
12	B062	38	46	8
13	B063	50	58	8
14	B064	36	46	10
15	B065	46	56	10
16	B066	44	54	10
17	B067	50	60	10
18	B068	10	22	12
19	B069	42	54	12
20	B070	48	60	12
21	B071	46	58	12
22	B072	52	64	12
23	B073	8	22	14
24	B074	18	32	14
25	B075	34	48	14
26	B076	34	48	14

27	B077	44	58	14
28	B078	44	58	14
29	B079	44	58	14
30	B080	68	82	14
31	B081	32	48	16
32	B082	44	60	16
33	B083	52	68	16
34	B084	52	68	16
35	B085	56	72	16
36	B086	68	84	16
37	B087	2	20	18
38	B088	32	50	18
39	B089	50	62	12
40	B090	42	62	20
41	B091	54	74	20
42	B092	60	80	20
43	B093	60	80	20
44	B094	58	78	20
45	B095	62	82	20
46	B096	48	70	22
47	B097	52	74	22
48	B098	56	80	24
49	B099	2	28	26
50	B100	12	40	28
		42.32	55.48	13.16

APPENDIX J

T-DISTRIBUTION CRITICAL VALUES



	Confidence Level					
	80%	90%	95%	98%	99%	99.8%
	Right-Tail Probability					
df	$t_{.100}$	$t_{.050}$	$t_{.025}$	$t_{.010}$	$t_{.005}$	$t_{.001}$
1	3.078	6.314	12.706	31.821	63.656	318.289
2	1.886	2.920	4.303	6.965	9.925	22.328
3	1.638	2.353	3.182	4.541	5.841	10.214
4	1.533	2.132	2.776	3.747	4.604	7.173
5	1.476	2.015	2.571	3.365	4.032	5.894
6	1.440	1.943	2.447	3.143	3.707	5.208
7	1.415	1.895	2.365	2.998	3.499	4.785
8	1.397	1.860	2.306	2.896	3.355	4.501
9	1.383	1.833	2.262	2.821	3.250	4.297
10	1.372	1.812	2.228	2.764	3.169	4.144
11	1.363	1.796	2.201	2.718	3.106	4.025
12	1.356	1.782	2.179	2.681	3.055	3.930
13	1.350	1.771	2.160	2.650	3.012	3.852
14	1.345	1.761	2.145	2.624	2.977	3.787
15	1.341	1.753	2.131	2.602	2.947	3.733
16	1.337	1.746	2.120	2.583	2.921	3.686
17	1.333	1.740	2.110	2.567	2.898	3.646
18	1.330	1.734	2.101	2.552	2.878	3.611
19	1.328	1.729	2.093	2.539	2.861	3.579
20	1.325	1.725	2.086	2.528	2.845	3.552
21	1.323	1.721	2.080	2.518	2.831	3.527
22	1.321	1.717	2.074	2.508	2.819	3.505
23	1.319	1.714	2.069	2.500	2.807	3.485
24	1.318	1.711	2.064	2.492	2.797	3.467
25	1.316	1.708	2.060	2.485	2.787	3.450
26	1.315	1.706	2.056	2.479	2.779	3.435
27	1.314	1.703	2.052	2.473	2.771	3.421
28	1.313	1.701	2.048	2.467	2.763	3.408
29	1.311	1.699	2.045	2.462	2.756	3.396
30	1.310	1.697	2.042	2.457	2.750	3.385
40	1.303	1.684	2.021	2.423	2.704	3.307
50	1.299	1.676	2.009	2.403	2.678	3.261
60	1.296	1.671	2.000	2.390	2.660	3.232
80	1.292	1.664	1.990	2.374	2.639	3.195
100	1.290	1.660	1.984	2.364	2.626	3.174
∞	1.282	1.645	1.960	2.326	2.576	3.091

Source: "Table of Percentage Points of the *t*-Distribution." Computed by Maxine Merringtoı Biometrika, 32 (1941): 300. Reproduced by permission of the Biometrika trustees.