CHAPTER ONE

INTRODUCTION

1.0 Background of the study.

Throughout the study of physics mathematical related terms, facts, figures and concepts are used. Perhaps no other science is as close to mathematics as physics is (Sidhu, 2005). Mathematics is an essential tool for physics and many laws in physics are written in the form of mathematical equations, which may have to be manipulated (Duncan, 2007). Arithmetic, algebra and trigonometry are required to explain laws of physics and graphs are frequently used to represent results and relationships in physics (Sidhu, 2005). The laws of indices are frequently used in scientific notations.

Although the relationship between mathematics and physics is evident and interwoven, no studies of Zambian origin have focused on how mathematical concepts are understood and used by physics teachers in secondary schools. Yet, mathematical calculations occur at every step in physics and units of measurement are employed to quantities in physics as frequently as in mathematics (Manin, 2010).

1.1 Statement of the problem.

For many years now, Zambia has recorded an increase in failure rates in national examinations at secondary school level. The pass rate in physics is among the lowest (Ministry of Education [MoE]; 1996; 2011). MoE further states that, cumulatively one - third of boys and two - thirds of girls have failed mathematics and science since 1987, while only half of the boys and one-fifth of the girls have obtained the equivalent of an O-level pass in these subjects. This is not a good return for the many years of investment made by the nation and the students themselves in their education. Could this be associated with the way secondary school teachers of physics understand and use mathematical concepts in teaching physics? This situation indicates a gap in knowledge which calls for systematic investigating.

1.2 Purpose of the study.

The purpose of this study is to investigate how mathematical concepts are understood and used by teachers of physics in teaching physics at secondary school.

1.3 Objectives of the study.

The objectives of this study are:

(i) To determine how secondary school teachers of physics understand and use mathematical concepts in teaching physics.

(ii) To determine the feelings, opinions and impressions of the teachers with regard to the way mathematical concepts are understood and used by teachers of physics.

(iii) To determine the feelings, opinions and impressions of the learners with regard to the way mathematical concepts are understood and used by teachers of physics.

(iv) To establish whether or not the challenges faced by learners in secondary school physics are due to the way mathematical concepts are understood and used by teachers of physics.

1.4 Research questions.

The study will be guided by the following research questions:

(i) How do secondary school teachers of physics understand and use mathematical concepts in teaching physics?

(ii) What feelings, opinions and impressions do teachers have over the way teachers of physics understand and use mathematical concepts?

(iii) What feelings, opinions and impressions do learners have over the way teachers of physics understand and use mathematical concepts?

(iv) Are the challenges faced by learners of physics due to the way mathematical concepts are understood and used by teachers of physics?

1.5 Significance of the study.

The results of this research would be used by policy makers and curriculum developers in the Ministry of Education, Science, Vocational Training and Early Education (MoESVEE) to develop a curriculum that will explain how mathematical concepts could be understood and used in teaching physics.

The findings of this study would also influence text book writers, physics teachers and learners to develop effective methods of understanding and using mathematical concepts in physics. This is because the study has outline ways in which mathematical concepts would be understood and used in writing physics text books as well as teaching and learning physics. This would enable learners who avoid taking physics to develop interest for the subject (Burton, 1992).

Mathematics and physics educators and researchers could also use the findings of this study to conduct further related researches, because the findings will contribute to the existing mathematics and science literature base.

1.6 Definition of terms.

Basic units: Essential and necessary units based on the mksa (ie ; meter, kilogram, second and ampere).

Calculus: A branch of mathematics concerned with the study of such concepts as the rate of change of one variable quantity with respect to another.

Competencies: Ability to do something.

Curriculum: A decision about all what should be taught in a school.

Homogeneous: Having same kind of constituents.

Knowledge: Clear understanding and comprehension of explicit information, facts, truths and principles.

Ordinary level: An average education full form of pass obtained at General Certificate of Education (GCE). In Zambia an ordinary level is a grade of six (6) or better in a subject.

Parity: Equivalence.

Physics: A major science, dealing with the fundamental constituents of the universe. It is related to the laws of symmetry and conservation, such as those pertaining to energy, momentum, change and parity.

Physicist: A scientist who specialises in Physics.

Quantity: A measurable property of something.

Mathematician: An expert in mathematics or somebody whose job involves mathematics.

Mathematics A study of relationships among numbers, shapes and quantities using signs, symbols and proofs that include: Arithmetic, algebra, calculus, geometry and trigonometry.

Science: The study of the physical and natural world and phenomena especially by using systematic observations and experimentations.

Syllabus: Course out line or program of study and prospectors.

Understand: To interpret something in a particular way or infer or deduce a particular meaning from something.

1.7 Layout of dissertation

This dissertation consists of six chapters.

Chapter 1 consists of the background of the study, which outlines why this study emanated. It also has the statement of the problem which shows the Zambian problems which needed systematic investigation. This chapter also outlines the purpose of the study, objectives of the study and research questions which guided this research. The significance of the study is also stated here and some terms used in this study have been defined.

Chapter 2 reviews the literature related to this study. The chapter has four main sections which include: Relationship between physics and mathematics, mathematical concepts and competencies required in physics, solving physics problems and the role of mathematics in physics.

Chapter 3 identifies the methodology and research design used to conduct this research. It outlines the population, study sample, sampling procedures, procedure for data collection, research instruments used and their reliability. The chapter further explains, content validity, data analysis procedures, ethical considerations as well as limitations of the Study.

Chapter 4 presents the findings of the study, according to the objectives of the study. Tables of figures, frequencies and percentages are used in the presentation of quantitative data, while themes are used for qualitative data.

Chapter 5 is the discussion of the findings of this study. This chapter follows the research questions which ware posed in chapter 1.

Chapter 6 concludes the study and makes certain recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews the literature related to the study. The chapter has four main sections: (2.1) Relationship between physics and mathematics. (2.2) Mathematical concepts and competencies required in physics. (2.3) Solving physics problems and (2.4). The role of mathematics in physics.

2.1 Relationship between physics and mathematics

Perhaps no other science is as close to mathematics as physics is. If any standard physics text book is studied, it will be found that every rule or principle of physics ultimately takes a mathematical form. Mathematical calculations and concepts occur at every step in physics. The laws of the lever for example are based on the simple mathematical concepts of the balance of the sides of an equation. Interpretations of the laws of motion are all based on mathematical concepts. The law of gravitation, which explains the force exerted by the Earth on an object, can only be expressed using mathematical concepts (Sidhu, 2005; Berggren, 2012). Charles's law of expansion of gases is based upon mathematical calculations and the graduation of the stem of a thermometer and conversion of scales from Kelvin to Celsius and vise visa are all mathematical works. Tables of specific heat, latent heat and melting points have been prepared with the help of mathematical concepts (Sidhu, 2005). The development of optics, especially the study of the phenomena of reflection and refraction of light provides an interesting perspective on how mathematical concepts play a vital role in physics (Helfgott, 2009).

However, it is important to emphasize here that physics cannot be derived from mathematical concepts alone. In order to understand fully a physical process, physicists try to derive the processes from other more fundamental concepts. Kepler (1571- 1630) discovered the three laws of planetary orbit and constructed a model of the solar system which he used to predict the exact locations of the planets with precision. However, Kepler's model was explained by Newton (1687) who introduced the theory of gravity (Singer, 2012; Tzanakis, 2000). The first step in understanding a physical system is to find out how it works and then try to find out why it works that way. Newton's discovery of the three fundamental ways of how matter interacts helped him to derive his theory of gravity. Thus starting with Newton's three "laws" one can derive Kepler's model. The planets move the way they do because of gravity and gravity works the way it does because it follows the three basic rules or "laws" of forces. However, Newton could not have developed the theory of gravity without the calculus, a set of mathematical concepts he had developed for studying rates of change (Singer, 2012).

Nevertheless, starting from mathematical concepts alone, it is not possible to derive the existence of gravity or any Newton's laws. In the twentieth century mathematical theories from the fields of geometry were instrumental in constructing Einstein theory of general relativity as well as in the later development of superstring theory. All these theories have been predicated upon the prior development of mathematical concepts that had been invented for purely applied purposes (Berggren, 2012). Physics has seen a rebirth of the use of advanced mathematical concepts. In the 1980s physicists '10- dimensional superstring' theories received another mathematical boost from tools developed by Wilten (1951 -) and others (Singer, 2012). Mathematical and physics concepts should not be used independently from each other (Zeps, 2010).

2. 2 Mathematical concepts and competencies required in physics

Physics is probably one area of the sciences where many fields and concepts of mathematics have been directly applied. This is because nature seems to obey mathematical concepts. Natural laws can be expressed in terms of mathematics more clearly (Safkan, 2010). Many branches of mathematics are useful in a wide variety of physics application. When physics is first formally studied at senior secondary school, kinematics is first examined with algebra. This generally works may be because the curriculum sticks to simpler topics which algebra can handle (Landol, 2010).

Other areas of mathematics which find their application in senior secondary school physics are basic units and measurements, mathematical notations and indices, proportion and variation as well as equations. All these topics require the application of arithmetic or algebra. Trigonometry is also required when solving problems involving force vectors and when calculating the velocity ratio of an inclined plane. Furthermore, mathematical graphs have been identified as a useful way of finding relationships between two or more quantities (Duncan, 2006). Relationships of physical quantities are expressed as laws in physics. Some common laws are; Hooks' law, Charles' law, Newton's law and Ohm's law (Muunyu, 2005; Nelkon, 2008,). All these laws are expressed visually by means of graphs. In the current senior secondary school science programs mathematical tables are used to work out problems especially those involving refraction of light. Logarithms of natural numbers and logarithms of sins, cosines, and tangents are used. These requires that senior secondary school physics students should be equipped with the mathematical concepts and knowledge of handling mathematical tables or "log books"

The study of science (physics) through the current Zambian secondary school syllabus (MoE, 2000) strengthens the application of mathematical concepts and skills. It assumes that at the end of the secondary school course learners would be competent in the following mathematical techniques: They would be able to take account of accuracy in numerical works and handling calculations so that significant figures are neither lost unnecessary nor carried beyond what is justified. They would also be able to make approximations so as to evaluate numerical expressions. Pupils should be able to make calculations involving additions, subtractions, multiplications and divisions of quantities. They should also be able to calculate arithmetic of mean as well as transforming decimal notations to powers of ten or standard form. The current Zambian secondary school syllabus also strengthens competence in the ability for learners to change the subject of the formulae or an equation. These equations may involve simpler operations that may include positive and negative indices and square roots. It further stresses that; pupils should be able to express small changes or errors as percentages. This means they should be able to express fractions as percentages and vice versa (MoE, 2000).

Further, the current Zambian secondary school science (physics) syllabus strengthens calculation of areas of various shapes and the ability to deal with vectors in simple forms. It also strengthens the ability to plot results graphically after selecting appropriate variables and scales. Interpreting, analyzing and translating graphical information is also strengthened (MoE, 2000).

A scientific discipline concerned with the interface of mathematics and physics is called mathematical physics. It shows how mathematical concepts are used in solving problems in physics and the development of mathematical methods suitable for such concepts and for the formulation of physical theories. It helps the teachers and learners to understand mathematical concept related to physics (Zalsow, Eric, 2005). It is desirable that science teachers, at all levels in the educational system, acquire specific competencies during training at both pre- service and in- service for them to operate effectively and confidently (Muzumara, 2008).

2.3 Solving physics problems using mathematical concepts

Secondary school learners perform mathematical calculations and can use formulae but fail to connect formulae with reason. They are apt to use them in the wrong places or forget their precise form and not notice that the answers are clearly way out and often of the wrong dimensions (Mujtaba, Hoyles, etal. 2010). This could be because they have little knowledge of solving physics problems using mathematical concepts.

Most physics problems require that mathematical equations be formulated. To do this, knowledge of mathematical concepts is required because the equations need to be manipulated mathematically. When tackling physics problems using mathematical equations, it is advisable not to substitute numerical values until one has obtained an expression in symbols which gives the answer. Here it means, working in symbols until the problem is solved only then should the numbers and units be substituted in the expression to get the final result (Duncan, 2007). Adopting this symbolic procedure frequently requires one to begin with changing the subject of the equation. This means finding the value of a quantity which is not the subject of the formula. This is also called transposing the formula (Chawnon, 1988; Kanondo, 1992). To do this, think of the formula as an equation, and then solve the equation for the letter which is to become the subject. For example, in the formula $F = 9C/5 + 32$, to find C, one has to make C the subject. Multiplying throughout by 5 gives $5F = 9C + 160$. This can be written as $9C = 5F - 160$. Dividing both sides by 9 gives $C = 5F/9 - 160/9$. Not until one reaches this stage will the values of F be substituted to solve for C (Chawnon, 1988). Solving physics problems using this mathematical manipulatation of concepts has many advantages among the following: Firstly, it reduces the chances of arithmetical (and copying down) errors, and secondly, writing is lessened since a symbol is often a single letter whereas numerical values are usually strings of figures and mostly with units, which consumes time when writing (Duncan ,2007). In addition, when an equation is correctly transposed both numbers and units can be equated. Normally, if correctly done, they will be of the correct units and correct dimension.

The following question on density can be useful for one to understand these mathematical concepts and how they are manipulated.

The question is: What is the mass of air in a room measuring 6.0m x 5.0m x 2.0m if the density of air is 1.3Kgm^{-3}?

The equation for density is $\rho = m/V$, where ρ is the density of air, m is the mass and V is the volume of air. Changing the subject to m gives $m = \rho V$. (N.B: When handling such questions, the procedure for changing the subject should be explained. Assumptions should not be made that this concept was already handled in mathematics lessons). Here ρ = 1.3Kgm^{-3}, V =6.0m x 5.0m x 2.0m = 60m^3. So, substituting the values in the formula gives

$$m = 1.3 \text{ Kg m}^{-3} \times 60 \text{ m}^3$$

$$= (1.3 \times 60)(\text{Kg m}^{-3} \times \text{m}^3) = 78\text{kg}$$

It can be noted here that $m = \rho V$ stand for a number and a unit and both are substituted in the equation. The correct units obtained in the answer for m is Kg, since the symbols m^{-3} and m^3 cancel when the units are treated algebraically. This shows that the equation $m = \rho V$ is homogeneous and the correct one to use. Since the values of ρ and V are given to two significant figures, so too is the answer form (Duncan, 2007).

Dimensions can also be used to check an equation or formula for correctness or to suggest the form an equation may take. Every physical quantity can be expressed in terms of its basic dimensions of mass, length, time etc. Dimension of quantities should be placed in square brackets [ ]. For example [M] for mass [L] for length, [T] for time and [I] for electric current etc. Capital letters should be used inside the square brackets. This is to distinguish them from units of a quantity. Dimensions and units for derived quantities can be found from these basic dimensions. In deriving the dimensions for velocity, one has to understand that velocity = displacement (length) over time. Dimension for velocity are then [L/T] or $[LT^{-1}]$ (Wilkinson, 1996). Acceleration is defined as the rate of change of velocity with time (Muunyu, 2008), which can be expressed as change in velocity over change in time. The dimensions for acceleration therefore will be $[LT^{-1}/T]$ or $[LT^{-2}]$ or $[L/T^2]$.

Similarly, the dimensions for work (Force x distance) are [M L^2T^{-2}] since the dimension for force (mass x acceleration) are '[M x L T^{-2}] and that for length is [L] (Wilkinson, 1996).

By using dimension, one can show whether the equation is correct or wrong. One can check if the equation $v^2 = u^2 + 2as$ for correctness as follows: Let 'v' be the final velocity, 'u' the initial velocity, 'a' the acceleration and 's' be the displacement and 2 is a constant.

So, $[v^2] = [u^2] + [2as]$.

Here $[v^2] = [u^2] = [LT^{-1}]^2$, $[a] = [LT^{-2}]$, $[s] = [L]$

In the formula $v^2 = u^2 + 2as$, we have on the left side of the equation sign dimension of $[L^2T^{-2}]$ and on the right side the dimensions are $[L^2T^{-2}] + [LT^{-2}]$ x [L] which equals dimension $[L^2T^{-2}]$. This shows therefore that the equation is dimensionally correct. It should be noted here that numbers as prefixes in the formulae and have no dimensions (Wilkinson, 1996).

Further, an equation can be described as homogeneous if it gives the correct units of quantities involved on both sides. Calculation of density of a material can be from the correct equation $\rho = m/V$. The units for the various quantities involved are:

$\rho = g/cm^3$ or Kg/m^3, m = g or Kg and $V = cm^3$ or m^3.

Therefore, if the units of $\rho = g/cm^3$ or Kg/m^3 and the units for m /V = g/ cm^3 or Kg/ m^3, are the same units which occur on both sides of the equation, one can say the equation is homogeneous so far as units are concerned and is the correct one to use (Duncan, 2007). Correct equations normally lead to correct units. For example, if a correct formula for force is used to calculate force, then the correct units for force should be found. For instance if the correct formula for force is "F= ma" and the units for acceleration are m/s^2 and those for mass are Kg, can lead to Kg x m/s^2 = Kgm/s^2 which are the units of force (Muunyu, 2008). This shows that the formula for fore is correct. Checking that the units on both sides of the equation are the same (ie the equation is homogeneous) is a good way of guarding against using the wrong equation in calculation (Wilkinson, 1996). Knowing how to formulate equations and how to handle them is an invaluable tool in physics (Duncan, 2007).

In physics when forces are considered in two dimensions, the quantities should be resolved into horizontal and vertical directions to have a one- dimension situation. Many students initially approach the idea of adding vectors geometrically by moving them 'nose to tail' and yet they are liable to be confused by experiences that they have met in their earlier works in mathematics (Berggren, 2012).

Thus mathematical concepts are extremely important in terms of the development in fundamental physics because they are crucial to analysis in many fields of physics. Teachers of physics should indicate clearly to their learners how mathematical equations in physics should be used when handling physics problems.

2.4 The role of mathematics in physics

It took a long time in the history of humankind before it occurred to anyone that mathematical concepts were needed to understand physics. Physics is mathematical and the inter-disciplinary aspect of it is increasingly becoming pronounced as physicist work with mathematicians in order to understand and solve a wide range of problems confronting society (Boyo, 2008).

The mathematical structures of physics theories often point the way to further advance those theories and even to empirical predictions. This is not just a coincidence but it reflects larger and deeper truth about mathematics and physics. Various approximations that constitute current physics theories are successful because simple mathematical concepts provide a good approximation of aspects of more complex mathematical structures (Boyo, 2008). Mathematics is not only a "language" of physics or a tool for expressing, handling and developing logically physical concepts and theories but also determines to a larger extent the content and meaning of physical concepts and theories (Tzanaks, 2010). This is because to solve practical problems, one needs to translate the given problem into a mathematical language. This means writing an equation which needs to be solved (Kanondo, 1993).

Other roles of mathematics in physics are abbreviations, Concept mapping and thinking aids (Stanbrough, 2010). The role that mathematics plays as abbreviation is seen when algebra is used in solving physics problems. Algebra uses letters to represent numbers. Letters are imagined to stand for particular numbers. Most frequently in physics, letters stand for quantities. In most cases, internationally agreed upon symbols are used in physics instead of mere letters (Duncan, 2008). Equations which use letters to represent quantities are called formulae. The formula for volume given the mass 'm' and density 'ρ' is represented symbolically as $V = m/\rho$. Where V, m and ρ are internationally acceptable symbols for volume, mass and density respectively but ρ is not found in the English alphabet (Duncan, 2008). The role that mathematics plays as abbreviation is to get very concise statements that would take a lot of words in spoken language. For example Newton's second law of motion can be stated that "the magnitude of the acceleration of an object is directly proportional to the net force applied to the object and inversely proportional to the objects' mass. The direction of the acceleration is the same as the direction of the net force" (Stanbrough, 2010:1). What this mean is not important at the moment; what is important is that the statement can be expressed mathematically using a mathematical concept as;

"$a = F/m$," where 'F' is the net force applied 'm' is the mass and 'a' is the acceleration. (Nelkon, 2008: 46)

The point here is that to a physicist, both statements say exactly the same thing. The symbolism of mathematics can replace many words with just a few symbols (Sanbrungh, 2010).

The relationship between temperature in degrees Fahrenheit (F) and degrees centigrade(C) is given by the formula $F= 9C/5 + 32$ here 9, 5, and 32 are constants. In words this equation would take many words (Chawnon, 1992). Some other physics laws which take the form of mathematical expression as abbreviations are Hooks law, Charles law, Ohms law, gas law, density etc (Muunyu, 2008).

Many beginners of physicists get the notion that equations in physics are just something to "plug the numbers into and get the answer", which is one reason that numerical calculations are not emphasized in the physics course (Stanbrough, 2010). Physicists think differently, equations tell them how concepts are linked together. This is called concept mapping. For instance, in the equation $V = \Delta x /t$ arising from the study of kinematics, the symbol on the left side of the equation represents the concept "average velocity". Since there are two symbols (forgetting the division sign, and the Δx counts as one symbol) on the right side, to a physicist, the equation says (among other things) that the average velocity of an object depend on two (and only two) other concepts. And these are, the objects displacement (Δ x), and the time it has been moving (t). Thus equations tell scientists how concepts are related to one another and how concepts are mapped (Stanbrough, 2010).

Mathematical concepts aid thinking that is why they are used to solve problems one could possibly not work out without the help of mathematics. Mathematics makes it so much easier because all that is done is to follow the concepts and rules. As in a very simple example from kinematics, if you start with the equation $V = \Delta x /t$, which is often considered to be the definition of average velocity (in mathematical form). It is perfectly acceptable to multiply both sides of the equation by a variable, so one can multiplying both sides of the equation by 't' and get; $Vt = \Delta x\, t/t$, the rules of algebra say that $t/t = 1$ so, it must be true to say that $vt = \Delta x$ and the commutative property of algebra says that this is the same as $\Delta x = vt$. This is a new statement about nature (equivalent to the familiar "distance equals speed times time") derived using the concepts of mathematics (Stanbrugh, 2010). Thus using mathematical concepts, physicists can discover new relationships among physical quantities. Once an idea is expressed mathematically one can use the rules and concepts (axioms, theorems etc) of mathematics to change into other statements. If the original statement is correct, and follow the concepts faithfully, the final statement will also be correct. This is what one can do when solving a physics problem which involves mathematics. From a scientific point of view, however, if you start with one statement about nature, and end up with another statement about nature, what one is doing is thinking about nature (Stanbrough, 2011).

In addition, mathematical concepts have played a very important role in building up modern civilization by perfecting all sciences. Even though people have only a vague idea that all progress made by man is as a result of scientific progress, they are strongly in favor of scientific and industrial education. This emphasis is confined to sciences such as physics, chemistry, biology, medicine and engineering. Mathematics which is a science by any criterion, and which rightfully belongs to this group, has not been accepted and emphasized as a science. Mathematics is an efficient and necessary tool which is employed by all the sciences and without which all these sciences would not have made much progress (Sidhu, 2005). It has been said about mathematics that "it is a science of all sciences and art of all arts". Chords of musical instruments sound natural to us, because we unconsciously hear the overtone scale everywhere in nature. It is just another consequence of simple mathematics and physics. How musical patterns make up rhythm and melodies is of great interest to physicists and mathematicians. Mathematics is the pivot of all the sciences and art. It may be a back – stage performer, but a very powerful one (Sidhu, 2005).

Questions may arise. Which one comes first? Is it the egg or the chicken? Physics or mathematics? Physics is a fundamental study of nature. In other words, in physics we want to find out how things work. Mathematics on the other hand, is "abstract". But still this cannot be a complete story because many mathematical concepts are used to describe how physical objects interact and the nature of relationship among them (Schiffer and Bowden 1984). In physics one can use mathematical concepts as a tool to understand nature, but in mathematics, the pure notion of numbers and other structures do not need physics to exist or to be explained or even to be justified. Mathematical knowledge is in fact verbal knowledge. '3' means 2+1, and '4' means 3+1. Hence it follows that '4' is the same as 2 + 2. Thus mathematical knowledge ceases to be mysterious (Russel, 2010). The most surprising thing is that often some newly discovered abstract formulations in mathematics turns out, years later to describe physical phenomena which we had not known about earlier (Schiffer and Bowden, 1984). One reason why mathematics enjoys special steam (above all other sciences), is that its propositions are absolutely certain and indisputable. Though mathematical concepts are a human thought product which is independent of experience, it is so admirably appropriate to the objects of reality (Haselhurst, 2010).

Furthermore, mathematics has been cited to play the role of a slave in physics. It is a mere tool for physics. To a physicist, mathematics is a toolbox. Before handling a particular problem, you should have the necessary tools to do that. The tools here can be taken from the toolbox which is mathematics in the case of physics (Safkan, 2010). Here it means that Physics comes first and mathematics follows later to be used. Physics experimentations should be done first, observations made, results obtained and deductions made, that's when mathematical relationships can be derived and conclusions made (Schiffer and Bowden, 2010). Gundry made an observation among his first year students. In the context of a discussion with his students on the type of forces, they were asked to explain the cause of gravity. There answers typically referred to the atmosphere, the spine of the earth, or the earth's magnetic field. Yet, all of them recognize and were able to use the equation for Newton's laws of universal gravitation which clearly relates gravitational force to mass mathematically (Gundry, 2004). Conceptual understanding should be developed rather than mathematical competences only. Mathematical abilities for first years and secondary school students are generally weak. So it is advisable to avoid clouding physics with mathematical noise. At secondary school, students do not even use trigonometry when treating vectors, instead of traditional force vector problems, students apply Newton's laws to situations where the resultant force is in ether in the X or Y axis direction. However, the use of mathematics is delayed rather than omitted (Gundry, 2004).

Physics seem to be more than mathematics because explaining a concept is more than merely modeling the concept mathematically. The ability to manipulate equations to get the right answer does not prove understanding. Formulas in mathematics are just used but in physics they are theoretically and experimentally derived (Monk and Dilton, 1996). A distinctive feature of the scientific method is its demand that a model should make predictions to be tested against the real world. However mathematics is the "supreme judge" in the process of validation. Indeed, the degree to which mathematics is used in physics often is a measure of how far it has become a mature quantitative science (Helfgott, 2009).

2.5 Literature summary

The relationship between physics and mathematics which has closely been looked at in this literature review is a clear indication of the interdisciplinary nature of the two subjects. The new curriculum for the two disciplines should rapidly bring about a positive change in the traditional patterns of teaching and learning these subjects. The traditional patterns of teaching and learning of physics shows a gap in knowledge on how physics teachers use and understand mathematical concepts. This study will foster the interrelatedness of physics and mathematics in order to produce results which are beneficial to both disciplines. Students involved in modern programs should be well equipped to absorb the skills and concepts required of physicists, scientists, engineers and mathematicians of this technological age. This will make students of physics see the role of mathematical concepts as a tool for physics and students of mathematics will have opportunities to apply their mathematical concepts to the solution of science problems and application in physics.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.0 Introduction

This chapter explains how the study was conducted. The subsections in this chapter include the research design, population, study sample, sampling procedures, instrumentation, and procedures for data collection, data processing as well as data analysis. Ethical considerations and limitation of the study have also been considered.

3.1. Research design

This research was an action research as well as a descriptive one. In the action part of the research, randomization was used so as to achieve a high degree of scientific validity by controlling all variables. The participants were assumed to have identical main characteristics considered relevant for the research. A descriptive survey design was chosen as another method of collecting data due to the nature of the data and the purpose of this study. Typically, by surveys the researcher gathered data which identified and described standards against which existing conditions about the subject matter was compared. The survey design also included the cross - sectional survey which enabled the researcher to focus on relevant characteristics of the population for the study. The design had put into consideration factors like age group of the population, grade level, and educational background (Cohen and Manion, 1995*;* Mulendema , 2007).

3.2 Population

This study targeted secondary school learners in Grade 10, 11 and 12 in 2011. The population was chosen from five Lusaka district secondary schools identified only by letters A, B, C, D, and E. The target population was of male and female learners between 15 and 25 years of age where learners were regarded to be at a level at which they had secured an understanding of mathematics and physics due to their educational background. The study also targeted teachers of physics from the five selected secondary schools. The age of the teachers and experience however, were not limiting factors in this study as long as they taught physics at Grade 10, 11 and 12.

3.3 Study sample

A study sample of 250 (n = 250) learners in Grade 10,11 and 12 from five government run schools in Lusaka district were drawn from a population of about 6000 pupils from these schools. The sizes of the samples depended upon many factors, among them were; financial, time restrictions and homogeneity of the population (Nyanga, 2006). Further, the school samples were selected for the reasons like easy access, fairly low cost to be reached and reduction in time spent in conducting field work. The schools chosen were identified by letters A, B, C, D and E only. These schools where selected because they were accessible and the cost to reach them was low. It was assumed that these schools would suffice to represent Lusaka district and Zambia as a whole.

3.4. Sampling procedure

Fifty (50) pupils were selected randomly from each of the five chosen schools. For the purpose of this research, probability sampling was coupled with purposive sampling. The bias to purposive sampling was due to few numbers of physics teachers. So the physics teachers available at the school were included in the sample. A convenient or chunk sampling however was not used in this case as it did not represent the whole population. As the name suggests the convenient sampling uses a sample that is convenient to the researcher but not necessarily representative (Nyanga, 2006). Stratified and purposive sampling was used in order to validly generalize the findings for the sample to the defined population. It was imperative that the sample be representative of the population. Validity, both external and internal was achieved as it was hoped that probability sampling yielded unbiased samples.

In this study, the population was almost infinite as there were so many schools in Zambia and the world at large. For this reason a sample of five schools with a population of about 6000 pupils and 60 teachers was chosen. Even then, only 250 pupils and 20 teachers were used as samples.

3.5 Procedure for data collection.

The selection of the participants was done randomly from each class. The questionnaires were administered to the participants sampled in the class by the researcher. A few oral instructions were given other than those to emphasize that the sought information was not personally threatening. Therefore, honest responses were required, and the items were to be answered without consultation with pears. That meant the respondents were advised verbally to fill in the questionnaires independently and appropriately (Chilyabufu, 2009). The respondents were allowed as much time as adequate to complete the questionnaire. The questionnaires were given to them the day before, so that they had enough time to read and complete the questionnaires. Subsequently, the researcher collected, checked and counted the questionnaires.

After returning completed questionnaires to the researcher, participants were interviewed by the researcher using the ‘semi-structured focus group discussion questions. These were questions the researcher used as a follow up to the questionnaire. They were discussed individually with some participants. These ensured the reliability and validity of the questionnaire. Validity and reliability were further provided by the focus group discussions with teachers who participated. A qualitative focus group content analysis technique was used in this study. This had its emphasis on meaning rather than on questioning (Stewart and Shamdasan, 1988). This process involved studying the transcripts or notes taken carefully by the researcher, sorting the discussion into categories of thought and inquiry. They were organized around the research questions of the study. This analysis was included in the result section (Mulendema, 2007).

3.6 Research instruments

The instruments which were used in this study included questionnaires, interviews, examination analysis, analysis of documents and diaries as well as observations.

The researcher used a combination of these instruments in order to maximize the advantages and minimize the disadvantages of each instrument. However, ethical issues that would have been related to the use of these instruments were considered. Semi-structured focus group discussion questions were also used. The questionnaires were administered by the researcher himself and face - to - face interviews with the respondents were also conducted by him. Research assistants, mails and on - line methods were not incorporated.

The questionnaires had likert - type scale on the opinions of the use and understanding of mathematical concepts by physics teacher in learning and teaching physics at secondary school. The approach was adopted from Mulendema (2007). He used this approach when collecting data on the perception and attitudes of Zambian high school pupils towards mathematics. He modified the likert-type scale questionnaire in the 152 item-scale entitled questionnaire in the teaching of mathematics, which was developed by Ernest (1996).

The researcher's primary concern to choose the "likert - type" was to make sure that all the items were measured to the same level. A "likert - type" scale was linked to a number of statements to measure fillings, opinions or impressions of the learners and teachers. These questionnaires were categorized under scheduled structured interviews. The questionnaires were presented to each respondent in exactly the same way to minimize the role and influence of the interviewer to enable a more objective comparison of the results. These were self administered questionnaires, which were filled in by respondent themselves. It was done by distributing the questionnaires and collecting then after they were completed. The scores in this "likert-type" scale questionnaire were as follows: for favorable filling, opinion and impression, 5 for 'strongly agreed', 4 for 'agreed', 3 for 'uncertain', 2 for 'disagree' and 1 for 'strongly disagree [Mulendema, 2007; Strewing and Stead, 2007).

3.7 Reliability

The basic idea of reliability was summed up by the word consistency (Mulendema 2007). Reliability focused on the degree to which empirical indicators or measures of theoretical concepts were stable or consistent across attempts which measured those theoretical concept. Reliability of measures was concerned with the degree to which a particular measuring procedure had equivalent results over a number of repeated trials (Swartz C. E. 2009).

A pilot study was conducted to assess the reliability of the questionnaires. This pilot study was conducted at school A. The results for this pilot project were not included in the main study as they would alter the validity of the data. The aim of conducting a pilot study was to test the reliability of the questionnaires. In the test for reliability of the questionnaires, a "likert - type" test was conducted. According to Mulder (1996), "a "likert - type" test measured the internal consistency of the questionnaires". This pilot study only consisted of 25 learners rather than the required 50. This saved time and money. The results which were obtained were not included to the appendices of this research. In the result analysis of this pilot data collection, a score of one (1) indicated the statement which was favorably answered and a score of zero (0) indicated the statement which was unfavorably answered (Mulendema 2007: 33). The other part of questionnaire was assessed objectively. In order to further increase the reliability of the research, there were two focus group discussions conducted. One was for learners and another one for the teachers of physics. Which discussion was to be conducted first depend on which group was ready first?

3.8 Content validity

Validity was an important aspect to consider when research instruments were made. Some of the issues which content validity addressed were to ensure that appropriate contents were in the instruments. It looked at whether the instruments measured what were intended and whether the instruments contained accurate information. The reliability of measurements was not much useful unless the measure also had validity. Validity in this sense was taken to be the degree to which empirical measure of concepts was accurately presented to those elements which were reported in the literature. Validity for the questionnaires was also provided by the focus group discussions with both learners and physics teachers. Further validation was ensured by a pilot study which was conducted to assess the reliability of the questionnaire. A probability sample ensured that an error estimated was constructed which increased internal validity (Nyangah, 2006). The principal of validity required the researcher to be quiet genuine as much as possible so that the items were singly or collectively represented the concept it or they intended to. If they represent something other than ethnic acceptance, than they would for this specific research in question, then they would not be valid (Swartz, C. E. 2009; Mulendema, 2007).

3.9 Data analysis procedures

Before even starting compiling and coding the data, the researcher made sure that each question had been answered. The three controls on completeness, accuracy and uniformity were constituted as the main tasks of the editing process. Once the data had been gathered, the raw information contained in interviews and questionnaires were transformed so that they could go into tables of figures that had information value of those interested in the research findings. A code book (Swartz, C. E. 2009) was devised to explain "what each research question was, what values was associated with each question and what numerical values were to represent each question and each of the values assigned to it."

It was from this back ground that the collected data was statistically processed and analyzed. In fact data analysis was the statistical design and tests which was applied to the obtained data, to test the various hypotheses. The analysis of results was presented in form of tables.

3.10 Ethical Considerations

The researcher respected the participant's decision whether or not to get involved in the study. Since the researcher used interview schedules as one of the instruments for data collection, he took care of sensitive questions that would have conflicted the respondents' confidentiality, anonymity and non – traceability of the information they provided to the study were guaranteed in all data collecting procedures.

3.11 Limitation of the Study

This study was limited because only selected variables were considered to meet its objectives. Variables like learners and teachers anxiety levels, cultural effects to the study of physics and mathematics as well as economic factors which could have influenced the responses in some way or another were not considered. These variables would be considered in future studies by this or any other researcher.

CHAPTER FOUR
RESEARCH FINDINGS

4.0 Introduction

This chapter presents the findings of the study. The findings were presented according to the objectives of the study. Tables of figures, frequencies and percentages were used in the presentation of quantitative data, while themes were used for qualitative data.

4.1 Survey Participants

The survey participants included grade 10, 11 and 12 learners in 2010 and 2011 as well as teachers of physics.

4.2 Learners

Table 1 presents the learners survey participants from the five selected schools in Lusaka district. The schools have been identified by letters A, B, C and D.

Table 1: Learner's survey participants by gender.

Frequency (Number)				
School	**Female**	**Male**	**Total**	**Percentage (%)**
A	20	30	50	**20.0**
B	19	29	48	**19.2**
C	20	25	45	**18.0**
D	29	26	55	**22.0**
E	30	20	50	**20.0**
Total frequency	118	155	248	**99.2**
Percentage (%)	**47.58**	**62.50**	**99.2**	

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Table 2: Learner's survey participants by age group.

Age group	Female	Male	Frequency	Percentage (%)
Below 15	4	8	12	04.84
15 - 19	108	115	223	89.92
20 - 24	6	7	13	05.24
25 - 29	0	0	0	00.00
Total	**118**	**130**	**248**	**100**

Note: - The percentages were taken from actual observations.

Table 1 and 2 shows that the majority of the respondents were male learners who represented 62.50% and female represented only 47.58%. This was due to the reluctance of the female learners to take part in the study. However, this could not have changed significantly the learners' views. The age group from which most learners responded was 15 – 19 representing 89.92% as seen from Table 2. This could have been because the study sample was from grades 10 to 12 where most of the learners were within that age group.

4.3 Teachers of Physics

The numbers of teachers of physics who completed and returned the questionnaire were as indicated in Table 3.

Table 3: Survey participants by school categories and gender of teachers of physics.

Frequency (Number)				
School	**Female**	**Male**	**Total**	**Percentage (%)**
A	3	4	7	**28**
B	2	3	5	**20**
C	4	2	6	**24**
D	1	2	3	**12**
E	2	2	4	**16**
Total frequency	12	13	25	**100**
Percentage (%)	**48**	**52**	**100**	

4.4 The extent to which teachers of physics understood and used mathematical concepts in teaching physics.

In order to determine the extent to which teachers of physics understood and used mathematical concepts in teaching physics, the following aspects were considered: How often did teachers of physics used mathematical concepts in physics lessons? How far the teachers of physics did understood and used mathematical concepts? (Depth of the scope of mathematical concepts compared to the grade taught), how was the knowledge of the teachers of physics in the use and understanding of mathematical concepts and what methods did most teachers of physics often used when teaching mathematical concepts? The responses from the teachers were presented first followed by those from the learners. The themes whose result could only be obtained qualitatively were also analyzed. For example knowledge of teachers could only be obtained from the teachers themselves.

4.5 Frequency of the use of mathematical concepts by teachers of physics in physics lessons.

The frequency in this subsection meant the number of times the teachers of physics used mathematical concepts in teaching physics in physics lessons. The frequency was measured by taking into consideration the number of periods of physics lessons per week. In the Lusaka secondary schools the researcher visited, on average, the maximum number of periods in pure physics was 5 per week and 3 for physical sciences. Each level of frequency was determined by looking at the number of lessons per week in which mathematical concepts were used. The results were shown in Table 4.

Table 4: Frequency of the use of mathematical concepts by teachers of physics during physics lesson per week.

Frequency	**Level**	Frequency	Percentage (%)
In 5-3 lessons per week	Very often	0	0.0
In 3-2 lessons per week	Often	2	8.0
In 2-1 lesson every two weeks	Sometimes	23	92.0
Not used at all in any lesson	Not used	0	0.0
	Total	**25**	**100.0**

Table 4 shows that 23 (92%) of the respondents indicated that they sometimes used mathematical concepts in physics lessons almost fortnightly. The same table indicates that, 2 (8%) respondents used mathematical concepts twice or thrice a week in their physics lessons. It meant that the majority of the teachers (92%) used mathematical concepts in physics lessons in every two weeks. This frequency of the use of mathematical concepts in physics lessons by the majority of the teachers was not enough to have the desired skills in the use of mathematical concepts in physics to be imparted in the learners.

4.6 Knowledge in the use mathematical concepts by teachers of physics.

Below is the cross tabulation of relationship between the teachers level of knowledge in the use and understanding of mathematical concepts and the frequency of the use of the concepts in physics lessons.

Table 5: Knowledge of teachers of physics in the use of mathematical concepts and the frequency of the application of the concepts.

Parameter	Frequency of use of mathematical concepts				
Knowledge in use of mathematical concepts.	Levels	Not used	Sometime	Often	Total
	Adequate	0(0.0%)	4 (16%)	1 (4%)	5 (20.0%)
	Not adequate	2(8%)	17 (68%)	0(0.0%)	19 (76%)
	Not sure	0(0.0%)	1 (4%)	0(0.0%)	1 (4.0%)
	Total	2(8%)	22(88%)	1(0.0%)	25(100%)

Table 5 shows that of all the 5 (20%) respondents who said that their knowledge in the use of mathematical concepts was adequate, 4 (16%) used mathematical concepts in teaching physics sometimes. That is, once or twice every two weeks. The table also reviewed that 1 (4%) used the concepts often. This suggested that their frequency of the use of mathematical concepts might have been affected by other constraints which was beyond the scope of this study but might be discussed in future researches by this or other researchers. However, the relationship between the teachers' level of knowledge and the frequency of the use of mathematical concepts was clear. The majority of the respondents 17 (68.0%) of the 19 (76%) who said that their knowledge was inadequate, used mathematical concepts in one physics lesson every two weeks. The table also suggested that the respondents, who did not use mathematical concepts, had little knowledge of these concepts. This cross tabulation of the results showed that lack of adequate knowledge in the use of mathematical concepts in physics lessons affect the extent to which the concepts were used by teachers of physic.

4.7 Methods teachers of physics used in teaching mathematical concepts

To establish the methods teachers of physics used in physics lessons to teach mathematical concepts, lesson observations were conducted and implementation of the aspects of the lesson shown in Table 6 were used to find out the teaching approaches used by teachers and consequently determine the extent to which they used mathematical concepts in physics lessons.

Table 6: Ratings of the methods used by teachers of physics in the classroom.

Aspects of the lesson implementation	Rating (percentage)					
	Excellent	Very Good	Good	Satisfactory	Unsatisfactory	Absent
Were the methods used suitable to achieve the stated objectives?	4	8	40	36	12	00
How well did the teacher demonstrate knowledge of the subject?	0	4	12	60	24	00
Did the lesson help a pupils to learn mathematical concepts used?	0	0	08	12	28	52
How do you rate the pupils participation in the treatment of mathematical concepts used?	0	8	28	28	32	4
How did she/he guide pupils to check and verify their scientific ideals with mathematical concepts learned?	0	0	8	16	36	40
Identification of mathematical concepts on the topic taught?	0	0	8	60	20	12
Did the teachers questioning techniques lead the pupils to use and identify mathematical concepts used?	0	12	28	36	20	4
How was the general class response when mathematical concepts were introduced?	0	12	36	28	20	4
Score	5	4	3	2	1	0
Meaning	Excellent	Very good	good	Satis factory	Unsatis Factory	Absent

It was observed from Table 6 that, (36%) of teachers of physics used methods which were suitable to achieve the objectives in low cognitive domain which include knowledge and comprehension competencies only. They could not use methods that would bring about concept theories in new situations and solve problems using required skills and knowledge. They failed to recognize patterns, organize parts as well as hidden meanings. This was seen during the lesson observations schedule. This was further shown by 12% of the observed respondents who used methods which were just unsatisfactory to achieve the lesson objectives which needed the use of mathematical concepts. However, 40% and 8% showed good and very good approaches in the use of mathematical concepts and only 4% used methods which seemed too suited to the stated objectives. This suggested that some of the teachers of physics used appropriate approaches in teaching mathematical concept. Table 6 also suggested that the majority of teachers did not have adequate knowledge on the subject they were teaching. The subject knowledge of the majority was just adequate (60% was satisfactory and 24% unsatisfactory). Because of this, very few mathematical concepts were used during lesson implementations.

Table 6 further suggested that sixty percent (60%) of the respondents showed satisfactory in the identification of mathematical concepts in the topics they taught and 20% showed unsatisfactory well 12 % did not completely identify mathematical concepts. This could have been due to methods which the teachers used. Their questioning techniques did not lead the learners to identify mathematical concepts in physics as seen from 36 % who were satisfactory and 20% unsatisfactory with 4% absent. From the discussion on how they guided their learners to check and verify scientific ideas with mathematical concepts learned, 36% were unsatisfactory. The pupils' participation in the use of mathematical concepts in physics was very poor with 32% unsatisfactory and 4% completely absent. This can also be attributed to poor questing techniques which were not though provoking but only allowed lower cognitive level of thinking of acquiring mathematical concepts and skills which could help them in solving problems in physics.

After lesson observations process, the researcher also examined the work in pupils' exercise books. The written work in these books comprised notes which had simple exercises which used mathematical concepts. However, these exercises were of low cognitive nature because the questions where not framed in a way which would have provoked thinking. There were of knowledge level only. Further inspection of the books revealed some higher cognitive domain problems of mathematical concepts and expressions. This gave the researcher an impression that pupils did a lot of physics which required the use of mathematical concepts. However, in the depth of discussions with learners they disclosed that those mathematical concepts were produced from text books and given to them (learners) as part of notes but they did not know how to use them (mathematical concepts) adequately. This information suggested that teachers actually did not guide the learners on how to use mathematical concepts.

In general, most pupils revealed that most of the mathematical concepts in physics were difficult to understand and use. Their teachers did not explain these concepts in depth. The teacher's assumptions were that learns learned these concepts in mathematics lessons. So they thought that there was no need to teach them in depth during physics lessons. The extent to which they thought mathematical concepts was very low compared to the scope of the senior secondary physics course. Pupils were interested to learn mathematical concepts in physics as seen from 36% and 12% whose responses were good and very good when mathematical concepts were introduced in class. Only 4% responded negatively suggesting that the majority need to learn the concepts especially at introduction stage.

4.8 Feelings, opinions and impression of the learners and teachers on the understanding and use of mathematical concepts by teachers of physics.

To determine the feelings, opinions and impressions gained by learners and teachers on the understanding and use of mathematical concepts, the questionnaires for learners and teachers were used. The results were as interpreted in Table 7 and 8 for learners and teachers respectively.

Table 7: learners' feelings, impression and opinions on the understanding and use of mathematical concepts.

S/ N	Scoring	1	2	3	4	5
	Statement	Strongly agree N (%)	agree N(%)	Uncertain N (%)	disagree N (%)	Strongly disagree N (%)
1	My teacher understand and use mathematical concepts when teaching physics	22(8.87)	50(20.16)	14(5.65)	162(65.32)	0(0)
2	Physics is easy to understand without understanding mathematical concepts	3(1.21)	6 (2.32)	9(3.63)	205(82.66)	25(10.08)
3	Physics and mathematics are parallel in terms of how mathematical concepts are used and understood	0 (0)	0 (0)	6(2.42)	180(2.42)	62(25)
4	You cannot do well in physics if you have a weak background in mathematical concepts	52 (20.96)	170 (68.55)	11(4.33)	10(4.03)	6(2.13)
5	You can do well in physics if you do not understand mathematical concepts	17(6.85)	30 (12.10)	14(5.65)	150 (60.48)	37 (14.92)
6	Mathematical concepts should be understood and used in teaching and learning physics	210 (84.68)	20 (8.06)	8(3.32)	7 (2.82)	3 (1.21)
7	Most teachers make physics challenging because of the way they use mathematical concepts	5 (2.02)	131 (52.84)	20 (8.06)	15 (6.05)	77(31.05)
8	There are too many mathematical concepts to be learned in physics	3 (1.21)	151 (60.84)	76 (30.6)	12 (4.84)	6(2.42)
9	Teachers of physics should show mathematical concepts used to solve physics problems	175 (70.56)	55 (22.18)	18(7.26)	0 (0)	0 (0)
10	Mathematical concepts are tools for physics	205 (82.66)	43 (17.34)	0 (0)	0 (0)	0 (0)
11	I find physics challenging because of the way the teacher use mathematical concepts	37 (15.26)	194 (78.23)	1 (0.4)	12 (4.84)	4 (1.62)

Key:- to understand Table 7

N= Number or frequency of participants

(%) = Valid percentage

Table 7 showed that 162 (65.32%) of the learners disagreed that their teachers did not understand and use mathematical concepts when teaching physics. Although the majority were in disagreement with this statement, some 50 (20.16%) agreed that their teachers of physics understood and used mathematical concepts when teaching physics and these were supported by 22 (8.87%) who strongly agreed to that statement. This showed that although learners claimed that teachers of physics did not understand and use mathematical concepts, the teachers did not completely do way with the use of mathematical concepts. The learners were in disagreement with the statement which claimed physics was easy to understand without understanding how mathematical concepts were used. Only 6 (2.332%) and 3 (1.21%) out of 248 agreed and strongly agreed respectively. This showed that understanding how mathematical concepts were used in teaching physics was important as that could make one understand physics. Because of that aspect, most learners 205 (82.66%) had agreed that mathematical concepts were tools for physics and the majority 180 (72.53%) and 62 (25%) out of 248 were in disagreement with the claim that physics and mathematics were parallel subjects in terms of how the concepts were used in the two subjects.

Further, opinions by the learners showed that one could not do well in physics if he/she had a weak background in mathematical concepts. This was shown in statement 4 of Table 7 where 170 (68.55%) and 52 (20.96%) agreed and strongly agreed to the statement out of 248 and the rest shared scores of 3, 4, 5 as 11 (4.33%) 10 (4.03%) and 6 (2.13%) respectively. This statement was in line with the statement 5 which also suggested that one could do well in physics even if he/she could not understand mathematical concepts. Here the majority 150 (60.48%) were in disagreement with 37(14.92%) who strongly disagree. This meant that one had to have a strong background in the of mathematical concepts and could understand how mathematical concepts were used in physics for one to understand physics well.

To determine learners' opinions and impressions whether or not mathematical concepts could be used in teaching and learning physics, statement 6 of Table 7 was used and most of learners 210 (84.68%) strongly agreed to this statement, 20 (8.06%) agreed and only 8 (3.23%) were uncertain and 7 (7.82%) , 3 (1.21%) were in disagreement and strongly disagreement respectively. For learners to use mathematical concepts in the learning of physics, it was the responsibility of the teachers to show how mathematical concepts were used to solve physics problems. In statement 9 the majority 175 (70.56%) had strongly agreed with this statement showing that if mathematical concepts were to be used in teaching physics then teachers of physics could show how mathematical concepts should be used to solve physics problems.

4.9 Learners' feelings, opinions and impression on the challenges faced by learners in studying physics.

To establish the feelings, opinions and impressions by learners on the challenges faced by learners in studying physics, statement 7, 8, and 11 of Table 7 were used. The researcher wanted to establish if teachers made physics challenging because of the way they used mathematical concepts. Table 7 showed that 131 (52.84%) agreed to this statement showing that actually it is the way teachers of physics use mathematical concepts that make learners find physics challenging. But on the other hand it could be attributed to statement 8 where most learners 151 (60.86%) had claimed that there were too many mathematical concepts to be learned in physics which made their learning of physics challenging. They cited mathematical concepts like formulae, derivation, units, graph plotting and interpreting graphs and mathematical concepts applied in vectors. Statement 11 of Table 7 indicated that, the majority of the learners 194 (78.235) agreed that they found learning physics challenging because their teachers did not use mathematical concepts. This statement was in accordance with statement 8. In both statements the impressions established by the researcher was that to some extent teachers contributed to the challenges faced by learners in learning physics because of the way they used mathematical concepts.

4.10 Feelings, opinions and impression of teachers of physics on understanding and use of mathematical concepts

Table 8 was used to establish the Feelings, opinions and impression of teachers of physics on the understanding and use of mathematical concepts.

Table 8: Feelings, opinions and impression of teachers of physics on the understanding and use of mathematical concepts

	SCORING	**1**	**2**	**3**	**4**	**5**
S. No	Statement	Strongly Agreed	Agree	Uncertain	Disagree	Strongly Disagree
		N (%)	N (%)	N (%)	N (%)	N (%)
1.	There are a lot of mathematical concepts to be understood and used in physics	11 (44)	14 (56)	0 (0)	0 (0)	0 (0)
2.	Most teachers explain how mathematical concepts are understood and used in teaching physics to learners	2(8)	15(60)	8(32)	0(0)	0(0)
3.	You cannot teach physics if you have a weak understanding of mathematical concepts.	13(52)	8(32)	3(12)	1(40)	0(0)
4.	Mathematical concepts are a tool for physics teaching and learning	15(60)	6(24)	2 (08)	2(08)	0(0)
5.	Laws of physics can be explained clearly without understanding mathematical concepts	0(0)	1(04)	4(16)	8(32)	12(48)
6.	Most topics in physics require understanding and use of mathematical concepts	1(04)	16(64)	8(32)	0(0)	0(0)
7.	Topics in physics which require understanding and use of mathematical concepts should be taught at the same time when such concepts are taught in mathematics	12(48)	7(28)	3(12)	2(08)	1(04)
8.	Teachers of physics should also be trained in mathematics and also teach mathematics.	15(60)	8(32)	2(08)	0(0)	0(0)
9.	Mathematics and physics teachers should be holding CPDs. together regularly.	16(64	8(32)	1(04)	0(0)	0(0)
10	Challenges faced by learners in learning physics are due to the way teachers of physics understand and use mathematical concepts.	8(32)	14(56)	2(08)	1(04)	0(0)

Table 8 suggested that most of the teachers agreed with the statement which said 'there are a lot of mathematical concepts which needed to be understood and used when teaching physics. This was shown by 14(56%) out of the 25 respondents who agreed and 11(44%) who strongly agreed. Since there were no teachers who showed disagreement or strong disagreement to this statement, it showed that there were many mathematical concepts to be understood and used in teaching and learning physics. For these concepts to be used in physics teaching, teachers had an obligation to explain how mathematical concepts should have been used in teaching physics. The majority of the of the teachers [15 (60%)] agreed that they explained how mathematical concepts are used in physics and 2 (8%) strongly agreed. This synchronized with statement 1 of Table 7 where learners agreed that their teachers used mathematical concepts. Only 8 (32%) of the teachers however showed that they were uncertain. Table 8 further showed that one could not teach physics very well if he/she had a weak understanding of mathematical concepts. This was shown by 13 (52%) of the respondents who strongly agreed with statement 3 of Table 8 and 8 (32%) who agreed with the statement. Only 3 (12%) were uncertain and 1 disagreed strongly. These results therefore showed that since there were many mathematical concepts in physics, teachers could have explained these concepts and they could have possessed vast understanding of mathematical concepts in the way they were used in physics.

Table 8 also showed that mathematical concepts were a tool for physics learning and teaching. This was supported by 15 (60%) of the teachers who strongly agreed and 6 (24%) who agreed. The numbers of those who were uncertain and disagreed were 2 (08%) and 2 (08%) respectively. Most of these mathematical concepts are used in explaining physics laws. That's why 12 (48%) of the teachers had strongly disagreed with statement 5 which claimed that one could explain the laws of physics without the use of mathematical concepts. The teachers also showed in statement 6 that most topics in physics required understanding and use of mathematical concepts.

The researcher wanted to find out whether or not topics in physics which required the use of mathematical concepts could be taught at the time when those concepts are taught in mathematics? To do this he used statement 7 of Table 8.The majority of the respondents 12 (48%) strongly agreed with statement 7 which states that "topics in physics which require use of mathematical concepts should be taught at the same time when those concepts are taught in mathematics". Here only 1 (04%) strongly disagree with the statement and 2(08%) disagreed and 3 were uncertain. However, 7 (28%) disagreed with the statement. In Table 8 statements 8 also showed that teachers of physics should be trained in mathematics and also teach mathematics. This was revealed by 15 (60%) and 8 (32%) of the respondents who strongly agreed and agreed to statement 8 respectively. 2 (08%) were uncertain and none disagreed and strongly disagreed. When asked why this could be so, they said “if a teacher was trained in both physics and mathematics and was teaching both he/she could understand and identify how mathematical concepts could be used in physics”. This was why it was important for teachers of physics to be trained in mathematics and teach it too. If the formal training was not possible statement 9 of that same Table 8 had suggested that mathematics and physics teachers could be holding Continuous Professional Development (CPD) meetings together. This would have made teachers of the two subjects to understand the concepts of the two subjects and helped teachers of physics to use mathematical concepts accordingly.

In statement 10 of Table 8, the teachers’ impressions were that most of the challenges faced by learners in learning physics were also due to the way teachers of physics used mathematical concepts. Here 14 (56%) which was the majority of the teachers agreed to the view and 8 (32%) strongly agreed. however, apart from the use of mathematical concepts, there could be other factors at play which will be considered later in this or other studies.

4.11 Establishing if challenges faced by pupils in studying physics were due to the way mathematical concepts were understood and used by teachers of physics.

To establish theme in 4.11, findings from examination analysis, challenges faced by learners in learning physics according to the learners and challenges faced by learners in learning physics according to the teachers as well as responses from focus group discussion for teachers where used.

4.11.1 Findings from examination analysis.

To establish if learners found challenges in learning physics, the researchers took a cross examination of results analysis of 2010 presented at ZASE Conference of 2011. The conference suggested that on average 70% of the learners who sat for physics examination managed to get an “O” level (Grading system; 6 – 1 points sore in a subject) and 15% of the of those who sat for science managed an ‘O’ level pass. This showed that pupils faced a lot of challenges in studying physics. The researcher further took samples of marked scripts of grade 12 science (physics) end of year examination in 2011 and inspected the average mark. The average mark of the majority was 16 out of 65 the maximum mark in the science paper 2 (physics). This further reflected that learners had some challenges in studying physics. In attempt to find out if the challenges faced by the learners in physics were due to mathematical concepts, all the papers 50 (100%) showed that 60% of the failed questions were involving mathematical calculations, plotting or conversion data. Table 10 showed the analysis of the way mathematical concepts were treated by candidates who sat for the Joint Examination for the School Certificate and General Certificate of the Education (G C E) Ordinary level Science paper 2. 50 papers were sampled.

Table 9: Analysis of failed concepts due to lack of understanding and use of mathematical concepts

	TOPIC	FREQUENCY N (%)	MATHEMATICAL ASPECTS FAILED TO TREAT
1.	Motion	40(80)	- Interpreting information from the questions into mathematical concepts - Plotting of graph - Sketching a graph with correct points - labeling of axis of graph
2.	Moments	49(98)	- Equation of principle moment - Conversion of units - Algebraic calculations - Units to answers.
3.	Weight Work Energy and Power	45(90)	- Calculations of weight (mg) - Units - Mathematical equations - Conversion of units from Newton to Kg
4.	Gas pressure	48(96)	- General gas law equation - use of General gas law equation. - Substation of values - Units to the final answer.
5.	Waves	25(50)	- Substations - Units
6.	Light	35(70)	- Graphing to scale - Selecting axis
7.	Density	40(80)	- Calculations - Conversions - Substitutions - Units

Table 9 suggested that the mathematical concepts which learners failed to understand and use were almost the same in all the topics. They ranged from mathematical expression presentation, conversion of units, substitution of values in mathematical expression, algebraic calculations to interpreting mathematical information from questions and plotting of graphs. On graphs learners failed to choose correct scales, correct axis, plot points and draw correct graphs. This was seen in topic 1 on motion where 40 (80%) out of 50 (100%) of the candidates failed to plot the graph of motion completely. On moments, weight, work, energy and power and gas pressure, candidates failed in aspects concerning algebra and substitutions. They also failed to perform unit conversion and therefore failed to attach the answers with correct units. The reflection in Table 9 Suggested that 49 (98%) failed on the moments, 45 (90%) failed on work, energy and power while 48 (96%) failed on gas pressure. Considering waves only 25 (50%) failed. It could be that the calculations on this topic were in the lower cognitive domain. 40 (80%) out of 50 (100%) showed failure of these aspects on density. This further convinced the researcher that the learners faced many challenges in the study of physics and these challenges were due to mathematical aspects outlined here.

4.11.2 Findings from the learners.

To establish whether learners faced difficulties in studying physics due to lack of understanding and use of mathematical concepts, the researcher used Table 11. These were questions asked by the researcher to the learners.

Table 10: Learner's difficulties in studying physics.

QUESTION		**FREQUENCY RESPONSE**	
		Yes N (%)	No N (%)
1	Do you like learning Physics?	200 (80.64)	48 (19.35)
2	Do you find physics demanding?	150 (60.48)	98 (39.52)
3	Do you face any challenges in learning Physics?	195 (78.63)	53 (21.37)
4	Are the challenges you face due to the way mathematical concepts are used in physics?	129(52.02)	119 (47.98)

Table 10 suggested that 200 (80.64%) of the learners liked physics. When asked why, they said physics was very important for life and everyone needed to understand it, since everything we do is physics while others said it widened their chances of finding places in colleges and job prospects. However, 48 (19.35%) said they did not like physics. It is from those who did not like physics who said they just took it because it was compulsory and will not add any value to the careers they wanted to pursue in future. When asked further during focus group discussions, they said they find physics demanding and challenging because there were a lot of mathematical concepts to be understood and used. This could be seen from the big number of 150 (60.48%) out of the 248 (100%) respondents who said they find physics demanding and 195 (78.63%) who agreed that they faced challenges in learning physics. The researcher was wondering if these challenges were due to the way mathematical concepts were used. Table 10 showed that 129 (52.02%) agreed to the accession while 119 (47.98%) disagreed. Although it is evident that the challenges faced by learners in learning physics were due to the way mathematical concepts were used as seen from 129 (52.02%) of Table 10, others still felt that there could be other aspects which might lead to these challenges. These aspects however were attributed to overcrowded classes, lack of time to cover the syllabus, lack of adequate knowledge of the subjects by teachers and the teaching methods which was manly talk/lecturer methods as well as lack of materials for teaching physics like text books.

4.11.3 Responses from focused group discussion for teachers.

In establishing the views of the teachers on the challenges faced by learners in learning physics focused group discussion for the teachers were conducted. Below is a summary of the responses from the discussion.

The responses showed that the majority of the teachers had schools which performed badly in science (physics) some showed that the performance in science at their schools was very bad. This left the researcher to wonder if the performance was bad due to the way mathematical concepts were understood and used. Most of the teachers agreed with the researchers. However there were few who did not accept the researchers thought. These responses confirmed that the poor performance in science (physics) were to a larger extent due to the way mathematical concepts were used and understood by teachers of physics. It was further mentioned that learners regarded the use of mathematical concepts as challenging. In fact others regarded mathematical concepts as very challenging in studying physics. Very few teachers found the use of mathematical concepts easy. It can be established from here that the teachers had agreed that the learners regarded the use and understanding of mathematical concepts as very challenging. When asked on how learners reacted to the learning of mathematical concepts, they said most of them (learners) reacted negatively when learning mathematical concepts though few teachers said their learners reacted well.

From the overview of these findings on the challenges faced by learners in learning physics, it can be deduced that learners faced challenges in learning physics and most of these challenges were due to the way mathematical concepts were used in teaching and learning of physics by physics teachers.

4.12 Summary of the findings.

The following is a summary of the findings of the research study.

The majority of the teachers 23 (92%) showed that they used mathematical concepts fortnightly and 2(8%) used mathematical concepts in 2 to 3 lessons per week. This frequency was not enough to have the desired mathematical concepts and skills required by the learners. Table 6 showed that 17(68.0%) of the 19(76%) who said that their knowledge was inadequate used the concepts in one lesson every two weeks and 4(16%) out of 5(20%) whose knowledge in the understanding and use of mathematical concepts was adequate used the concepts as their counterparts with inadequate knowledge. These would have been affected by other factors but the majority revealed that the use of mathematical concepts in physics lessons is affected by knowledge one has and this affected the extent to which these concepts were used. From the results in Table 7, it can be deduced that teachers of physics (36%) used methods which were suitable to achieve objectives in low cognitive domain only and most of the teachers (60%) lacked adequate knowledge of the subject they were teaching as seen from 24% whose knowledge was unsatisfactory. Their questioning techniques did not lead the learners to identify mathematical concepts in physics and pupils could not verify their scientific ideas with mathematical concepts.

The pupils suggested that most of the mathematical concepts in physics were difficult to understand and teachers did not explain these concepts in depth. In Table 8 the majority 162 (65.32%) of the learners disagreed that their teachers did not use mathematical concepts when teaching physics. The learners had shown that 175 (70.56%) if mathematical concepts were to be used in teaching physics adequately then teachers of physics should show mathematical concepts in solving physics problems. In fact learners 194 (78.23%) have shown that they found learning physics challenging because of the way their teachers used mathematical concepts. The teachers also accepted [14 (56%) agreed and 8 (32%) strongly agreed] that most the challenges faced by learners in learning physics were due to the way they used mathematical concepts though they said there could be other factors at play. The researcher also established that 60% of the failed questions in final examinations were due to the way mathematical concepts were understood and used by learners themselves. Most of the learners failed to answer questions which involved mathematical concepts.

From these views it could be seen that challenges faced by learners in learning mathematical concepts ware attributed to the way mathematical concepts were understood and used by the teachers of physics.

CHAPTER FIVE
DISCUSSION OF THE FINDINGS

5.0 Introduction

The purpose of this chapter was to discuss the findings of the study, according to the research questions.

5.1 How did secondary school teachers of physics understood and used mathematical concepts in teaching physics?

5.1.1 Frequency of the use of mathematical concepts by teachers of physics in class?

Table 4 showed that 23 (92%) of the respondents indicated that they used mathematical concepts in physics lessons almost fortnightly with 2 (8%) of respondents saying they never used mathematical concepts in their physics lessons. It meant that the majority of the teachers used mathematical concepts in physics lessons once in every two weeks. This frequency of the use of mathematical concepts in physics lessons by the majority of the teachers was not enough to have the desired skills of the understanding and use of mathematical concepts in physics to be imparted in the learners.

5.1.2 Knowledge of the teachers in understanding and use of mathematical concept and the frequency of the use of the concept.

The study suggested that all the 5 (20%) of the teachers who said that their knowledge in the understanding of mathematical concepts was adequate, 4 (16%) used mathematical concepts in teaching physics sometimes. That is, once or twice every week. Only 1 (4%) oftenly used the concepts. This suggested that their frequency of the use of mathematical concepts was affected by other constraints which were beyond the scope of this study. However, the relationship between the teachers' level of knowledge and the frequency of the use of mathematical concepts was clear. The majority of the respondents (teachers) 17 (68.0%) of the 19 (76%) who said that their knowledge was inadequate, used the concepts in one physics lesson every two weeks. The study also suggested that the respondents who did not use mathematical concepts had little knowledge in these concepts. Cross examination of the results from Table 5 suggested that lack of adequate knowledge of mathematical concepts in physics lessons affected the extent to which the concepts were used by teachers of physic.

5.1.3 What methods did teachers of physics use in the teaching of mathematical concepts?

To answer this question, the study observed the following from Table 6: Most of the physics teachers (36%) used methods which were suitable to achieve the objectives in the lower cognitive domain only. Only 4% used methods which suited the stated objectives. This was further shown by 12% of the observed respondents who used methods which were unsatisfactory to achieve the lesson objectives which needed the use of mathematical concepts. However, 40% and 8% showed good approaches of the use of mathematical concepts respectively which were based on demonstrations and problem – solving as well learner centred. This showed that actually some of the teachers of physics used suitable approaches in the use of mathematical concept resulting in effective classroom practices which led to higher order understanding of the subject matter. Table 6 also showed that the majority of teachers did not have adequate knowledge in the subject they were teaching. The subject knowledge of the majority (60%) was just satisfactory with 24% unsatisfactory knowledge. Because of this, very few if any mathematical concepts were used during lesson implementation. It was also suggested that 60% of the respondents showed satisfactory in the identification of mathematical concepts in the topics they taught, 20% showed unsatisfactory and 12 % did not completely identify mathematical concepts. This could have been due to the methods which they teachers used. Their questioning techniques did not lead the learners to identify mathematical concepts in physics as seen from 36 % who were satisfactory and 20% unsatisfactory with 4% absent. In the quest to discussion how teachers guided the pupils to check and verify their scientific ideas with mathematical concepts learned, 36% were unsatisfactory and 28% good respectively. This showed that teachers of physics did not adequately guide their learners to check and verify their scientific ideas with mathematical concepts. The pupils' participation in the use of mathematical concepts in physics was very poor with 32% unsatisfactory and 4% completely absent. This could have been attributed to poor questing techniques which were not though provoking but only allowed lower cognitive domain thinking of acquiring mathematical concepts and skills which could help them in solving problems in physics.

In general, most learners suggested that much of the mathematical concepts in physics were difficult to understand and the teachers did not explain those concepts in depth. The teacher's assumptions were that the pupils learnt the concepts in mathematics lesson so they thought there was no need to teach them in depth when teaching science. The extent to which the teachers used mathematical concepts was very low compared to the scope of the senior secondary physics course. Pupils were interested to learn mathematical concepts in physics as it was seen from 36% and 12% who responded very well when mathematical concepts were introduced in class. Only 4% responded negatively showing that actually the majority needed to learn the concepts especially at introduction stage

5.2 What feelings, opinions and impressions did learners have over the way teachers of physics understood and used mathematical concepts?

5.2.1 General feelings, opinions and impressions

Table 7 of the findings suggested that the majority 162 (65.32) of the learners disagreed that their teachers did not use mathematical concepts very well when teaching physics. Although the majority were in disagreement with this statement, some 50 (20.16%) felt that their teachers of physics used mathematical concepts very well when teaching physics and these were supported by 22 (8.87%) who strongly agreed to this statement. This gave an opinion which suggested that "although learners claimed that teachers of physics did not use mathematical concepts very well (60.30%) the teachers did not completely do way with mathematical concepts". The learners disagreed with the statement which claimed that physics is easy to learn without understanding how mathematical concepts are used. Only 6(2.3%) and 3(1.21%) out of 248 agreed and strongly agreed respectively. This gave an opinion and impression that understanding how mathematical concepts are used in teaching physics is important as this could make one learn physics easily. Because of this aspect, most learners 205(82.66%) had suggested that mathematical concepts were tools for physics and the majority 180 (72.53%) and 62 (25%) out of 248 were in disagreement with the claim that physics and mathematical were parallel subjects in terms of how the concepts were used in these two subjects. Further opinions by the learners showed that one could not perform well in physics if he/she had a weak background in mathematical concepts.

This was shown again in statement 4 of Table 7 where 170 (68.55%) and 52 (20.96%) agreed and strongly agreed to the statement out of 248. Others shared scores 3, 4, 5 as 11 (4.33%), 10 (4.03%) and 6 (2.13%) respectively. This statement was in line with statement 5 of the same table which also claimed that one could do well in physics even if he/she could not understand mathematical concepts. Here, the majority 150 (60.48%) were in disagreement with 37 (14.92%) strongly disagreeing. This gave an impression that one has to have a strong background in the use of mathematical concepts and should understand how mathematical concepts are applied in physics for one to learn physics easily.

Most of the respondents 210 (84.68%) strongly agreed with statement 6 of Table 7 which stated that "mathematical concepts should be used in teaching and learning physics". The study also gave an impression that the use the mathematical concepts in the teaching of physics, is the responsibility of the teacher to show how mathematical concepts can be used in solving physics problems. In statement 9 of the same Table 7, the majority 175 (70.56%) have strongly agreed with this statement giving an opinion that if mathematical concepts were to be used in teaching physics then teachers of physics should show mathematical concepts to solving physics problems.

5.2.2 Feelings, opinions and impression on the challenges faced by learners in studying physics.

To discuss the feeling, opinions and impression by learners on the challenges faced by learners in studying physics, statement 7, 8, and 11of table 7 were used.

Table 7 showed that 131(52.84%) agreed to statement 7, which accused teachers to make physics challenging because of the way they used mathematical concepts in physics. This opinion gave an impression that it is actually the way teachers of physics used mathematical concepts that made the learners to find physics challenging. But on the other hand it could be attributed to statement 8 where most learners 151 (60.84%) have claimed that there were too many mathematical concepts to be learned in physics which made their learning of physics challenging. They cited mathematical concepts like formulae, derivation, units, graph plotting and interpreting graphs as well as mathematical concepts applied in vectors. In statement 11 the majority of the learners 194 (78.23%) agreed that they found learning physics challenging because their teachers did not use mathematical concepts very well. This statement was in accordance with statement 8 of Table 7. In both statements the impression established by the researcher was that to some extent teachers contribute to the challenges faced by learners in learning physics because of the way they used mathematical concepts.

5.3 What feelings, opinions and impressions do teachers have over the way teachers of physics understand and use mathematical concepts?

The study suggested from Table 8 that there were a lot of mathematical concepts which need to be understood and used when teaching physics. Most of the teachers 14 (56%) out of the 25 respondents agreed with the opinion and 11(44%) strongly agreed. Since there were no teachers who showed disagreement or strong disagreement to this statement, it showed that the impressions of the teachers were that, there were many mathematical concepts to be used and understood in physics. For these concepts to be understood and used in physics teaching, teachers had a feeling that they had an obligation to explain how mathematical concepts could be used in teaching physics. The majority 15 (60%) had agreed that they explained how mathematical concepts could be used with 2 (8%) strongly agreeing. This was synchronized with statement 1 of table 8 where learners agreed that their teachers used mathematical concepts. Only 8 (32%) of the teachers however gave an impression that they were uncertain. Table 8 further suggested that one could not teach physics if he/she had a weak understanding of the mathematical concepts. This was shown by 13 (52%) of the respondents who strongly agreed to statement 3 of Table 8 and the 8 (32%) who agreed to the statement. Here only 3(12%) were uncertain and 1 disagreed strongly. The results therefore gave an opinion that, since there many mathematical concepts in physics teachers should explain these concepts and they should possess vast understanding of mathematical concepts in the way they are use in physics.

Further discussions in Table 8 also suggested that mathematical concepts were a tool for physics learning and teaching. This had been supported by 15(60%) of the teachers who strongly agreed and 6 (24%) who agreed. The number of those who were uncertain and those who disagreed, 2 (08%), 2 (08%) respectively were too small to overshadow those who were in support. Most of these mathematical concepts were used in explaining physics laws. That's why 12 (48%) of the teachers had strongly disagreed with statement 5 which claim that one can explain the laws of physics without the use of mathematical concepts. The teachers also felt that, in statement 6 of Table 8 all topics in physics required the understanding and use of mathematical concepts. The same table also showed that 16 (64%) of the respondents who were the majority had agreed to the same statement.

Some other feelings, opinions, and impressions created by the teachers were that topics in physics which required use of mathematical concepts could be taught at the same time when such concepts are taught in mathematics. The majority of the respondents 12 (48%) strongly agreed with statement 7 of Table 8 which stated that "topics in physics which required use of mathematical concepts should be taught at the same time when those concepts are taught in mathematics". Here only 1 (04%) strongly disagree with the statement and 2(08) disagreed and 3 were uncertain. However, 7 (28%) disagreed with statement 7.Table 8 also suggested that teachers of physics could be trained in mathematics and also teach mathematics. This was suggested by 15 (60%) and 8 (32%) of the respondents who strongly agreed to statement 8 but 2 were uncertain. When asked why that was so, their opinions were that if a teacher is trained in both physics and mathematics and were teaching both he/she can understand and identify how mathematical concepts could be used in physics. Their feelings were that, it was important for teachers of physics to be trained in mathematics and teach it. If the formal training was not possible statement 9 from the same table has suggested that mathematics and physics teachers should hold Continuous Professional Development (CPD) together.

The general feelings and impressions were that teachers of physics should understand the concepts of mathematics which could help them teach physics well. As seen in statement 10 of Table 8 the teachers' impressions were that most of the challenges faced by learners in learning physics were also due to the way teachers of physics used mathematical concepts. Here 14(56%) who were the majority of the teachers agreed to the view and 8 (32%) strongly agreed. however, apart from the use of mathematical concepts, there could be other factors at play which will be considered later in this or other studies.

5.4 Are the challenges faced by learners of physics due to the way mathematical concepts are understood and used by teachers of physics?

5.4.1 Findings from examination analysis.

To establish if learners find challenges in learning physics, the researchers took a cross examination of results analysis of 2010 presented to Zambia Association for Science Educators (ZASE) Conference of 2011. The conference revealed that on average 70% (percent) of the learners who wrote physics managed to get an 'O' level and 15% (percent) of the learners who sat for science managed an 'O' level pass. This showed that pupils faced a lot of challenges in studying physics. The researcher further took samples of grade 12 end of year examination in 2011 and inspected the average mark. The average mark of the majority was 16 out of 65 of the maximum mark in the science paper 2 (physics). This further reflected that learners had challenges in studying physics.

The researcher wanted to find out if the challenges faced by the learners were due to the way mathematical concepts were understood and used by learners. He inspected marked scripts. All the papers 50 (100%) showed that 60% of the failed questions were involving mathematical calculations, or conversion of data or plotting. Table 9 revealed that the aspects which learners failed to handle were almost the same in all the topics. They ranged from mathematical expression presentation, conversion of units, substitution of values in mathematical expressions, algebraic calculations to interpreting mathematical information from questions and plotting of graphs. On graphs learners failed to choose correct scales, plot points and plot correct smooth curves or line. This was seen in topic 1 on motion where 40 (80%) out of 50 (100%) of the candidates who failed to plot the graph completely. On moments, weight, work, energy and power and gas pressure, candidates showed failure in aspects concerning algebra and substitutions. They also failed to perform unit conversions and therefore failed to attach the answers with correct units. The research also reviewed that 49 (98%) failed on the moments, 45 (90%) failed on work, energy and power while 48 (96%) failed on gas pressure. Considering waves, only 25 (50%) failed. It could be that the calculations on this topic were of lower cognitive domain. It was seen further that 40 (80%) out of 50 (100%) showed failure on aspects of density. This further convinced the researcher that the learners faced many challenges in the study of physics and these challenges were due to the aspects outlined.

5.4.2 Challenges faced by learners in learning physics according to the learners.

In further establishment of the fact that learners faced difficulties in studying physics, Table 10 was used

Table 10 suggested that 200 (80.64%) of the learners like physics. When asked why they liked physics? They said physics was very important for life and everyone needed to learn it. Others brought out answers like everything they did was physics and others said it widened their chances of finding places in a college and job prospects. However, 48 (19.35%) said they did not like physics. It was from those who did not like physics who said they just took it because it was compulsory and would not add any value to the careers they wanted to pursue in future. When asked further during focus group discussions, they said they found physics demanding and challenging because there were a lot of mathematical concepts to be understood and used. The researcher was wondering if these challenges were due to the way mathematical concepts were understood and used. Table 10 further showed that 129 (52.02%) agreed to the accession while 119(47.98%) disagreed.

Although it was evident that the challenges faced by learners in learning physics were due to the way mathematical concepts were used and understood as seen from 129 (52.02%), others still felt there could be other aspects which might have led to these challenges. These aspects however were attributed to overcrowded classes, lack of time to cover the syllabus, lack of adequate knowledge of the subjects by teachers and the teaching methods of teachers which was manly talk/lecturer as well as lack of materials like text books and teaching/ learning aids.

5.4.3 Challenges faced by learners in learning physics according to the teachers

In establishing the views of the teachers on the challenges faced by learners in learning physics, focused group discussion for the teachers were conducted. Below is a summary of the responses from the discussion.

The responses suggested that pupils performed badly in science (physics) at most of the schools where the majority of teachers came from. This left the researcher to wonder if the performance was bad owing the way mathematical concepts were understood and used. Most of the teachers agreed with the researcher. However there were few who did not accept the researcher's assumptions. However, the responses confirmed that the poor performance in science (physics) were to a larger extent due to the way mathematical concepts were used and understood by teachers of physics. It was further mentioned that learners regarded the use of mathematical concepts as challenging. In fact learners regarded mathematical concepts as very challenging in studying physics. Very few teachers found the use of mathematical concepts easy. It was established from there that the teachers had agreed that the learners regarded the use and understanding of mathematical concepts as very challenging. When asked on how learners reacted to the learning of mathematical concepts, they said most of them (learners) reacted negatively when learning mathematical concepts though few teachers said their learners reacted positively.

From the overview of these findings on the challenges faced by learners in learning physics, it can be deduced that learners faced challenges in learning physics and most of these challenges were due to the way mathematical concepts were used in teaching and learning of physics by physics teachers.

5.5 Summary of the discussion

The following is a brief summary of the discussion of the research study.

The majority of the teachers 23 (92%) showed that they understood and used mathematical concepts fortnight and 2 (8%) used mathematical concepts in 2 to 3 lessons per week. This frequency was not enough to have the desired mathematical concepts and skills imparted in the learners. Table 5 showed that 17 (68.0%) of the 19 (76%) who said that their knowledge was inadequate used the concepts in one lesson every two weeks and 4 (16%) out of 5 (20%) whose knowledge in mathematical concepts was adequate as their counterparts with inadequate knowledge. These would have been affected by other factors but the majority revealed that understanding and use of mathematical concepts in physics lessons was affected by knowledge one had and this affected the extent to which these concepts were used. From the results in Table 6 it could be deduced that teachers of physics (36%) used methods which were suitable to achieve objectives in low cognitive domain only and most of the teachers (60%) lacked adequate knowledge of the subjects they were teaching as seen from 24% whose knowledge was unsatisfactory.

The questioning techniques of the teachers did not enable learners identify mathematical concepts in physics and learners could not verify their scientific ideas with mathematical concepts. The learners revealed that most of the mathematical concepts in physics were difficult to understand and teachers did not explain those concepts in depth. In table 7 the majority 162 (65.32%) of the learners disagreed that their teachers did not use mathematical concepts very well when teaching physics. The learners had shown that 175 (70.56%) of mathematical concepts were to be used in teaching physics adequately then teachers of physics should show how mathematical concepts could be used to solve physics problems. In fact learners 194 (78.23%) had shown that they found learning physics challenging because of the way their teachers used mathematical concepts. The teachers also accepted 14 (56 % agreeing)and 8 (32% strongly agreeing) that most the challenges faced by learners in learning physics were due to the way teachers of physics understood and used mathematical concepts. However others still claimed that there could be other factors at play mentioned earlier. The researcher also established that 60% of the failed questions in final examinations were due to the way mathematical concepts were understood and used by learners themselves. Most of the learners failed to answer questions which involved mathematics. However, to pin point most of the challenges faced by learners in the use and understanding of mathematical concepts had been attributed to the way mathematical concepts were used by the teachers of physics.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.0 Conclusions

The conclusions of this study were done according to the objectives of the study.

6.1 How teachers of physics understood and used mathematical concepts in teaching physics.

The research suggested that the majority (92%) of the teachers of physics used mathematical concepts in one physics lesson every two weeks. Their inadequate knowledge in mathematical concepts prevented them from using these concepts. The frequency of the use of mathematical concepts was very less though teachers claimed to use them. The lesson observations revealed that the teachers of physics used methods which failed to reflect mathematical concepts as most of the lesson objectives were of low cognitive domain.

6.2 The feelings, opinions and impressions of the teachers and learners with regard to the way mathematical concepts were treated by teachers of physics.

The majority of the learners 162 (65.32%) felt that their teachers did not use mathematical concepts very well when teaching physics and 175 (70.56%) of the learner had an impression and a feeling that teachers of physics should show mathematical concepts to solving physics problem. Others felt that they found learning physics challenging because of the way their teachers used mathematical concept. The feelings and impressions of the teachers were the same as those for the learners because 14 (56%) agreed and 8 (32%) strongly agreed that most of the challenges faced by learners in learning physics were due to the way teachers of physics used mathematical concepts.

6.3 Establishing whether or not challenges faced by learners in physics were due to the way mathematical concepts were understood and used.

The research established that 60% of the failed questions in final examinations were due to the way mathematical concepts were understood and used by the learners in the examination. Most of the learners failed to answer questions which involved mathematical concepts. However challenges faced by the learners in learning physics were attributed to a large extent to the way mathematical concepts were used by teachers of physics. The majority of the teachers 10 (40%) agreed that the performance at their schools in science (physics) was bad and it was affected by the way teachers of physics understood and used mathematical concepts. The majority of the learners 129 (52.02%) had also accepted that the challenges they faced in learning physics were due to the way mathematical concepts were used by their teachers of physics. This showed that teachers of physics did not adequately guide their learners to check and verify their scientific ideas with mathematical concepts.

It was hoped that the findings of this study would help mathematics and physics educators to apply approaches that would instill into the learner's methods that would utilize mathematical concepts in learning physics. In that case therefore, the study could help Zambian secondary school learners develop flexible problem – solving skills and data analysis as well as an inquiry mind which would use mathematical concepts. Teaching methods of science should be as concrete as possible and be applied to things and events in real situations. The study would also improve national examination results at secondary school and other levels of education.

6.4 Recommendations

This study had a number of findings as indicated in the chapter on findings which are very important to take note of if appropriate measures are to be taken to improve the teaching and learning of physics. The study suggests the following recommendations:

1 Teachers of physics should use methodologies of teaching that promote the acquisition of the ability to use mathematical concepts. Apart from having physics knowledge, teachers must deepen their understanding of the subject and use of mathematical concepts in teaching physics and learn to think about academic content

from learners' point of view. They should present physics lessons in appropriate and engaging way which allows learners to learn how to use mathematical concepts.

2 In order to bring out or encourage teachers to use methods of teaching that fully involve learners in the learning process of the use of mathematical concepts, the MoESVTEE should develop a deliberate policy or programme that would bring about reforms in the teaching and learning of physics. This could be done by first choosing one or two provinces to start as a pilot project, by training physics teachers as in - services training (IN-SET) in use mathematical concepts in physics. Or this can be done by allowing teachers of physics and mathematics to hold CPD workshops together and then share their experiences with others in form of classroom CPDs or actual workshops for a period of about one year. The teachers could then be assessed and certificated or externally accredited and allow them to teach mathematics as well.

3 Science (physics) and mathematics educators at all levels and stakeholders like the government, donor agencies and other interested parties should draw up a curriculum that will emphasizes methodologies of teaching particularly in the use of mathematical concepts in science rather than on physics content only as the situation is now. Restructuring the curricula in colleges and universities can help relevant people to do this. Colleges and universities must teach pre-service teachers the methodologies that are in line with problem – solving approaches which lead to proper understanding and use of mathematical concepts in physics.

4 A free education television channel should be introduced in Zambia. On the channel, subjects like science (physics/ chemistry), mathematics and technology could be featured. This would allow viewers to ask questions on area they find challenges. This study has revealed that most of the learners found challenges in understanding and use of mathematical concepts so this could help them appreciate the subject. This could be done by seeking for help from banks, donors, non-government organizations (NGOs) and corporate companies, to mention but a few. Such a channel could help learners, country wide to develop abilities that could help them understand and use mathematical concepts.

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Appendix I

QUESTIONNAIRE FOR TEACHERS.

This questionnaire is designed for teachers of physics who were teaching grades 10, 11 and 12. The questionnaire saves as a tool for conducting a study on the topic: **A study of the understanding and use of mathematical concepts by secondary school teachers of physics: The case of selected schools in Lusaka.**

Your opinion will help the researcher to come up with the rightful information on the understanding and use mathematical concepts in teaching physics at secondary school to make teaching and learning of physics more effective.

The questionnaire is anonymous, and your answers to it will be kept strictly confidential. The result of this research will be used for research purposes only. I therefore request you to answer the questions as accurately as possible, by giving true answers without consultations from your colleagues.

Thank you very much for your cooperation in this matter.

N.B. DO NOT WRITE YOUR NAME ANYWHERE ON THIS QUESTIONNAIRE.

For further information or clarifications you can contact the researcher on the address below.

Kabwita James

Libala High School

P.O. Box 50018

Lusaka.

CELL; 0977542487/ 0969274084

INSTRUCTIONS

This questionnaire is in two parts. The first part is about your background information. The second part is about your feelings, impressions and opinions on the understanding and use of mathematical concepts by teachers of physics in teaching physics. For the first part (PART 1) tick ✓ the box that is appropriate to your response or fill in the boxes or blanks with appropriate words as instructed by each question.

For the second (PART 2) consider each item carefully and for each item tick in box ✓ of the comment that best represents your feelings impressions and opinions.

PART I: BACKGROUND INFORMATION.

1.1. What is your gender? (Tick)

NO	GENDER	TICK
1	Female	
2	Male	

1.2. At which school are you? (Names of schools have been identified by letters A, B, C, D and E. Actual names are reviewed to respondents)

NO	SCHOOL	TICK
1	A	
2	B	
3	C	
4	D	
5	E	

1.3 What is the frequency of the use of mathematical concepts in your class during physics lessons?

Level	Frequency	Percentage (%)
Very often		
Often		
Sometimes		
Not used at all		
Total		

Key to understand the frequency of the use of mathematical concepts by teachers of physics

Frequency	**Level**
In 5-3 lessons per week	Very often
In 2-2 lessons per week	Often
In 1-0 lesson server two weeks	Sometimes
Not used at all in any lesson	Not used

1.4 Knowledge of teachers of physics in the treatment of mathematical concepts against the frequency of the treatment of the use of the concepts.

Parameter	**Frequency of treatment of mathematical concepts**				
Knowledge in understanding and use of mathematical concepts.	Levels	Not used	Sometime	Often	Very Total
	Adequate				
	Not adequate				
	Not sure				
	Total				

PART 2

What are your feelings, opinions and impression on the understanding and use of mathematical concepts by teachers of physics?

	SCORING	**1**	**2**	**3**	**4**	**5**
S. No	Statement	Strongly Agreed	Agree	Uncertain	Disagree	Strongly Disagree
1.	There are a lot of mathematical concepts to be understood and used in physics					
2.	Most teachers explain how mathematical concepts are understood and used in teaching physics to learners					
3.	You cannot teach physics if you have a weak understanding of mathematical concepts.					
4.	Mathematical concepts are a tool for physics teaching and learning					
5.	Laws of physics can be explained clearly without understanding mathematical concepts					
6.	Most topics in physics require understanding and use of mathematical concepts					
7.	Topics in physics which require understanding and use of mathematical concepts should be taught at the same time when such concepts are taught in mathematics					
8.	Teachers of physics should also be trained in mathematics and also teach mathematics.					
9.	Mathematics and physics teachers should be holding CPDs. together regularly.					
10	Challenges faced by learners in learning physics are due to the way teachers of physics understand and use mathematical concepts.					

Key: - To understand table 4.8
N = number of frequency of participants
% = Valid percentage

Thank you very much for your cooperation in this matter.

Appendix II

QUESTIONNAIRE FOR LEARNERS

This questionnaire is designed for learners in Grade 10, 11, and 12. The questionnaire saves as a tool for conducting a study on the topic: **A study of the understanding and use of mathematical concepts by secondary school teachers of physics: The case of selected schools in Lusaka.**

Your opinion will help the researcher to come up with the right information about the understanding and use of mathematical concepts in teaching and learning physics at secondary school more effective. The questionnaire is anonymous and your answers will be kept strictly confidential. The results of the research will be used for research purposes only. I request you to answer the questions as accurately as possible by giving true answers without consultating your peers.

NB: DO NOT WRITE YOUR NAME ANYWHERE ON THIS QUESTIONNAIRE.

For further information or clarifications you can contact the researcher at the address below.

KABWITA JAMES

LIBALA HIGH SCHOOL

P.O. BOX 50018

LUSAKA.

CELL: 0977-542487 OR 0969-274084

INSTRUCTIONS

This questionnaire is in two parts. The first part is about your background information. The second part is about your feelings , impressions and opinions on the understanding and use of mathematical concepts by teachers of physics in teaching physics.

1. For the first part (PART I) put a tick in the box ✓ that is appropriate to your response or fill in the boxes or blanks with appropriate words as instructed by each question.

2. For the second (PART II) consider each item carefully and for each item tick in box ✓ of the comment that best represents your feelings impressions and opinions.

PART I: BACKGROUND INFORMATION

1.1 What is your gender? (Tick)

NO	GENDER	TICK
1	Female	
2	Male	

1.2 To which age group do you belong?

NO	AGE GROUP	TICK
1	Below 15	
2	15 – 19	
3	20 – 24	
4	25 – 29	

1.3 At which school are you? (Names of schools have been identified by letters A, B, C, D and E. Actual names are reviewed to respondents)

NO	SCHOOL	TICK
1	A	
2	B	
3	C	
4	D	
5	E	

1.4 Do you like learning physics?

Yes ( ) No ( )

a. If the answer is yes or no, give a brief explanation for the reason of liking or not liking physics

(i) Brief reasons for liking the physics

NO	REASON	TICK
1	I like mathematical concepts it	
2	I like calculations	
3	I like understanding mathematical concepts	
4	I like challenging subjects in it	
5	I like simple subjects.	
6	Others (Specify)	

(ii) Brief reasons for disliking the physics.

NO	REASON	TICK
1	I like mathematical concepts	
2	I do not like calculations	
3	I like understanding mathematical concepts in it	
4	I do not like challenging subjects	
5	I do not like simple subjects	
6	Others (Specify)	

1.6 Do you face any challenges in learning physics? (Tick)

Yes ( ) No ( )

1.7 If the answer is yes or no in 1.6, give a brief reason why you find it challenging?

(i) Brief explanation for finding the physics challenging.

NO	REASON	TICK
1	Because of mathematical concepts in it	
2	I do not like calculations	
3	Because of not having mathematical concepts	
4	I do not like challenging subjects	
5	I do not like simple subjects	
6	Others (Specify)	

(ii) Brief explanation for the physics not challenging.

NO	REASON	TICK
1	Because of mathematical concepts	
2	I like calculations	
3	Because of not having mathematical concepts	
4	I like challenging subjects	
5	I like simple subjects.	
6	Others (Specify)	

1.8 Do you find learning physics demanding?

Yes ( ) No ( )

1.9 Give a brief reason for finding the physics demanding or not demanding.

NO	REASON	TICK
1	Because of mathematical concepts in it	
2	I do not like calculations	
3	Because of not having mathematical concepts	
4	I do not like challenging subjects	
5	I do not like simple subjects	
6	Others	

1.10 If you face any challenges in learning physics are they due to the way mathematical concepts are used? (Tick)

Yes (   )   No (   )

(ii) Why?

6	Others	
NO	REASON	TICK
1	Because of mathematical concepts	
2	I like calculations	
3	I like reading Because of not having mathematical concepts	
4	I like challenging subjects	
5	I like simple subjects.	
6	Others	

1.1.1 Which of the following aspects affect you in learning physics?

	TOPIC	FREQUENCY N (%)	MATHEMATICAL ASPECTS FAILED TO UNDERSTAND AND USE
1	Motion		- Interpreting information from the questions - Plotting of graph - Sketching a graph with correct points - Tabling of axis of graph
2	Moments		- Equation of principle moment - Conversion of units - Algebraic calculations - Units of answer.
3	Weight Work Energy and Power		- Calculations of weights (mg) - Units - Mathematical equations - Conversion of units
4	Gas Pressure		- General gas law equation - Treatment of the equation - Substation of values - Units of the final answer.
5	Waves		- Substations - Units
6	Light		- Graphing to scale - Selecting axis
7	Density		- Calculations - Conversions - Units

PART II : Your feelings, impressions and opinion

Put a tick ✓ in the box that is appropriate according to your feelings, impression and opinion in the column of comments. For example if your answer is 'strongly agree'tick underneath 'strongly agree. ✓

Learners' feelings, impression and opinions on the treatment of mathematical concepts

S/ N	Scoring	1	2	3	4	5
	Statement	Strongly agree	agree	Uncertain	disagree	Strongly disagree
1	My teacher understand and use mathematical concepts when teaching physics					
2	Physics is easy to understand without understanding mathematical concepts					
3	Physics and mathematics are parallel in terms of how mathematical concepts are used and understood					
4	You cannot do well in physics if you have a weak background in mathematical concepts					
5	You can do well in physics if you do not understand mathematical concepts					
6	Mathematical concepts should be understood and used in teaching and learning physics					
7	Most teachers make physics challenging because of the way they use mathematical concepts					
8	There are too many mathematical concepts to be learned in physics					
9	Teachers of physics should show mathematical concepts used to solve physics problems					
10	Mathematical concepts are tools for physics					
11	I find physics challenging because of the way the teacher use mathematical concepts					

Thank you very much for your cooperation in this mater.

Appendix III

LESSON OBSERVATION SCHEDULE.

Aspects of the lesson implementation	rating (percentage)					
	Excellent	Very Good	Good	Satisfactory	Unsatisfactory	Absent
Were the methods used suitable to achieve the stated objectives ?						
How well did the teacher demonstrate the knowledge of the subject?						
Did the lesson enable pupils to learn mathematical concepts used?						
How do you rate the pupils participation in the use of mathematical concepts used?						
How did she/he guide pupils to check and verify their scientific knowledge with mathematical concepts learned?						
Identification of mathematical concepts on the topic taught.						
Did the teacher's questioning techniques lead the pupils to use and identify mathematical concepts used?						
How was the general class response when mathematical concepts were introduced?						

Key to understand the rating.

Score	5	4	3	2	1	0
Meaning	Excellent	Very good	good	Satisfactory	Unsatisfactory	Absent

Thank you very much for cooperation in this mater.