CHAPTER 1

INTRODUCTION

1.0 Background and Context

It is clear from research in physics education that student teachers of physics do not enter the classroom as "empty vessels" but are filled with a lot of conceptions about fundamental physics concepts which they are going to learn (Tytler, 2002; Knight, 2002). Some of their conceptions are in conformity with scientific explanation while others differ from accepted scientific view points and so are commonly known as alternative conceptions, alternative frameworks or misconceptions (Driver and Easley, 1978; Driver, 1983; Driver and Erickson, 1983; Blosser,1987; Boyes, 1988; Treagust, 1988; Veiga, 1989; Rowell, Dawson and Lyndon, 1990; McDermott, 1993; Wandersee, Mintzes and Novak, 1994; Coetzee, 1998; Yip et al. , 1998; Groves and Pugh,1999; Palmer, 1999; Knight, 2002; Papadimitriou, 2004). Examples of such misconceptions are that:

i. 'Gravity gets stronger closer to the ground, which is why objects speed up as they fall
ii. Motion of an object implies a force acting on the object
iii. If half of a lens is covered by a piece of opaque paper, half of the image on a screen will disappear
iv. Electric current gets used up as it flows through a circuit' (Knight, 2002: p. 27).

So far no research has been done in Zambia to ascertain these misconceptions. However, the researchers' teaching experience at secondary and university levels, including his monitoring of school teaching experience (STE) and peer teaching sessions, point to the fact that student teachers of physics in this country also hold similar views. No wonder Tytler (2002, p.3), contends that 'Students from different countries and cultures have been found to have very similar prior ideas, so that there seems to be a common set of alternative conceptions that untutored life experience encourages.' But what causes these misconceptions in student teachers of physics?

Research in physics education indicates that student teachers' misconceptions may arise as a result of several reasons, such as: inadequate pre-requisite knowledge, negligence on the conditions and assumptions behind a rule, over generalisation of principles from inadequate evidences, interference of learnt materials, uncritical acceptance of incorrect information, past teaching and a wrong deduction due to fallacious reasoning (Ausubel, 1968; Yip et al., 1998). Other causes of misconceptions include: the variety of contacts students make with the physical and social world, subjective experience before learning the scientific views, physics textbooks, interaction with people and through the media (Ivowi, 1984; Clement, 1989; Ozmen, 2004; Sweetland, 2012). In Zambia, all these sources may contribute to misconceptions in physics student teachers (Tytler, 2002), but the major ones seem to be: inadequate pre-requisite knowledge, past teaching and interference of learnt materials. This is because during physics education classes, student teachers explain some physics concepts erroneously and when asked why they do so, some respond that they have inadequate knowledge on the concepts, the majority attribute their answers to what they learnt from teachers of physics at secondary school while the rest admit that they are confused by similar concepts which they covered before their tertiary education. One question worth asking is whether physics student teachers' misconceptions can be minimised, dislodged or changed into scientifically acceptable conceptions. While this is not impossible, it is not an easy thing to do.

According to Fisher (1985), once developed, misconceptions tend to be highly stable and very resistant to change. Rather than being momentary conjectures that can quickly be discarded, misconceptions consistently appear not only before but also after instruction, in substantial numbers of student teachers of physics and are actively defended (Cohen et al., 1983). Smith and diSessa (2013) speculate that 'Perhaps most troubling is that students can doggedly hold onto mistaken ideas even after receiving instruction designed to dislodge them' (p.13). As long as a misconception seems to work, it will persist (Semanek, 2008). Summarising years of research into misconceptions in Newtonian mechanics, Clement (1989) also admits that many misconceptions are deep seated, resistant to change and a serious problem to learners.

Due to their strength and flawed content, misconceptions interfere with students' learning of correct scientific principles or concepts (Posner et al., 1982; Fisher, 1985; Knight, 2002; Smith, diSessa and Roschelle, 1993). For example they are the source of students' difficulty in learning "formal" notions of probabilistic events, such as the "Law of small

numbers" (Shaughnessy, 1985; Lindquist, 1989). This is supported by Cohen et al. (1983) who argues that misconceptions about circuits "impede" the rigorous study of electricity.

Indeed there is enough evidence to suggest that many of the difficulties students encounter in physics content are due to the misconceptions they hold about the subject (Knight, 2002). Hunt and Minstrell (1977) support this assertion by stating that learners' difficulties in science occur because students' conceptions before teaching are not taken into account and therefore communication barriers between instructors and learner's cannot be overcome. The ideas are logical, sensible, and valuable from the students' point of view, strongly held by the students, but may be significantly different from accepted scientific view points and may not be in conformity with the true or the scientific explanation (Osborne, 1983). This is why many physics educators have at one time or the other experienced the frustration of explaining a concept, in what they thought was the clearest possible way, only to be faced with expressions of mute incomprehension from the class or worse; Others have had the experience of having successful conversations in class, in which they felt sure they had achieved some clear understandings, only to find on testing that nothing much seemed to have been gained at all (Tytler, 2002).

In addition, misconceptions affect the teaching of physics negatively (Knight, 2002). According to Tytler (2002), ' Students' alternative conceptions have proved surprisingly difficult to shift, and can offer a serious barrier to effective teaching' (p.3). This is why Groves and Pugh (1999) expressed concern about the ability of teachers with misconceptions to instruct their students correctly since they, themselves, do not have proper understanding of how the world works. Both theory and common sense support the argument that teachers' inadequacy in subject content knowledge will affect teaching performance as well as pupils' learning (Ball and Mc Diarmid, 1989; Driver, 1994; Haambokoma et al, 2002). The complexity and multiplicity of a lesson event, such as selecting suitable content, planning and conducting productive learning activities, asking meaningful questions, answering unprepared questions, diagnosing learning difficulties, and assessing students' progress demand teachers to have a good command of subject knowledge (Yip et al., 1998).

Therefore, it is well established from the aforementioned that student teachers of physics do not come to the classroom with empty minds, but with a wide range of some already

strongly held ideas, which in many cases differ from the theories the educator must develop (Driver, 1983). Such ideas are resistant to change and if not taken into account, they make it difficult for student teachers to learn and later teach physics, Cohen et al., 1983; Yip et al., 1998). While this is so, research does not show what misconceptions teachers of physics in Zambia still hold about basic electronics as they complete their degree programme. This is not good because according to the baseline study, conducted in Zambia about a decade ago, although all sections of ordinary level physics are difficult to teach, basic electronics is the most challenging not only to student teachers of physics, but also those who are qualified to teach physics (Haambokoma et al., 2002). Hence, the need to identify any misconceptions that may be making it difficult for student teachers of physics to understand this section well, so as to prepare them for effective teaching when they join the teaching profession.

Next, research claims that misconceptions make the learning of physics difficult but it does not show what correlation exists between misconceptions and performance of student teachers of physics in basic electronics content and if such a correlation is causal. In physics education, it is very important to know this correlation and if it is causal, so that if variables (in this case misconceptions and performance) are not highly related, they can be eliminated from further consideration. However, if the correlation is highly negative and causal, researchers can work tirelessly to determine all possible misconceptions and find ways to minimise or dislodge them so as to prepare our student teachers of physics fully for effective teaching. In other words, knowing the correlation and if it is causal is crucial because based on this knowledge, researchers can make an informed decision whether to labor to dislodge the misconceptions or not.

Research also claims that misconceptions affect the teaching of physics negatively (Ball and Mc Diarmid, 1989; Yip et al., 1998; Groves and Pugh ,1999). However, it does not indicate and explain ways in which misconceptions held by student teachers of physics affect their teaching of basic electronics in the Zambian context. Knowing such ways is cardinal because it would help physics educators to introduce interventions to enable student teachers complete their teaching course with appropriate pedagogical knowledge which they need to handle basic electronics in secondary physics competently.

Lastly, research does not point to any particular education resource, as a solution to the problem of misconceptions on basic electronics. Such a resource would be very useful

because it cannot only minimise misconceptions but also enhance student teachers' performance in content and teaching of basic electronics.

Hence this study, which investigated physics student teachers' conceptions and performance in basic electronics. The study was important because it aimed at making the training institutions in Zambia aware of the unrecognized inconsistencies and erroneous set of concepts held by trainee teachers of physics in basic electronics, show how such misconceptions impede learning and teaching of physics and also suggest a possible solution to that problem.

It is hoped that the findings from this study will be of practical use in dislodging or minimising physics student teachers' misconceptions in basic electronics in Zambia, thereby improving student teacher's performance, and in turn the performance of the pupils they will handle in senior secondary physics. Furthermore, it is hoped that the study will help fill the gaps identified and generate academic debate on the notion of physics student teachers' misconceptions in the Zambian context.

1.1 Statement of the problem

The researchers' teaching experience at secondary and university levels including his monitoring of STE and peer teaching sessions, revealed that student teachers of physics in Zambia enter the university with alternative conceptions in basic electronics, hold on to these misconceptions as they undergo their physics teacher training and later, leave the training institution with the same misconceptions on completion of the course. This is supported by several scholars, who contend that learners of physics enter the classroom with misconceptions about what they are going to learn (Driver and Easley, 1978; Driver and Erickson, 1983; Blosser,1987; Yip et al., 1998; Groves and Pugh,1999; Palmer, 1999; Knight, 2002; Papadimitriou, 2004), hold on to these misconceptions even after receiving instruction to dislodge them (Knight, 2002) and upon completion of their teacher training in physics, join the teaching profession with such misconceptions (Knight, 2002; Halloun and Hestenes, 1985b). These misconceptions are surprisingly difficult to shift, and if not changed into scientifically acceptable conceptions, minimised or dislodged, they do offer a serious barrier to effective teaching (Tytler, 2002)

Unfortunately, research does not indicate the misconceptions about basic electronics which student teachers of physics in Zambia have, as they complete their teacher training at the University of Zambia (UNZA).

Next, although research claims that misconceptions impede the learning of physics (Tytler, 2002), it does not show what correlation exists between misconceptions and performance of student teachers of physics in basic electronics content and whether such a relationship is causal or not.

Research also claims that misconceptions affect the teaching of physics negatively (Ball and Mc Diarmid, 1989; Yip et al., 1998; Groves and Pugh,1999). However, it does not state and explain ways in which misconceptions held by student teachers of physics affect their teaching of basic electronics in the Zambian context.

Lastly, research does not point to any particular education resource, as a solution to the problem of misconceptions on basic electronics.

This situation implies a gap in knowledge which calls for a systematic investigation.

1.2 Purpose of the study

The purpose of this study was to determine the misconceptions held by student teachers of physics about basic electronics and how such misconceptions affect performance of such students in content and teaching of basic electronics in senior secondary physics in the Zambian context.

1.3 Objectives of the study

The objectives of the study were to:

(i) Determine the misconceptions student teachers of physics have about basic electronics, as they finish their training.

(ii) Determine the correlation between these misconceptions and performance of student teachers in basic electronics content in senior secondary physics.

(iii) Establish ways in which misconceptions affect student teachers' teaching of basic electronics in senior secondary physics.

(iv) Investigate the effect of the 'BE' Education Resource on physics student teachers' misconceptions and performance in basic electronics when used as a supplement to traditional educational resources (TER)?

1.4 Research questions

The central research question was:

What conceptions do student teachers of physics have about basic electronics and how do such conceptions affect student teachers' performance in basic electronics content and teaching, in senior secondary physics?

The specific questions which guided data collection were:

(i) What misconceptions do student teachers of physics have about basic electronics, as they finish their training?

(ii) What is the correlation between such misconceptions and performance of physics student teachers in basic electronics content?

(iii) How do such misconceptions affect the teaching of basic electronics by student teachers in senior secondary physics?

(iv) What effect does the 'BE' Education Resource have on physics student teachers' misconceptions and performance in basic electronics when used as a supplement to traditional education resources (TER)?

1.5 Null Hypotheses

H_o1: There is no statistically significant correlation between misconceptions and performance of physics student teachers in basic electronics content.

H_o2: There is no statistically significant difference in the performance of physics student teachers who use the 'BE' Education Resource as a supplement to TER and those who do not.

1.6 Significance of the study

The findings of this study shall inform: UNZA, CDC, Examinations Council of Zambia (ECZ), Policy makers in the Ministry of Education, Science, Vocational training and Early Education (MESVTEE), School Head teachers, qualified teachers and student teachers of physics in Zambia so that they are aware of misconceptions held by teachers of physics in Basic Electronics as they join the teaching profession. This in turn might:

- Help the School of Natural Sciences, Department of Physics and the School of Education, Department of Mathematics and Science Education at UNZA pay

attention to misconceptions in the course of teaching and learning of existing courses.

- Help the CDC to pay attention to misconceptions as they develop physics materials for teachers and pupils.
- Help the ECZ to consider student misconceptions when preparing final examinations.
- Help physics education researchers in Zambia to use the findings as a starting point for further research into student misconceptions in physics
- Add to the existing literature about student teachers' misconceptions in senior secondary physics in Zambia.

1.7 Definition of key terms

(a) Correlation:

The term meant the statistical association or relationship between two or more variables. The correlation was positive if increase in one variable resulted in an increase in the other variable and negative if increase in one variable resulted in a decrease in another variable.

(b) Variable:

This term referred to a characteristic of the participants that had different values. The active **independent variable** were "physics student teachers' misconceptions" while the **dependent variable** was their "performance" in ordinary level basic electronics content and peer teaching.

(c) Traditional instruction

This referred to any teaching approach/strategy which does not use the 'BE' resource.

(d) Conception

This term referred to a physics student teacher's belief, description, interpretation, or explanation/understanding of a basic electronics concept.

The conception was viable or valid if it was in line with the accepted scientific view points as stated in the book titled " Principles of Physics, by Nelkon (1981, pp.532 – 593) or in the book titled " Essentials of Physics, by Wilkinson" (1993, pp. 473 – 504).

(e) Misconception:

The term referred to a physics student teacher's conception of any basic electronics concept which was significantly different from that in either of the two physics textbooks already mentioned, by Nelkon (1991) and Wilkinson (1993). In the current study, this definition also applied to the term, alternative conception. Therefore, the two terms were used interchangeably.

(f) Performance:

The term referred to the number of marks or grades obtained by student teachers of physics in pre and post-tests in basic electronics content and teaching, during participants' peer teaching sessions at the time of the study.

(g) Basic Electronics:

This term referred to a branch of senior secondary physics, which comprises the following subsections: Thermionic emission and electrons, Circuit components, Simple electronic systems and Computers (CDC, 2015). Each of the sections has a number of concepts, giving a total of twenty concepts, on which the physics student teachers were to show their understanding of basic electronics.

(g) BE Education Resource

This referred to basic electronics materials which were used as a treatment in the study. The materials were mainly from the two recommended textbooks for the Zambian ordinary level physics syllabus (5054) by Wilkinson (1993) and Nelkon (1981). However, they also contained some improvised demonstrations and computer simulations. They were prepared by two physics educators, who were at the same time grade 12 physics examiners to see if the 'BE' resource could make help the students.

(h) Traditional Education Resources (TER)

This term referred to all physics teaching/learning materials other than the 'BE' Education resource.

1.8 Structure of the Thesis

This thesis is divided into 11 chapters which are arranged as follows:

Chapter 1 is an introduction to the study. It gives the background to the study, the statement of the problem; purpose of the study, objectives of the study, research questions; significance of the study and operational definitions of key terms.

Chapter 2 discusses the Origin, Development and value of electronics. After the introduction the chapter describes the origin and some advances of electronics. In the next section the chapter describes further advances in electronics. Then, it distinguishes between the two types of electronics. The chapter ends with several triumphs of electronics in various sections of our society. Hence, it justifies why electronics is part of the physics syllabus at every level of our education system and why this section of physics should be taught effectively.

Chapter 3 is a discussion of the theoretical framework of the study. After the introduction, the chapter explains two cognitive constructivist theories which were combined to form the theoretical framework and how the framework guided the study. Then, it highlights the main premises common to both theories and two areas in which the theories differ. The chapter continues with the implications of the framework used for science pedagogy and teacher training. Then, it ends with a summary.

The framework acted as a lens through which research ideas were perceived, oriented thinking and approach to research and informed how the researcher related to research setting. Furthermore, it acted as a guide to what was important, helped research data to cohere, enabled research to be systematic, provided a context for interpreting research data and informed choice of research methods.

Chapter 4 presents the literature reviewed on physics student teachers' conceptions and performance in basic electronics. The literature was reviewed according to the four research questions. Therefore, Chapter 4 has five sections, 4.1 to 4.5. The first four sections address the four research questions of the study in the order they are arranged in chapter 1. Section 4.5 is a chapter summary and it includes the gaps which were identified in the literature reviewed.

Chapter 5 presents the research designs and methodology of the study. It starts by describing and justifying the research designs which were used, and the broad methodological approach that was adopted. It includes a description of the study area, study population, sample size, sampling procedure, instruments, validity and reliability, data collection procedures, data analysis, limitations and delimitations and ends with ethical issues. All these steps were adhered to because the collection of data is a vital component in research, for it is through this that major research findings are made, recommendations offered and the way forward formulated (Kombo and Tromp, 2010).

Chapter 6 presents the findings about the misconceptions held by physics student teachers in basic electronics. The findings in this chapter were meant to answer the first research question which reads 'What misconceptions do student teachers of physics have about basic electronics, as they finish their training'? A summary of all the misconceptions which were revealed by the study is presented in a table. At the end is a chapter summary.

Chapter 7 presents the findings on the relationship between misconceptions and performance of student teachers of physics in basic electronics. The findings were meant to answer the second research question which reads: 'What is the correlation between such misconceptions and performance of physics student teachers in basic electronics content'? The chapter has a summary at the end.

Chapter 8 presents the findings about ways in which misconceptions held by physics student teachers affect their teaching of basic electronics. The findings were meant to answer the third research question. The findings were from the lesson observations which were conducted as participants did their peer-teaching on basic electronics. Others were the responses participants gave to the items on the Likert scale. The chapter ends with a summary.

Chapter 9 presents the findings about the fourth research question which investigated the effect of the 'BE' Education resource used as a treatment in the study. The question to be answered reads, 'What effect does the 'BE' Education Resource have on physics student teachers' misconceptions and performance in basic electronics when used as a supplement to TER?' The chapter ends with a summary.

Chapter 10 discusses the results of the study. It starts by discussing the results relating to the misconceptions held by physics student teachers. This is followed by a discussion of results concerning student teachers' performance in basic electronics content. Third is the discussion of how misconceptions affected student teachers' teaching of basic electronics. The last section discusses the effect of the 'BE' Education Resource on performance of student teachers of physics in basic electronics when it is used as a supplement to TER. The chapter ends with a summary.

Chapter 11 presents the conclusions and recommendations arising from the study. The chapter outlines the conclusions and recommendations which were considered reasonable and valid as suggested by data in Chapters 6, 7, 8 and 9.

CHAPTER 2

THE ORIGIN, DEVELOPMENT AND TRIUMPHS OF ELECTRONICS

2.0 Introduction

This chapter describes the Origin, Development and Triumphs of electronics. It has five sections 2.1 to 2.5. Section 2.1 describes the origin of electronics. Section 2.2 describes the advances in electronics while Section 2.3 describes further advances in electronics. Section 2.4 describes the two types of electronics which many people in society find difficult to distinguish. The chapter ends with several triumphs of electronics in various sections of our society. Hence, it justifies why electronics is part of the physics syllabus at every level of the Zambian education system and why physics student teachers who are being trained to teach basic electronics must be free of misconceptions on this section of physics.

2.1 The Origin and Development of Electronics

'Electronics is a branch of science and engineering that is closely related to the science of electricity. However, it can do a lot of jobs that electricity alone can't do and it has made possible such great advances as television, radio, high fidelity phonographs, radar, X-rays, tape recorders and high speed computers' (Pierce, 1977, p. 1092).

Electrical experiments in the 1800s marked the start of the *development of electronics* (Williams et al., 1976). The experiments involved using a gas discharge tube, which had some of the air removed, leaving a thin mixture of gases. When a high voltage was impressed across the tube, it glowed with bright colors (Hausmann and Slack, 1950; Williams et al., 1976; Breithaupt, 1994).

According to Williams et al. (1976, p.585), the above 'Early tubes had metal electrical poles at each end. One electrode was called a cathode and the other an anode. The negative electrode, the cathode, gave off invisible rays that were called cathode rays' (p. 585). This was deduced from Maltese cross tube, in which the walls of the tube glowed everywhere except where the cross inside the tube cast a shadow on the face of the tube as shown in Fig 2.1.

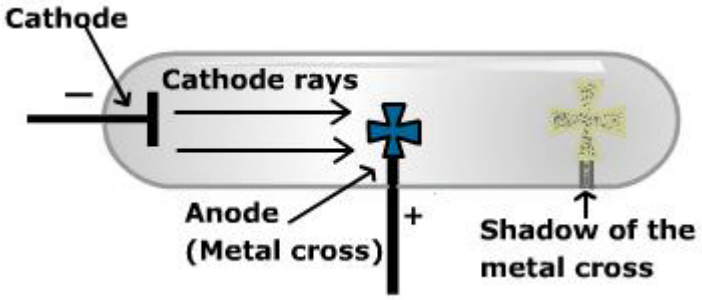


Fig. 2.1 Maltese cross tube, from http://chem-guide.blogspot.com/2010/04/discovery-of-electron.html.

This indicated that the glow was produced by something coming from the cathode in straight lines (Williams et al., 1976; Breithaupt, 1994; Pople, 1997).

About 1878 a British scientist named Sir William Crookes developed a special tube to study cathode rays (Williams et al.,1976). Nine years later, a British physicist Joseph Thompson proved that cathode rays were made up of negatively charged particles of atoms (Nelkon, 1981). He used the Crookes tube in Fig. 2.2, in which he observed the deflection of cathode rays by an electric field and later measured their mass to charge ratio.

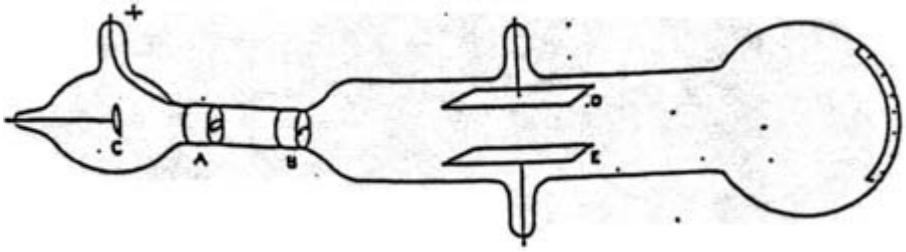


Fig 2.2 Crookes tube at http/onlinephy.com/giants2.html

Cathode rays were emitted from the cathode C, passed through slits A (the anode) and B (grounded), then through the electric field generated between plates D and E, finally impacting the surface at the far end. Between the plates D and E, the cathode rays were deflected by the electric field. These particles soon came to be called electrons and so Thompson is credited with the first discovery of a subatomic particle, the ***electron*** (Williams et al., 1976). The discovery of electrons led to the invention of devices that could control an electron flow, or electric signal, and put it to work.

‘As a result of the discovery of electrons, in 1904 John Ambrose Fleming an English physicist, patented the first **diode**, called the *Fleming valve’* (Williams et al., 1976, p. 553). It was a two electrode tube that utilised the Edison effect to detect radio ignals.

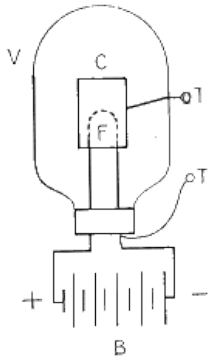


Fig. 2.3 The Fleming valve, from http://www.sparkmuseum.com/FLEMING.HTM

The valve consisted of an incandescent electric lamp comprising a filament (F) of carbon, tungsten, or other material which could be made incandescent by an electric current. Around the filament, but not touching it, was a cylinder of metal (C). The electrical connection to the cylinder was brought out through the side of the glass enclosure. The valve operated as a simple rectifier when a positive charge was applied to terminal (T). Electrons emitted from the filament passed through the vacuum of the valve and were collected by the metal cylinder. The tube turned out to be much more effective than earlier magnetic or crystal detectors and gradually replaced them almost entirely.

‘In the year 1907, an American inventor named DeForest came up with a three electrode tube which was later called a triode’ (Williams et al., 1976, p.553). He did this by placing a third electrode, consisting of a grid of line wire, between the cathode and anode of the diode as in Fig 2.4.

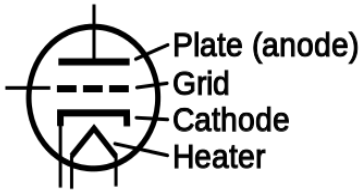


Fig. 2.4 Lee Deforest Triode

He found that a small variation in voltage applied to the grid produced a large variation of current in the plate circuit of the tube. Thus, the feeble radio signals from an antenna could be amplified by De Forest's triode and then successfully detected by Fleming valve to provide the varying direct current signal necessary to operate headphones. The success of the De Forest triode led to the development of *modern vacuum tubes* (Williams et al., 1976).

The vacuum tube era lasted up to 1950s but the peak of this era was in 1946 when a team of scientists at the University of Pennsylvania completed the first all electronic computer, called ENIAC (for Electronic Numeric Integrator And Calculator). According to Meyer and Baber, 1997; p.32),

> *ENIAC, was a huge monster, whose circuits included 500,000 soldered joints with 70,000 resistors and 10,000 capacitors. ENIAC also had its own dedicated power lines and used about 200 kilowatts of electricity. It weighed over thirty tons and had around 18,000 vacuum tubes that constantly burned out, making it very unreliable. However, it worked faster than the fastest non electronic computers then in use (Pierce, 1977). "ENIAC could do five multiplication operations in a second, which was much faster than even the Mark 1. However, ENIAC was difficult to use because every time it was used to solve a new problem, the staff had to rewire it completely to enter the new instructions (Meyer and Baber, 1997, p. 32)*

The problem was solved by von Neumann, who came up with the 'stored-program concept', where the computer's program was stored in internal memory with the data. The key advantage of this was that the computer could easily go back to a previous instruction and repeat it.

It should be noted that the **First generation of computers**, usually dated from 1951 to 1959, used vacuum tubes. 'According to Meyer and Baber (1997): "Dates for computer generations are not precise, varying from source to source due to the major hardware innovation' (p. 34). First generation computers were large and slow, and they produced lots of heat. The vacuum tubes failed frequently as they were burning out, so first-generation computers were " down'' (not working) much of the time" (p. 35). Fortunately, a 1947 invention, described in Section 3.1.2 was to change the way computers were built, leading to the **second generation of computer technology**.

2.2 Advances in Electronics

Schopman (1981) contends that:

> *After years of scientific and technological research with a largely ad hoc character, several research fellows of the Bell Telephone Laboratories had the idea that the existing vacuum tube technology could be replaced by something radically new. There was a good deal of wishful-thinking around at that time, based on the inconvenience of the existing vacuum tube technology. There was no reason to expect a realization of this dream, and certainly not from the side of semiconductor-physics. Therefore, the expectation of such a development could not be other than very vague. Nevertheless, it set research directors of the Bell Laboratories such as Shockley and Brattain to work on the problem. No one in the tube industry expected such a radical innovation* (p.297).

But 'Drawing on both experimental and theoretical experience, the solution Shockley, Brattain and Bardeen were looking for was found in December 1947' (Braun and MacDonald, 1978, p.48). The ***point contact Germanium transistor*** was invented quite unexpectedly during a study of germanium surfaces and so a new electric age had dawned (Schopman, 1981). That electronic component was capable of not only amplifying signals but also controlling current between or voltage across two terminals.

At that time people did not think that the discovery of the transistor was a new technology. It was just seen as a larger step towards the process of miniaturization which had been going on for some time. In other words, the transistor was just seen as the next step in the process of reducing size of the electronic components. To put it differently, the discovery only received recognition as a replacement for the existing vacuum tubes.

Schopman (1981) further reports that:

> *Although the transistor was invented in 1947, much research had still to be done before Bell were prepared to make it known. The actual production did not start until 1951. Even then, the transistor was more promise than reality. It was mainly a direction in which to work. Moreover, the original device-the point contact transistor could never have fulfilled such promise. Until 1966 Bell themselves hesitated to apply those transistors in the underwater cables. When production started there were several difficulties still to overcome* (p. 298)

Some of the difficulties were that:

- The first transistors made much more noise than the vacuum tubes ;
- They could stand less tension
- The frequency range was more limited
- Transistors were more sensitive to radiation and high temperatures
- It was difficult to construct transistors to specific requirements, and even more difficult to produce two transistors to the same requirements
- At first transistors were expensive and difficult to obtain.

'The successor to the first generation of transistors, the **junction transistor**, had less inconveniences, but was limited to even lower frequencies' (Braun and MacDonald, 1978, p.62). Altogether it was not a very attractive product, unless its size and weight were important enough to justify a high price. Schopman (1981) asserts:

> *The people who had to work with transistors, the engineers/technicians, had been educated in tube-electronics and had to become accustomed to the new technology, the background to which they did not understand. They were used to working with tubes and their insight and experience was not always applicable to the new technology. Hence, the new technology was given a hostile reception by those already experienced in the field of electronics.* (p. 298).

'Despite the challenges above, transistors were used to create **second generation computers**. Those computers were faster, smaller, easier to program (due to high level languages used) and more reliable than first-generation computers (Meyer and Baber, 1997). In those computers memory was composed of small magnetic cores strung on wire within the computer. For secondary storage, magnetic disks were developed, although tape was still commonly used (Meyer and Baber, 1997).

As with the first generation computers, a device that ended the second generation had began. By the second generation scientists had already known that more powerful computers could be created by building more complex circuits. But because the circuits had to be wired by hand, those computers were too complex and expensive to build.

In the early 1950s it was recognized in the UK, and subsequently in the USA, that conceptually at least it should be possible to fabricate the key electronic components (**transistor, diode, resistor and capacitor**) within the same piece of silicon, thus reducing both the physical size and the number of material interfaces. This exciting new concept was first termed the **'Solid circuit'**, but later became widely known as the **silicon integrated circuit (SIC**) - or **silicon chip** and led to third generation computers (Noyce, 1977).

By the early 1960s **SICs** were being made with a silicon chip measuring 1 to 2 mm square (and about 0.2 mm thick) containing several tens of components, mainly transistors and resistors (Moore, 1965; Moore, 1998). Later, SICs were made in which the silicon chip measured about 1 cm square and contained more transistors. Moore (1965, p.1) indicates that 'The number of transistors used on a single chip of silicon would grow exponentially.' In 1971 Rob, Noyce and Moore invented the first microprocessor well known as 4004 having 2300 transistors on one silicon *chip* (Noyce, 1977).

Credit should go to Ted Hoff who planned to have even larger integrated circuits which could have the whole computer on a single chip (Kumar, 2013a; Kumar, 2013b). The above microprocessor led to the successors like the 8080, 8085, 8086 Pentium series and the Xeon, all of which were commonly referred to as the **Fourth Generation computers** (Kumar, 2013a). The section that follows shades more light on the generations of Silicon Integrated Circuits (SICs).

2.3 Further advances in Electronics (generations of Silicon Integrated Circuits (SICs).

As already stated, an integrated circuit (IC) is the name for collections of electronic components imbedded onto a single piece of silicon (Meyer and Baber, 1997). Silicon is the base for most transistors, diodes and other semiconductors. Each IC is designed to carry out certain tasks and the circuit is designed accordingly. The circuit is then printed or etched onto the silicon substrate and then into a plastic or ceramic enclosure as shown in Fig. 2.5

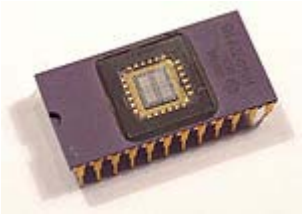


Fig. 2.6 Silicon Integrated Circuit, from http://www.fotosearch.com/photos-images/integrated-circuit.html

Sections (a) and (b) briefly describe the generations of Silicon Integrated Circuits.

(a) Small Scale Integration Circuits (SSI), Medium Scale Integration Circuit (MSE) and Large Scale Integration Circuit (LSI)

Small Scale Integration circuits (**SSI)** are those that contain up to *ten transistors* (Meyer and Baber, 1997). These were crucial to early aerospace projects, which in turn helped inspire development of the technology. Both the Minuteman missile and Apollo program needed lightweight digital computers for their inertial guidance systems (Meyer and Baber, 1997). The Apollo guidance computer led and motivated the integrated-circuit technology while the Minuteman missile forced it into mass-production (Meyer and Baber, 1997; Mindell, 2008). The demand by the U.S. Government supported the nascent integrated circuit market until costs fell enough to allow firms to penetrate the industrial and eventually the consumer markets.

The next step in the development of integrated circuits, taken in the late 1960s, introduced devices which contained *hundreds of transistors* on each chip, called "**medium-scale integration**" (**MSI**) (Meyer and Baber, 1997). These were attractive economically because while they did cost little more to produce than SSI devices, they allowed more complex systems to be produced using smaller circuit boards, less assembly work (because of fewer separate components), and a number of other advantages (Meyer and Baber, 1997).

Further development, driven by the same economic factors, led to "**large-scale integration**" (**LSI**) in the mid 1970s, with *tens of thousands* of transistors per chip (Meyer and Baber, 1997, Mindell, 2008, UK Essays, 2014).

Integrated circuits such as 1K-bit RAMs, calculator chips, and the first microprocessors, that began to be manufactured in moderate quantities in the early 1970s, had under 4000 transistors. True LSI circuits, approaching 10,000 transistors, began to be produced around 1974, for computer main memories and second-generation microprocessors (UK Essays, 2014).

(b) Very Large-Scale Integration (VLSI)

'The final step in the development process, starting in the 1980s and continuing through the present, was '**very large-scale integration**' (VLSI). The development started with *hundreds of thousands* of transistors in the early 1980s, and continued beyond several billion transistors as of 2009' (UK Essays, 2014).

Multiple developments were required to achieve this increased density. Manufacturers moved to smaller design rules and cleaner fabrication facilities, so that they could make chips with more transistors and maintain adequate yield. The more energy efficient Complementary Metal-Oxide Semiconductor (CMOS), replaced N-type metal-oxide-semiconductor **(**NMOS) and P-type metal-oxide-semiconductor **(**PMOS), avoiding a prohibitive increase in power consumption (UK Essays, 2014).

In 1986 the first one megabit RAM chips were introduced, which contained more than one million transistors. Microprocessor chips passed the million transistor mark in 1989 and few years later, the billion transistor mark (Clarke, 2005). The trend continues largely unabated, with chips introduced in 2007 containing tens of billions of memory transistors (Gonsalves, 2007).

It should be noted that the most advanced integrated circuits are the microprocessors or "**cores**", which control everything from computers and cellular phones to digital microwave ovens (UK Essays, 2014). Digital memory chips and **A**pplication **S**pecific **I**ntegrated **C**ircuits (ASICs) are examples of other families of integrated circuits that are important to the modern information society. While the cost of designing and developing a complex integrated circuit is quite high, when spread across typically millions of production units the individual IC cost is minimized. The performance of ICs is high because the small size allows short traces which in turn allows low power logic (such as CMOS) to be used at fast switching speeds (UK Essays, 2014).

ICs have consistently migrated to smaller feature sizes over the years, allowing more circuitry to be packed on each chip. This increased capacity per unit area can be used to decrease cost and/or increase functionality in accordance with Moore's law which, in its modern interpretation, states that the number of transistors in an integrated circuit doubles every two years (Moore, 1965). In general, as the feature size shrinks, almost everything improves—the cost per unit and the switching power consumption go down, and the speed goes up. However, ICs with nanometer-scale devices are not without their problems, principal among which is leakage current (UK Essays, 2014).

If there is a fifth generation of computers, it may be slow in coming; after all, the last one began in 1975. However, dates are arbitrary, and we may soon learn that the fifth generation began in 1992. What is cardinal is to bear in mind that major changes are occurring in software as well as in hardware. According to experts in computers, the trademark of next generation will be artificial intelligence **(AI).** "Computers that use artificial intelligence will have some attributes associated with human intelligence, such as the capabilities to decode and respond to natural language (a human language such as English), to reason and draw inferences, and to recognize patterns in sensory input" (Meyer and Baber, 1997; p. 39).

The history and development of electronics is really a vast area and nobody can present all the details about it in this limited scope. It started as a philosophy, became physics and later electrical engineering. Today it has its own identity and will even be more diverse in the future. But thanks to John Ambrose Fleming for building the first **vacuum electron tube** and to Shockley, Brattain and Barden for inventing the **transistor**, whose effect is considered as the development of the modern electronics.

At this stage, it is important to distinguish between two types of electronics, namely: Analogue and Digital electronics. This is because, although they may be serving the same purpose, they operate differently.

2.4 Two types of Electronics

This subsection describes two types of electronics, namely: analogue and digital. It distinguishes between the two types of electronics and highlights some advantages and disadvantages of one type over another.

(a) Analogue electronics

This refers to electronic systems with a continuously variable signal (Millman and Halkias, 1972). The term “analogue” describes the proportional relationship between a signal and a voltage or current that represents the signal. An analogue signal may use some attribute of the medium to convey the signal's information. For example, in an analogue sound recording, the variation in pressure of a sound striking a microphone creates a corresponding variation in the current passing through it or voltage across it. An increase in the volume of the sound causes the fluctuation of the current or voltage to increase proportionally while keeping the same waveform or shape. Therefore, in that system, if one volt represents a (sound) pressure of one newton per square meter, then two volts will represent two newtons per square meter and so on and so on. Mechanical, pneumatic, hydraulic and other systems may also use analogue signals (Millman and Halkias, 1972).

Another method of conveying an analogue signal is to use modulation. In this case, some *base carrier signal* has one of its properties altered: amplitude modulation **(AM)** involves altering the amplitude of a sinusoidal voltage waveform by the source information, frequency modulation **(FM)** changes the frequency. Other techniques, such as phase modulation or changing the phase of the carrier signal, are also used, though this is just another form of frequency modulation (Poole, 2008).

According to Poole (2008), the basis of any radio signal or transmission is the carrier, which consists of an alternating waveform like that shown in Fig 2.7. The carrier is generated in the transmitter, and if it is radiated in this form it does not carry any information but reaches and appears at the receiver as a constant signal.

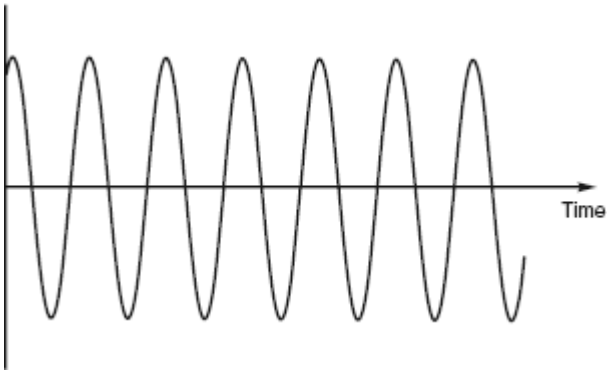


Fig. 2.6 An alternating waveform. From http://www.eetimes.com/document.asp? doc_id =1275573. Retrieved on 7th Jan 2015.

In Amplitude Modulation, which is the most obvious method of modulating, the amplitude of a carrier is changed in line with the modulating signal. 'More generally, the amplitude of the overall signal is varied in line with the incoming audio or other modulating signal, as shown in Figure 2.8. Here, the envelope of the carrier can be seen to change in line with the modulating signal. This is known as Amplitude Modulation (AM)' (Poole, 2008, p. 1).

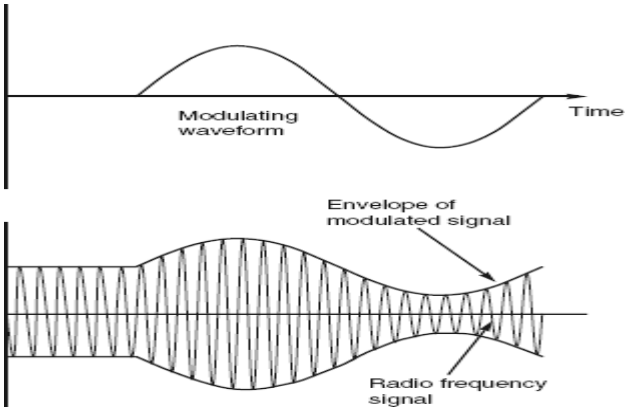


Fig. 2.7. An amplitude modulated signal, from http://www.eetimes.com/document.asp?

doc_id = 1275573.

Converting the modulated signal back into an audio frequency signal is very easy. A simple diode detector circuit like the one shown in Fig. 2.9 can be used.

In this circuit the diode rectifies the signal, only allowing the one-half of the alternating radio frequency waveform through. A capacitor is used as a simple low-pass filter to remove the radio-frequency parts of the signal, leaving the audio waveform. This can be fed into an amplifier, after which it can be used to drive a loudspeaker (Poole, 2008, p.1).

This form of demodulator is very cheap and easy to implement, and is still widely used in many AM receivers today.

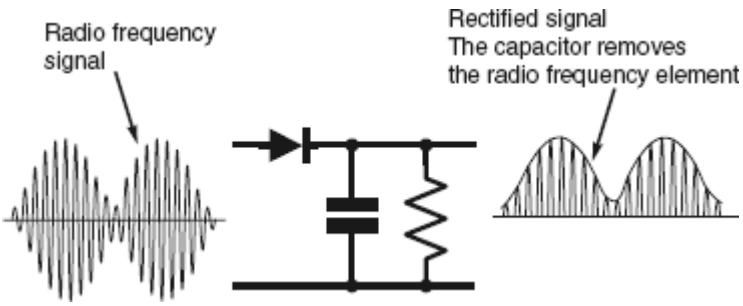


Fig. 2.8. A simple diode detector circuit, from http://www.eetimes.com/document.asp?

doc_id=1275573.

Analogue systems invariably include noise; that is, random disturbances or variations, some caused by the random thermal vibrations of atomic particles. Since all variations of an analogue signal are significant, any disturbance is equivalent to a change in the original signal and so appears as noise. As the signal is copied and re-copied, or transmitted over long distances, these random variations become more significant and lead to signal degradation. Other sources of noise may include external electrical signals or poorly designed components. Nowadays, these disturbances are reduced by shielding, and using low-noise amplifiers

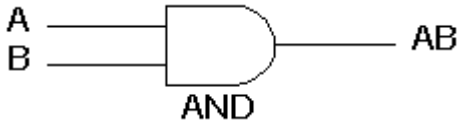
(b) Digital electronics

This refers to the electronics which represents signals by discrete bands of analog levels, rather than by a continuous range (Millman and Halkias, 1972). While analogue signals vary continuously in amplitude, frequency or both, digital signals are a series of pulses with two states, **On** or **Off**. The states are normally represented by the symbols '1' (a high value) or '0' (a low value). Telephone messages, letters and books can all be coded

into a series of ones and zeroes which are easily transmitted, stored and decoded (Wilkinson,1993).

Digital electronics uses Logic gates, which are made with transistors often grouped together as an integrated circuit (IC). The *inputs* to a gate may be the binary numbers 1 or 0. The gate, however, has only one output, which may be 1 or 0 (Nelkon, 1981). The main types of logic gates (and their truth tables), which serve different purposes, are as described below. They were from the books titled, Principles of Physics by M. Nelkon, M (1981) pages 588 to 589 and Essentials of Physics by Wilkinson, J (1993) on pages 482 to 485.

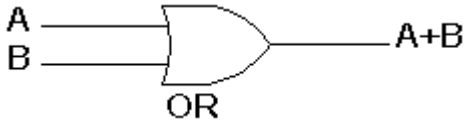
AND gate



2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

The AND gate is an electronic circuit that gives a **high** output (1) only if **all** its inputs are high. A dot (.) is used to show the AND operation that is A.B. Bear in mind that this dot is sometimes omitted and hence written as AB

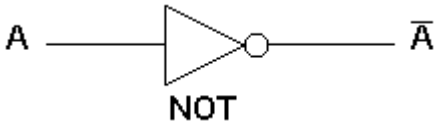
(i) **OR gate**



2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

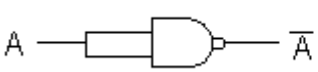
The OR gate is an electronic circuit that gives a high output (1) if **one or more** of its inputs are high. A plus (+) is used to show the OR operation.

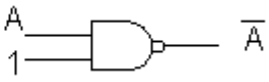
(ii) **NOT gate**



NOT gate	
A	$\overline{A}$
0	1
1	0

The NOT gate is an electronic circuit that produces an inverted version of the input at its output. It is also known as an *inverter*. If the input variable is A, the inverted output is known as NOT A. This is also shown as A', or A with a bar over the top, as shown at the outputs. The diagrams below show two ways that the NAND logic gate can be configured to produce a NOT gate. It can also be done using NOR logic gates in the same way.





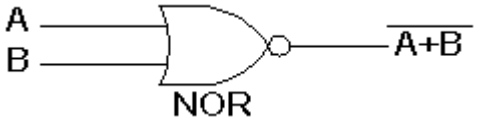
(iii) **NAND gate**



2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

This is a NOT-AND gate which is equal to an AND gate followed by a NOT gate. The outputs of all NAND gates are high if **any** of the inputs are low. The symbol is an AND gate with a small circle on the output. The small circle represents inversion.

(iv) **NOR gate**



2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

This is a NOT-OR gate which is equal to an OR gate followed by a NOT gate. The outputs of all NOR gates are low if **any** of the inputs are high. The symbol is an OR gate with a small circle on the output. The small circle represents inversion.

Digital signals carry more information per second than analogue signals and they maintain their quality better over long distances (Nelkon, 1981, p. 588).

Advantages of Digital over Analogue electronics.

i. One advantage of digital circuits when compared to analogue circuits is that signals represented digitally can be transmitted without degradation due to **noise**. For example, a continuous audio signal, transmitted as a sequence of 1s and 0s, can be reconstructed without error provided the noise picked up in transmission is not enough to prevent identification of the 1s and 0s. An hour of music can be stored on a compact disc using about 6 billion binary digits.

ii. In a digital system, a more precise representation of a signal can be obtained by using more binary digits to represent it. While this requires more digital circuits to process the signals, each digit is handled by the same kind of hardware. In an analogue system, additional resolution requires fundamental improvements in the linearity and noise characteristics of each step of the signal chain (Moore, 1965).

iii. Analogue circuits are harder to design, requiring more skill, than comparable digital systems. This is one of the main reasons why digital systems have become more common than analogue devices. An analogue circuit must be designed by hand, and the process is much less automated than for digital systems. However, if a digital electronic device is to interact with the real world, it will always need an analogue interface. For example, every digital radio receiver has an analogue preamplifier as the first stage in the receive chain.

Disadvantages of Digital over Analogue Electronics:

There are several disadvantages of digital over analogue electronics (Electronics, 2007).

i. In some cases, digital circuits use more energy than analogue circuits to accomplish the same tasks, thus producing more heat which increases the complexity of the circuits such as the inclusion of heat sinks. In portable or battery-powered systems this can limit use of digital systems Digital circuits are sometimes more expensive, especially in small quantities (Electronics, 2007).

ii. Most useful digital systems must translate from continuous analogue signals to discrete digital signals. This causes quantization errors. Quantization error can be reduced if the system stores enough digital data to represent the signal to the desired degree of fidelity (Electronics, 2007).

iii. In some systems, if a single piece of digital data is lost or misinterpreted, the meaning of large blocks of related data can completely change. Because of the cliff effect, it can be difficult for users to tell if a particular system is right on the edge of failure, or if it can tolerate much more noise before failing (Electronics, 2007).

Having described the origin and development of electronics, the study now turns to the widespread and astonishingly various triumphs of electronics. These wonders have not only benefited other countries in the world but also Zambia and shall continue to do so.

2.5 The triumphs of electronics in various sections of our society

We frequently read of the triumphs of the computer in class or in recognising patterns or in transcribing speech or in reducing profoundly the bandwidth required to transmit television or in processing theorems or in controlling traffic or in providing information instantly and cheaply (Pierce, 1977, p.1092). We cannot deny the fact that electronics is wonderful. But how wonderful? Pierce (1977) made a short list of things which he believed illustrated the wonders of electronics. Though certainly not complete, it included three sorts of things that were important. The wonders were as stated under each of the following titles:

i. Things that would be impossible without the speed and accuracy of electronics:

Telegraphy, telephone, Radio, Talking pictures, Public address system, Television, Data communication, Radar, All automatic service (except slot) vending machines,

Management of airports and air traffic, Controlling moment by moment the total power used in industry, Radar and Radio astronomy, A good deal of work in physics, chemistry, biology, psychology, statistics, mathematics, archaeology, seismology, optical astronomy, Some medical diagnosis and treatment, Nuclear energy and Nuclear weapons, Ballistic and guided missiles, Production of highly organised complex sounds, and even a machine to play chess (p.1092). In Zambia some of these have been used in communication, medical treatment, teaching and entertainment.

ii. Things that would be exceedingly difficult or imperfect without electronics:

Calculators, Automation and process control, Guidance and navigation, Phonographs, Numerically controlled tools and processes, Collision avoidance, Large scale testing, Seismography, Analysis of complex structures, Complex machines and fabrication, Much medical testing and treatment (p. 1092).

iii. Things that are greatly aided or improved by electronics:

Surveying, Banking, Retail sales, Typing, editing and publishing, Operation of automobile engines and Repressive government (Pierce, 1977, p.1093).

Indeed, advances in electronics have done so much for us, including the production of a pocket calculator, cell phone, television and computers. No wonder electronics is said to be so important to our society. According to Modin (2010):

> The importance of electronics to society today is most easily represented by our reliance on technology. Many of the technologies that are continually transforming the world we live in can be directly traced back to important physics research in electronics. For example, research on the physics of semiconductors enabled the first transistor to be developed in 1947. This seemingly simple device is the key component in all of our electronic systems, including computers, and it is now considered one of the most important inventions in human history. In addition, it is the law of optics describing the way light behaves that has led to the development of the optical fibre networks that are beginning to craw over the entire globe, drawing the entire world together.
>
> There are more examples of research in electronics leading to the development of important technologies. It is hoped that today's research on nanostructure

> (structure a billion times smaller than a meter), quantum information or photonics (basically electronics with light) will lead to the next generations of technologies including faster and more robust computer and communication systems.
>
> On a less tangible level physical theories have allowed us to obtain a greater grasp of the universe that we live in. It is the theories of physics (part of which is electronics) that provide us with some of our deepest notions of Space, Time, Matter and Energy. Physical theories allow us to conceptualise the workings of the building blocks of matter. These are things students would never be able to experience in everyday life (p. 1).

The list of triumphs in electronics is endless. Electronics is wonderful and it has done a lot to the world and is yet to do more for Zambia. Indeed, it cannot go without saying that it is possible to exist with little or no knowledge of electronics but it is almost impossible to lead a full and satisfactory life without it. Electronics is an aid to good living, good citizenship, agriculture, industry, home making and leisure. For these reasons and several others not mentioned in the study, electronics has been and shall remain a very important component of the Zambian secondary school physics syllabus, particularly, 5054.

It follows that teachers of physics should handle basic electronics effectively so that learners can understand it fully and be able to use it not only for their benefit but also for the betterment of the nation. However, this may not be possible if teachers themselves have misconceptions about basic electronics. Hence, this study which endeavoured to determine any alternative conceptions held by student teachers of physics about basic electronics, as they complete their programme.

CHAPTER 3
THEORETICAL FRAMEWORK

3.0 Introduction

This study is informed by the cognitive constructivist theory of learning as interpreted and applied to science education by Kelly (1966), and von Glasersfeld (1995) respectively. In this context, cognitive constructivism states that '*learners* construct the new knowledge *actively by themselves* on the grounds of the *already existing knowledge*' (Duit, 1996; p.41). The main aim of Chapter 3 is to explain the meaning of cognitive constructivism in the context of science teaching and learning and to show how the theory informs the present study on misconceptions in physics education.

In the current study the theory of cognitive constructivism was as a result of combining Kelly's constructivism and von Glasersfeld's radical constructivism. Therefore, in order to be clear about the meaning of cognitive constructivism, Sections 3.1 and 3.2, will first explain Kelly's constructivism and Glasersfeld's constructivism respectively. In Section 3.3, the study will describe the premises common to the two theories (Kelly's and Glasersfeld's constructivism), which enabled the researcher to combine the theories, thereby forming a theoretical framework that guided the research. Section 3.4 will address some implications for science pedagogy and teacher training while the last Section, 3.5 will present the chapter summary and show how the cognitive constructivist theory informs the study.

3.1 Kelly's constructivism (commonly known as Kelly's Personal Construct Theory)

The Personal Construct Theory was presented by George Kelly in 1955 and so is neither a new nor a revolutionary approach (Pervin and John, 2002). But over the years, the theory has not only been thoroughly revised and developed but also successfully applied to many fields of research and practice (Pervin & John, 2002). According to Paszkowska-Rogacz, and Kabzińska (2012), Kelly's theory regards the individual as 'An active "**scientist**" who constantly analyzes the surrounding reality, observes and looks for patterns, formulates hypotheses about the causes of events, builds theories, and makes conclusions based on gained experience (p. 408).

Kelly expresses the "fruitful metaphor" that,

> *'People – ordinary people – are scientists, too. They have constructions of their reality, like scientists have theories. They have anticipations or expectations, like scientists have hypotheses. They engage in behaviours that test those expectations, like scientists do experiments. They improve their understandings of reality on the bases of their experiences, like scientists adjust their theories to fit the facts' (Boeree, 2006; p. 5)*

The point Kelly makes in this metaphor is that the way people make up their own theories to figure out the world is the same way scientists use theories to predict behaviour. He calls people's theories *personal constructs*. The way people test and later change their personal constructs if they are not useful is the same way scientists test their theories and change them if they don't work.

Kelly based his theory on the philosophical approach called "constructive alternativism", according to which, 'The universe (physical reality) exists; however, it does not reveal itself to us directly, but rather is subject to as many different constructions as we are able to invent' (Bradshaw et al. 1993, p.2). Every individual has a choice of various options of giving meaning to events, or constructing reality (Fransella and Dalton, 2000; Boeree, 2006). Therefore, any event is open to a variety of different interpretations. 'Of course, this does not mean that all constructions are equally effective in anticipating events, but this does refute the existence of any definite and undisputed criteria' (Paszkowska-Rogacz and Kabzińska, 2012; p. 409). Different ways of construing the same event can be evaluated in terms of their relative predictive utility. 'That is, some interpretations of an event may prove more useful than others for anticipating similar events in the future' (Paszkowska-Rogacz and Kabzińska, 2012; p. 409). Therefore, nobody can claim any real "truth", because people have freedom to revise their views any time (Kelly (1966).

When applied to classroom situations, Kelly's theory implies that learners bring their personal experiences, such as knowledge, feelings and skills, into the classroom and that these experiences have a tremendous impact on students' views of how the world works (Schulte, 1996). Since each person's experiences may differ from other people's experiences, they will anticipate events differently. Therefore, in the current study we could not expect all the physics student teachers to have same understanding of the concepts about basic electronics, namely: Thermionic emission, cathode rays, resistor,

potentiometer, thermistor, light dependent resistor, diode, capacitor, reed switch, reed relay, transistor, logic gates, bistable circuit, astable circuit, computer hardware and computer software. Some conceptions were expected to be acceptable while others were not and so would be called alternative conceptions or misconceptions. This view is supported by Ozmen (2004:1) who says that 'Learning science is a cumulative process and each new piece of information is added to what students already know about the topic at hand.' The Personal Construct Theory is further based on one fundamental postulate and 11 corollaries, which explain the basic concepts and specify the main issues concerning the system of constructs. Section 2.1.1 explains the fundamental postulate.

3.1.1 The fundamental postulate of Kelly's personal constructivism

Kelly's (1966, p.7) fundamental postulate states that: ***'A person's processes are psychologically channelized by the ways in which he or she anticipates events'***

By processes, Kelly means our experiences, thoughts, feelings, behaviours, and whatever might be left over. All these things are determined, not just by the reality out there, but by our efforts to anticipate the world, other people, and ourselves, from moment to moment as well as day-to-day and year-to-year.

This implies that physics student teachers' past experience actively influences their behaviours and emotions. The way they think about various situations in class depends on their prior knowledge. Since each individual is unique, each one with his or her past experiences, they interpret reality in different ways, some of which may not be in conformity with acceptable scientific explanation. Section 2.1.2 explains four corollaries emanating from Kelly's fundamental postulate which apply to the current study.

3.1.2 Four corollaries emanating from Kelly's fundamental postulate

(a) The construction corollary

This states that **'A person anticipates events by construing their replications'** (Boeree, 2006). In this corollary, what Boeree means is that we construct our anticipations using our past experience. This is because as human beings, we are fundamentally conservative creatures who always expect things to happen as they have happened in the past.

It is this corollary which introduces Kelly's **constructivist position**. He uses the term construing, which means 'placing an interpretation'. Therefore, the corollary refers to a person placing an interpretation upon what is construed. He erects a structure, within the framework of which the substance takes shape or assumes meaning. The corollary supports the constructivist position by claiming that the learner's prior knowledge is the primary determiner of what anticipations one can construct next. Since individuals' prior knowledge differs from one person to another, they cannot construct their anticipations in the same way. Some anticipation will be viable while others will not. The more unviable the prior knowledge one has about reality, the more unviable anticipations one will construct about it. In other words, the more alternative conceptions one holds about reality, the more difficult it will be for one to perform to people's expectation. Referring to the current study, the more misconceptions one has about the concepts in basic electronics, the lower will be one's performance in basic electronics and vice-versa, which points to a negative relationship between misconceptions and learner performance in basic electronics. The fact that learners hold alternative conceptions and so anticipate events differently, is also highlighted in the next corollary.

(b) The individuality corollary

This corollary states that 'Persons differ from each other in their construction of events' (Boeree, 2006; p. 10). This implies that, since everyone has different experiences, everyone's construction of reality is different (Boeree, 2006**)**. It is for this reason that Kelly's theory is called the theory of personal constructs. Therefore, individuals such as physics student teachers will have different constructions of same reality. However, not all constructions will be viable. Some of them will, while others will not be and shall be referred to as alternative conceptions or misconceptions.

(c) The commonality corollary

This states that 'To the extent that one person employs a construction of experience which is similar to that employed by another, his psychological processes are similar to the other person.'

According to Boeree (2006, p.11),

> *Just because we are all different doesn't mean we can't be similar. If our construction system – our understanding of reality – is similar, so will be our experiences, our behaviors, and our feelings. For example, if we share the same culture, we'll see things in a similar way, and the closer we are, the more similar we'll be. That is why we look for support from those who are similar to ourselves. Only they can know how we truly feel!*

Therefore, it is possible for student teachers of physics who have attained the same level of education, covered the same syllabus and have the same understanding of reality, that is, electronics concepts to perform in the same way.

(d) The experience corollary

This states that **'A person's construction system varies as he successively construes the replication of events' (**Boeree, 2006; p.6)**.** The corollary implies that when things don't happen the way they have in the past, we have to **adapt**, to reconstruct. This new experience alters people's future anticipations and this enables them to learn. Therefore, based on the results of their experiments in class, the behaviours they engage in, or their observations and the experiences they have, physics student teachers can either continue their faith in their alternative conceptions, or change to those which are feasible and acceptable. In other words they can either hold on to their misconceptions or replace them with acceptable scientific view points. The more they replace misconceptions with acceptable scientific conceptions, the better will their performance be in basic electronics. This is because when students hold on to misconceptions they reject what they are taught and so find it difficult to learn (Sewell, 2002). Such ideas seem to contradict what students read in their textbooks and/or are taught by their teachers (Driver et al.; 1994). This is why, student teachers' misconceptions have to be changed or dislodged, if their learning is to make sense.

Knight (2002) suggests the following measures for physics educators, as ways of altering or eliminating student misconceptions: Keep students actively engaged and provide rapid feedback, focus on phenomena rather than abstractions, deal explicitly with student alternative conceptions, teach and use Explicit problem-solving skills and strategies and write homework and exam problems that go beyond symbol manipulation to engage

students in the qualitative and conceptual analysis of physical phenomena. These measures are explained in detail in Chapter 4, the Literature Review.

3.1.3 Use of Kelly's Personal Construct Theory in Science Learning

Kelly's view is that each person constructs for himself/herself a representational model of the world which enables that person to chart a course of behaviour (Maggon, 1977). His notions of "personal constructs" and "representational models" have been utilised by researchers such as Wittrock (1974) and Osborne and Wittrock (1983) in the development of the concept of *generative learning*, which in turn incorporates aspects of both the constructivist and information processing traditions of cognitive psychology.

The fundamental premise of "generative learning" is that people tend to generate perceptions and meanings that are consistent with their prior learning, and which are additional to it (Osborne and Wittrock, 1983). The constructivist aspect of the model consists of four phases, namely: the preliminary, focus, challenge and application. The preliminary phase is characterised by the teacher determining the prior knowledge that students might bring into the learning environment that is relevant to the new topic. This is because students' prior knowledge and experiences have a powerful influence on their new knowledge and understanding (Osborne & Wittrock, 1983; Gardner, 1993). If students' prior knowledge is not relevant to what they are going to cover in class, learning becomes difficult if not impossible. The focus phase deals with the activity that students engage in that makes explicit the range of students existing beliefs related to the new concept. This phase is important because it brings to the attention of the teacher any alternative conceptions students may have about a topic to be taught which may impede learning. The challenge phase is characterized by students comparing the scientific explanation with their own ideas and those of other students through debate, challenge and testing each others' ideas and so on. The final phase is the application phase during which students determine whether the concept could be useful and applicable to a variety of situations and so assimilate or accommodate it (Osborne and Wittrock, 1983).

On the other hand, the information processing aspect of the model, specifically the scientific inquiry, 'brings students into the scientific process and helps them to collect and analyse data, check out hypotheses and theories, and reflect on the nature of knowledge construction' (Joyce and Weil, 1996; p. 16). It emphasises concept formation, hypothesis testing and creative thinking. The generative model stresses learner-centred

education, which has been a central emphasis in constructivist approaches (Olssen, 1996). Maggon (1977, p. 284) adds that 'The central constructivist tradition, and especially the generative learning model that has developed within that tradition, has profound implications for learning, and specifically in the learning of science, in the emphasis given to learner-initiated activity and exploration.' Therefore, the generative model is very useful as it helps to identify, challenge and consequently minimise or dislodge student misconceptions in physics. This in turn enables students to achieve better in the subject.

3.1.4 Criticisms of Kelly's Personal Construct Theory

Although Kelly's emphasis on meaning as a primarily personal endeavour supports classifying it as a form of *epistemological constructivism*, the theory contains several elements of *limited realism* (Stevens, 1998). According to Raskin (2002),

> ***Epistemological constructivists*** *… believe in the existence of an external reality that is independent of the observer. However, they also believe that it is not possible for observers to know that independent reality except through their constructions of it. Therefore, knowledge is a compilation of human-made constructions……..…..' **Limited realists** believe that an external reality exists. They also contend that it is possible to know that reality directly. However, because human perception is fallible, limited realists assume that the correspondence between knowledge and reality is imperfect'(p. 5)*

Stevens (1998) had no doubt that the theory in question is a form of limited realism because numerous Personal Construct Psychology (PCP) researchers argue that some constructions are indeed better than others if they conform more adequately to the contours of external reality (Landfield,1980; Walker, 1992; Warren, 1992, Howard, 1997; and Warren, 1998). Raskin,(2002; p. 8) contends that 'Whereas epistemological constructivists emphasize the viability of knowledge structures, PCP limited realists believe that some correspondence can be established between constructions and external reality, even if it is imperfect.' This is why Chiari and Nuzzo (1996b) do not consider Kelly's theory a genuine constructivist approach. They go further to suggest that 'Limited realist approaches should not be considered constructivist because such approaches claim that subjective representations mirror, with varying degrees of accuracy, an independent reality' (Raskin, 2002; p.5). However, various PCP theorists who consider PCP just as a version of limited realism do not share that concern. Instead they argue that PCP as a theory of constructivism can only be enriched by greater contact with other constructivist

approaches (Matthews,1992; Wittrock, 1985). This view is supported by Olssen (1996, p. 292) who asserts that 'As the basic constructivist position does not strictly entail ant-realism, it may be possible to preserve the many valuable insights it contains by reconstructing it along more acceptable (realist) lines. This would, of course, be something quite different to what the radical version of the doctrine, as presently defined, claims to represent, however.'

Another recurrent criticism is that Kelly did not talk about development—that is, from birth to adulthood as Piaget did (Fransella, 1995). But it has been argued that the omission was deliberate, in the sense that the whole theory of personal constructs is about development—human beings are seen as forms of motion, no matter what our age (Fransella, 1995). There is a second reason for the omission. The theory rejects all attempts to put people into categories or boxes. It follows that Kelly was sceptical of the prescriptive age and- stage models that characterized the developmental theories of his day, even those of theorists like Piaget who shared some of his constructivist leanings.

Therefore, Kelly's cognitive constructivism alone cannot explain the process of individual knowledge acquisition to the full satisfaction of all the cognitive constructivists in the world. This is because his philosophical perspectives are heavily criticised by other constructivists. Nonetheless, important implications of Kelly's theory which are worthy emphasizing, are that:

i. Learners, in this case student teachers of physics, come into our classes with a range of prior ideas or conceptions of the physical world. In short they are not "empty vessels".
ii. Many of these conceptions differ in important ways from the view of the world scientists have constructed.
iii. Alternative conceptions normally prove difficult to shift and can offer a serious barrier to effective teaching or learning (Tytler, 2002).

Therefore, the more alternative conceptions one holds about any given concepts, the more difficult it is to learn or teach such concepts. In short the theory points to a negative relationship between misconceptions and learner understanding and teaching of physics knowledge. Personal constructivism by Kelly is often seen as related to, but less extreme

than, radical constructivism. It is to the radical constructivist theory of von Glasersfeld (1995) that the researcher turns next.

3.2 Radical constructivism by David von Glasersfeld

3.2.1 The Theory

Since Glasersfeld's radical constructivism is based on Piagetian personal or Individual constructivism, it is necessary to start with a brief account of the former, before explaining the latter. Piaget believed that intellectual development from infancy to adulthood is characterized by movement through a number of stages, each marked by particular ways of thinking about the world, called **cognitive schemas** (Piaget, 1962; Piaget and Inhelder,1969; Piaget,1973; Fontana, 1995; Goswami, 1998). Piaget explains that, this movement is made possible by means of two main psychological processes, assimilation and accommodation (Crain,1992). According to Santrock (2001, p.37),

> *Assimilation refers to using an existing schema to deal with a new object or situation. It occurs when children incorporate new information into their existing schema. Accomodation refers to a situation whereby the existing schema (knowledge) does not work, and needs to be changed to deal with a new object or situation. It occurs when children adjust their schemas to fit new information and experiences (p. 37).*

Therefore, in order to make sense of their world, children cognitively organize their experiences. 'Organisation in Piaget's theory is the grouping of isolated behaviours and thoughts into a higher-order system. Continual refinement of this organization is an inherent part of development'(p. 38).

Santrock (2001), adds that Piaget proposed the process of *equilibration* to explain how children shift from one stage of thought to the next. The shift occurs as children experience cognitive conflict, or disequilibrium, in trying to understand the world. Eventually, they resolve the conflict and reach a balance, or equilibrium, of thought. Therefore, the processes of assimilation and accommodation always take the child to a higher ground.

Santrock (2001, p.38), summarises the Piagetian theory by saying,

> *For Piaget, the motivation for change is an internal search for equilibrium. As old schemas are adjusted and new schemas are developed, the child organizes and reorganizes the old and new schemas. Eventually, the organization is fundamentally different from the old organization, it is a new way of thinking. Therefore, the result of these processes is that individuals go through four stages of development, namely: sensory motor stage (0 to 2 years of age), preoperational stage (2 to 7years of age), concrete operational stage (7 to about 11 years of age) and the formal operational stage (11 to 15 years of age) (p. 38).*

Piaget viewed knowledge acquisition as a process whereby through interacting with the environment *an individual uses past experience to construct new knowledge* (Crain, 1992; Bettencourt, 1993), a view of human knowledge acquisition which is essentially the same one held by Kelly (1966) and many modern constructivists.

In view of the Piagetian theory presented above, most commentators agree that the current constructivist movement in education which began in the mid-1970s has its primary roots in the research and theorizing of the Swiss psychologist Jean Piaget (Gallagher and Reid, 1981; Crain, 1992; Ernest, 1993; Jaworsk, 1994; Steffe and Kiren, 1994; Cobb, 1994; von Glasersfeld, 1995; Rodriguez, 1998; Gunstone, 2000; Howe and Berve, 2000; Matthew, 2000). Von Glasersfeld (1995), the proponent of radical constructivism admits that his views on **cognitive constructivism** are based on those of Piaget' and he states, 'Although I do not continually cite Piaget, I sincerely hope one realizes that almost everything I write herein can be written only because Piaget spent 60 years establishing the basis for a dynamic constructivist theory of knowing' (p. 6). Glasersfeld's own version of Piaget's psychological constructivism, called radical constructivism rests on the following key principles:

1. ' Knowledge is not passively received but actively built up by the cognizing subject

2. The function of cognition is adaptive and serves the cognisation of the experiential world, not the discovery of ontological reality' (Jaworski, 1994; p. 16).

All constructivists agree with **the first principle** given by von Glasersfeld, which boils down to saying ' knowledge is made rather than found' (Bredo, 2000, p.131). According

to this principle it is not possible to transfer ideas into students' heads intact, rather students construct their own meanings from the words or visual images they hear or see (Jaworski, 1994). What the learners already know is of key importance in this construction process. Therefore, ***the first principle emphasizes active construction of knowledge on the basis of the already existing conceptions***. It implies that learners construct the new knowledge actively by themselves on the grounds of the already existing knowledge. 'There is no learning from scratch, there is no simple transfer of pieces of knowledge from a certain source to the learner' (Duit, 1996, p.41). Even Ausubel (1968), a cognitivist who proposed meaningful reception learning contends that 'The most important single factor influencing learning is what the learner already knows; Ascertain this and teach him accordingly points to the key importance of the already existing knowledge' (p.6). According to Burbules (2000, p. 327), 'It is almost a truism to say that all learning is constructed since understanding and evaluating new ideas and skills, even those of the most apparently rote character, requires reinterpreting them in the light of one's existing understandings and abilities.'

Therefore, all constructivists have no problem with the first principle and they accept it as it is. They accept that it is not possible to transfer ideas into students' heads intact; rather students construct their own meanings from the words or visual images they hear or see. What the learners already know is of key importance in this construction process, suggesting that if their prior knowledge is not viable, so shall be their anticipations of reality. In the current study, lack of acceptable scientific views about the concepts in basic electronics would lead to unviable anticipations by physics student teachers. However, many constructivists have a problem with the second principle, which is very controversial and those who accept it, are said to be radical constructivists (Jaworski, 1994).

According to **the second principle**, knowledge of the world outside, is viewed as human tentative construction. 'All knowledge or ideas constructed by the individual about traits of the world outside or about ideas another may have is tentative in nature; It is hypothetical and may need minor or major changes when other evidences become available' (Duit, 1996, p.42). This means that science knowledge as accepted today in scientific communities in principle is tentative in nature and open for revision (Glasersfeld, 1992, 1995). Riegler (2001) supports the second principle by saying that the history of scientific ideas shows all too blatantly that there has been no over-all linear

progression; Fundamental concepts were relinquished and replaced by ideas that were incompatible with earlier pictures of the world. A renowned scientist by the name of Albert Einstein also supports the second principle in the following striking metaphor,

> *Physical concepts are free creations of the human mind, and are not, however it may seem, uniquely determined by the external world. In our endeavor to understand reality we are somewhat like a man trying to understand the mechanism of a closed watch. He sees the face and the moving hands, even hears it ticking, but he has no way of opening the case. If he is ingenious he may form some picture of a mechanism which could be responsible for all the things he observes, but he may never be quite sure his picture is the only one which could explain his observations. He will never be able to compare his picture with the real mechanism and he cannot even imagine the possibility or the meaning of such a comparison (Einstein & Infeld, 1967, p.31).*

The metaphor implies that from the point of view of a person experiencing ontological reality, it is like a 'black box,' in that he has no way of discovering what 'is' and how it might be structured. However, this does not suggest that radical constructivism denies the existence of a world, but it does deny the possibility of rationally describing such a 'real' world. In other words, a 'reality' outside is not denied but it is only possible to know about that reality in a personal and subjective way. The cognizing organism would have no way of determining or deciding whether or not its constructs in any sense reflect the structure of a 'real' world, even if it could come up with structures that are not dependent on its concepts of space and time (Glasersfeld,1989). It is also important to note that, the second principle does not mean that every human construction is allowed. The only constructions which are allowed are those that are "viable". The term"viable". is based on an analogy to the development of the species in evolution. Only those species "survive" that are adapted best to the environment. Per analogicam: 'Only those constructions are "viable" that prove to be useful for the constructor' (Duit, 1996, p. 42).

3.2.2 Application of Von Glasersfeld's (radical) constructivism to classroom situations

Like Kelly's constructivism, when applied to classroom situations, radical constructivism also **implies** that learners do not enter the classroom with "blank minds" but bring their personal experiences, which have a tremendous impact on students' views of how the world works (Schulte, 1996). Since each person's prior knowledge may differ from that

of others, learners anticipate events differently. Some anticipations are acceptable to the scientific community while others are not and so are called alternative conceptions or misconceptions. This view is supported by Dykstra et al., (1992) who says that students come to physics classes with a range of informal ideas about scientific phenomena, interpretations for terminology, and reasonable explanations for how and why things work, based on every day experience and language. In agreeing with Dykstra, Schulte (1996) writes that, Research further indicates that alternative conceptions common to elementary students are not only found among secondary school pupils but also college and university students (Kyle and Shymansky,1989). In fact, at the end of secondary school, large numbers of students still hold many ideas, or conceptions, which are not in accord with the way that scientists understand our world (Guest, 2003).

Misconceptions often interfere with learning because students resist change unless they are dissatisfied with their current explanations and can find sensible alternatives with supporting evidence (Driver and Easley, 1978; Driver and Erickson, 1983; Fleer, 1999; Palmer, 1999). Put differently, since misconceptions may differ from accepted scientific views and are resistant to change, they affect how the corresponding scientific explanations are learned. Champagne, Klopfer, and Gunstone, (1982, p.2) contend that,

> *The constructivist perspective leads to an interpretation of many of the observed regularities and consistencies in students' responses as alternative conceptions that students hold about the natural world and how it works. Two notable characteristics of alternative conceptions are that they are often significantly different from, and thus alternative to, generally accepted views of the subject, i.e., they conflict with ideas teachers want students to learn; and they are surprisingly resistant to change as a result of traditional instruction.*

Learning can only take place if students are dissatisfied with their existing unviable conceptions. The more dissatisfied students are the more likely they will search for and accept new explanations (Palmer, 1999). This reorganization of ideas may require students to discard old views and construct new ones (Posner et al., 1982). The learner must first recognize that his or her current knowledge is insufficient to explain an experience. As learners experience this conflict between their misconceptions and newly discovered scientific explanations, a state of disequilibrium occurs and the student becomes uncomfortable (Palmer, 1999). Once a particular explanation fits the situation, equilibrium exists. 'Piaget believes that people are always trying to reach this state of

equilibrium and constantly test the adequacy of their ideas through assimilation and accommodation' (Schulte, 1996, p. 1). The fewer misconceptions one has about physical reality, the better is one's performance in science knowledge and vice-versa.

Therefore, it is clear from the theory of radical constructivism that humans cannot be given information that they will immediately understand and use. Instead, human beings must build their own knowledge and meaning through experience or rather what they already know.

3.2.3 Criticisms of Glasersfeld's radical constructivism

Von Glasersfeld likes to call the first principle the trivial constructivist principle in order to lead attention to the crucial importance of the second one but he is criticised so much for this by cognitive and social constructivists. They say that the term "trivial constructivism" appears to be "ill-chosen" (Ernest, 1993; Solomon, 1994; Duit 1996). This is because it is far from being trivial to put this principle into practice. They further argue that, there are strong logical relations between the two principles. The key idea is in some way already in the first principle, the second one may well be viewed as a further elaboration of the first. As Bredo (2000) puts it, the second principle amounts to saying that 'The objects and properties that we experience and know are…….in some manner products of human (mental or physical) activity' (p.131). This view is endorsed by von Glasersfeld himself, who asks what radical constructivism is, and then explains as follows:

> *It is an uncontroversial approach to the problems of knowledge and knowing. It starts from assumptions that knowledge, no matter how it is defined, is in the heads of persons, and that the thinking subject has no alternative but to construct what he or she knows on the basis of his or her own experience. What we can make of experiences constitutes the only worlds we consciously live in…..Taken seriously, this is a profoundly shocking view (von Glasersfeld, 1995, cited in Phillips 2000b, p. 10).*

According to Phillips (2000b, p.12), 'What von Glasersfeld says is shocking because it isolates each one of us in a universe of our own construction.' Howe and Berv (2000, pp. 32-33) agree with Phillips by saying, 'The unpalatable implication of von Glasersfeld's second statement is that 'Individual knowers can construct truth that needs no corroboration from outside of the knower, making possible a number of truths.' In other

words, this would mean that ‘No form of knowing can make any kind of a claim to have a higher value or privileged position’ (Terhat, 2003, p.27). This is why social constructivists argue that accepting this view of learning would create difficult pedagogical puzzles for schools. They question what the teacher is trying to teach if students are all busy constructing their own private worlds, what the grounds for getting the world right are and why we should even care whether these worlds agree. They argue that, ‘For school learning to be meaningful there should be “a shared world”, that is a world made up of shared meanings’ (Howe and Berv, 2000, p.33). Serpel (1993) also shares this view and states, ‘Many of society’s institutions are based on the premise that knowledge is shared; No laws, or schools, or libraries would make any sense in the absence of this premise’ (p.357). Therefore, it is a common feature of critiques on radical constructivism (arising from the second principle) that this position is accused of leading to the denial of the existence of the physical world outside (Goldin, 1991; Suchting, 1992; Olssen,1996).

But Ernest (1993) says that this is an incorrect conclusion, because von Glasersfeld points out in a number of articles that ‘Radical constructivism is ontological neutral’ (von Glasersfeld, 1992, p. 32). A ‘reality’ outside is not denied by Glasersfeld (1992), but it is only possible to know about that reality in a personal and subjective way. From a cognitive constructive perspective, he believes that there is a real world that we experience (Duffy and Jonassen, 1992), thus appearing to find an ontological base in objectivism; however, this world cannot be directly known (Derry, 1992), which broadens the nature of the ontology to realism. That reality exists is not denied; however, what we know of the world is only an interpretation based on our experiences (Glasersfeld, 1995). In other words, like Kelly (1966), all he denies is the possibility of any certain knowledge of reality. This means that the constructivist view does not necessarily lead to an idealist position but is also compatible with a critical realist view (Duit, 1996).

Hawking (1988) further clarifies this, saying,

> *The most frequent objection takes the form of the accusation that constructivism denies reality. But this it does not. It only denies that we can rationally know a reality beyond our experience. Constructivism has no quarrel with the mystics who express their intuitions about a transcendent world in poetic metaphors which, of their nature, are not translatable into scientific language. From my point of view, the trouble is that most critics seem to be unwilling to accept the explicit, programmatic statement that constructivism is a theory of knowing, not of being. (p.10).*

Therefore, von Glasersfeld's radical constructivism seems to most clearly exemplify epistemological constructivism which supports the existence of an external reality that is independent of the observer. However, it also believes that it is not possible for observers to know that independent reality except through their constructions of it. This is why Raskin (2002, p. 4) says,

> *Knowledge is a compilation of human-made constructions. Such constructions are heuristic fictions useful for understanding the world. In this regard, epistemological constructivism sees knowledge schemes as being classifiable as more or less viable rather than more or less accurate. People cannot know for certain if their constructions correspond to an independent reality, but they can know if their constructions work well for them.*

But in practice, constructivism faces difficulties here because, usually, the epistemological and ontological claims are not that easy to separate. A chief difficulty with the constructivist idea of 'making sense' or 'constructing' experience is that ultimately it leads to **idealism** and invariably to **relativism**, as it is impossible to say that one view of the world or of the state of society is any more valid than any other (Olssen, 1996).

Duit (1996), also questions the emphasis of radical constructivism on the individual. He explains that, 'Self-activity may lead to overlooking the point that a substantial amount of guidance is necessary to make students able to construct desirable conceptions' (p.43). Activity theory views "self-development" and "being-developed" as complementary issues in knowledge construction but in radical constructivism, there is a tendency to overemphasize the "self-development" side (Wolze and Walgenbach, 1992).

In an effort to address the criticism that ‘radical constructivism puts its main emphasis on the individual and hardly pays attention to the social aspects’ (Solomon, 1994), radical constructivism as proposed by von Glasersfeld now implicitly includes a third principle. It proposes that ‘Although individuals have to construct their own meaning of a new phenomenon or idea, the process of constructing meaning always is embedded within a social setting of which the individual is part’(Duit, 1996; p 42). This implies that, although every individual has to construct knowledge by her or himself the construction process always also has a social component. Individuals' construction of their ways of knowing is the focus of von Glaserfeld, but, he also recognizes the importance of social interaction as a process of meaning negotiation in this subjective construction of knowing. Von Glasersfeld sees learning as an active process of self-organization in which the individual eliminates ‘perturbation’ (disequlibrium in Piaget's term) from the interaction with others as well as an active construction of viable knowledge adapted from the interaction with others. Duit (1996) states, ‘Knowledge and ideas that have been constructed need to be viable, i.e. useful for the individual (or a group of individuals respectively); Only constructs that stand the test of being viable survive so to speak’ (p, 42).

Therefore, von Glasersfeld’s radical constructivism alone cannot also explain the process of individual knowledge acquisition to the full satisfaction of all constructivists in the world. This is mainly because his second principle is heavily criticised by various constructivists, including some post-positivists such as Matthew (1992), who could have been on his side.

Despite these criticisms, it is clear that radical constructivism, like Kelly’s constructivism, acknowledges that learners enter the classroom with alternative conceptions which are often significantly different from, and thus alternative to, generally accepted views of the subject they may be learning. These misconceptions conflict with ideas teachers want students to learn and they are surprisingly resistant to change as a result of traditional instruction (Champagne, Klopfer, & Gunstone, 1982.) This implies that the more misconceptions a learner has the more difficult it is for one to gain expert understanding (Hammer, 1996; Knight, 2004). The following Section , 2.3, now presents important ideas that led to the combination of the two theories above into a single theory of cognitive constructivism, which was used as the theoretical framework of the study.

3.3 Important things emanating from Kelly's constructivism and Glasersfeld's Radical constructivism.

From Sections 2.1 and 2.2, it can be seen that there are four premises common to Kelly's constructivism (1966) and Glasersfeld's radical constructivism (1995), a combination of which constituted the theory of cognitive constructivism, which was used as the theoretical framework of the study.

The first premise is that 'People are informationally closed systems, only in direct contact with their own process' (Raskin, 2011; p. 2). It springs from personal construct psychology and radical constructivist presumptions of meaning as personal and private (Kelly, 1955; Glasersfeld, 1995). The premise challenges the usual view of information as independent of people, passing in and out of them. Instead, what people know is conceived as something they generate in response to internal and external triggers (Mahoney, 1991; Glasersfeld, 1995).In that regard, people are closed systems because they only know what is outside indirectly via how their internal processes respond to and make meaning upon being stimulated (Raskin, 2011).

The second premise is that People are active meaning makers (Raskin, 2011). Both Glasersfeld and Kelly spoke of this in somewhat different, but complementary, ways. Glasersfeld (1995) theorized that 'People create a subjective internal environment populated by "repeatable objects" that are treated as "external and independent". People also construct representations of other people, who not only are treated as external and independent entities, but also as having the same powers of active meaning-making and intentionality that they attribute to themselves' (Raskin, 2011, p.2). Similarly, Kelly (1955) presumed people to be active meaning-constructors who devise hypotheses about the world and then test them out in the course of daily living. He criticized approaches that saw people as passively determined by external forces (Kelly, 1966). Instead he proposed his person-as-scientist metaphor (Kelly, 1955), because to him, people are always actively constructing, testing, and revising the hypotheses they have devised (Raskin, 2011).

The third premise claims that "People are social beings, using their intersubjective experiences to confirm the utility of their constructions. 'This premise attempts to integrate the insights of social constructionism with the traditionally private and personal

constructivist worldview' (Raskin, 2011, p.2). However, though Glasersfeld (1995) and Kelly (1955) stressed the importance of the social, neither of their theories is readily compatible with the social constructionist idea that meaning is a shared creation (Raskin, 2011). 'Rather, each person construes the constructions of others and, in so doing, comes to coordinate with others in ways that subjectively feel like shared understandings – or social constructions' (Raskin, 2011, p.3). Glasersfeld (1995) conveyed this when discussing how we come to experience an intersubjective reality, which results when others respond to us in a manner that confirms our sense that they understand things as we do. Similarly, Kelly (1955) posed the notion of sociality, whereby we construe one another's constructions and, in doing so, are able to effectively adopt roles in relation to one another.

The last but not the least premise is that people engage in both ontological and epistemological modes of construing, alternating between them as necessary (Raskin, 2011) that is they alternate between two modes of construing. The ontological mode refers to instances when one's construing focuses on the external world, or that which is experienced as distinct from oneself and real in its own right while the epistemological mode refers to instances when people switch their attention to how and why they construe as they do. Therefore, when construing epistemologically, focus changes from understanding the world to understanding one's understanding. People regularly toggle back and forth from ontological to epistemological modes of construing (Raskin, 2011).

It is important at this stage to note that although the theories above have several premises in common, there are few differences between them. The first one is that while Glasersfeld's ontological base seems to be in realism (Derry, 1992), Kelly's ontological base seems to be in limited realism. This is because of the latter's claim that some correspondence can be established between constructions and external reality, even if it is imperfect (Raskin, 2002). Put differently, Kelly's approach claims that 'Subjective representations mirror, with varying degrees of accuracy, an independent reality' (Raskin, 2002; p.5). Another difference is that Kelly did not consider development—that is, from birth to adulthood which von Glasersfeld adopted from Piaget. Regardless of the above differences, it is clear that:

- The combination of the two cognitive constructivist theories above (cognitive constructivism), acknowledge that learners enter the classroom with alternative

conceptions which are often significantly different from, and thus alternative to, generally accepted views of the subject they may be learning. These misconceptions conflict with ideas teachers want students to learn and they are surprisingly resistant to change as a result of traditional instruction (Champagne, Klopfer, and Gunstone, 1982) The more misconceptions a learner has the more difficult it is for one to gain expert knowledge (Hammer, 1996; Knight, 2004). Therefore, the framework points to a negative relationship between physics student teachers' misconceptions and their performance in basic electronics.

- Individuals, create mental maps or cognitive structures that enable them to understand their environment. If new information is presented that fits into existing structures, the person incorporates (assimilates) the information (Crain, 1992). If it does not fit into a structure, that person accommodates it, that is, constructs new mental structures into which it fits (Santrock, 2001). In doing so, the individual continually constructs his or her understanding of the world around him or her.

It is this cognitive constructivist position the present study adopted as the theoretical framework. This view of learning has for the last two decades guided a number of successful curriculum innovations around the world in mathematics and science. One of these was the Cognitive Acceleration through Science Education (CASE) in London, United Kingdom whose aim was to determine whether changing secondary pupils' cognitive ability would improve their performance in science (Bennett, 2003). 'As a result of CASE experiments, many schools in the United Kingdom adopted and implemented CASE ideas, making a far greater impact on science classroom practice than any other research study' (Benette, 2003; p. 67).

3.4 Implications of the cognitive constructivist theory

(a) For science pedagogy

It is clear from the theory above that as learners, student teachers of physics have several misconceptions about the content they learn, which in turn negatively affect the way they teach. The implication of this is that, physics educators should use physics student teachers' previous knowledge to help them assimilate or accommodate new information.

Furthermore, 'innovations in physics pedagogy such as conceptual change teaching strategies may help in dealing with students' alternative conceptions' (Cakir, 2008, p. 203).

(b) **For science teacher training**

In view of the above misconceptions, Cakir (2008, p.203) advises that physics teacher training programmes should aim at equipping physics student teachers with the following:

(i) **What physics educators have found out about students' misconceptions in physics:** This knowledge helps the teacher to develop an awareness and understanding of the nature and sources of students' misconceptions, which is a first step in designing suitable instructional strategies.

ii. **Methods for diagnosing misconceptions held by students before and after instruction:**

This information allows the teacher to monitor students' learning problems, which will provide continuous feedback on the effectiveness of the teaching strategies used.

iii. **Designing instructional strategies that tackle students' misconceptions:**

This involves planning and structuring curriculum materials and learning activities using the constructivist approach that aims at promoting conceptual change and development such as the use of examples and analogies, cognitive conflicts, concept maps, demonstrations and student activities.

iv. **Reviewing selected areas of subject matter in which teachers have conceptual problems.**

Teacher training courses should provide learning experiences for teachers to refresh and consolidate their understanding on certain difficult concepts of the school curriculum such as those in basic electronics.

3.5 Chapter Summary

The aim of Chapter 3 was to explain the meaning of cognitive constructivism as it is used in the context of science teaching and learning, and to show how the theory informs the present study. To do this, it was first necessary to explain Kelly's constructivism and

Glasersfeld's radical constructivism as they are the two cognitive constructivist theories that guided the study. Although both theories propose that '***learners construct the new knowledge actively by themselves on the grounds of the already existing knowledge***' (Glasersfeld, 1995), they are at the two extreme ends of the constructivist continuum with Kelly appearing to be in limited realism and von Glasersfeld appearing to be in realism.

Therefore, in this case a combination of Kelly's theory and Glasersfeld's constructivist theory informs the study in a number of ways. It suggests that :

- The learner's prior knowledge is the primary determiner of what he/she learns next.

- The prior knowledge (cognitive structure) above may either be viable or unviable. According to Knight (2004), many of the students' common-sense theories turn out to be unviable and are called misconceptions. The central ideas of these misconceptions are that they are strongly held, stable cognitive structures which differ from expert conceptions, affect how students understand natural phenomena and scientific explanations and must be overcome, avoided, or eliminated for students to achieve expert understanding (Hammer, 1996). One way to do this is to utilise a generative model of learning approach (Biddulph and Osborne, 1984).

- Third, the framework suggests that the more misconceptions a learner has the more difficult it is for one to achieve expert understanding and vice versa (Hammer,1996), which implies a negative correlation between learner misconceptions and their performance in a subject area such as physics.

- Fourth, since Kelly's ontological base seems to be in limited realism while Glasersfeld's ontological base seems to be in realism a combination of the two theories promotes objective and subjective side of personality research respectively (Boeree, 2006) and so allows use of both quantitative and qualitative research approaches. This is the theoretical framework that guided the study. The next chapter discusses the literature related to misconceptions held by student teachers of physics.

CHAPTER 4

REVIEW OF RELATED LITERATURE

4.0 Introduction

Chapter 4 presents the literature reviewed on physics student teachers' conceptions and performance in basic electronics. The literature was reviewed according to the four research questions. Therefore, Chapter 4 has five sections, 4.1 to 4.5. The first four sections address the four research questions of the study, as they are arranged in chapter 1. Section 4.5 is a chapter summary and it includes the gaps which were identified in the literature reviewed.

4.1 What misconceptions do student teachers of physics have about basic electronics, as they finish their training?

This study worked in a framework explained in Chapter 3, which does not see a student as an empty vessel but as someone with some understanding of basic electronics concepts, namely: Thermionic emission, cathode rays, action of resistor, potentiometer, thermistor, light dependent resistor, diode, capacitor, reed switch, reed relay, transistor, logic gates, bistable circuit, astable circuit including computer hardware and computer software. The study compared that prior understanding with what has been established in Zambian ordinary level physics as acceptable scientific viewpoints about such concepts as presented in two physics text books, namely: Principles of physics by Nelkon (1981, pp. 532-555; 584-593) and Essentials of physics by Wilkinson (1993, pp. 472- 516). The two textbooks have been used for a long time in the teaching of ordinary level physics in Zambian secondary schools and the preparation of grade 12 physics examinations. The concepts above were used to establish what conceptions student teachers of physics had in basic electronics. Student teachers' understanding (i.e description, explanation, interpretation etc.) of the basic electronics concepts above which were significantly different from those given in either of the two named text books were regarded as *misconceptions or alternative conceptions*. The chapter starts with a review of literature on misconceptions about basic electronics, which is the main area of concern in the current study. After that the chapter presents a review of literature on misconceptions

about other sections of ordinary level physics. These sections are not part of basic electronics, but are in one way or the other connected or applicable to it.

4.1.1Physics student teachers' misconceptions about basic electronics

Basic electronics is a wide section of the "Zambian ordinary level physics syllabus, 5054" and is divided into five main subsections: Thermionic emission and electronics, Circuit components, Simple electronic systems, Computers and the Impact of electronics on society and industry. The first subsection, 'Thermionic emission and electronics', involves: describing thermionic emission and properties of cathode rays; distinguishing between direction of flow of electrons and flow of conventional current; illustrating applications of electron beams in electronic devices and finally describing the basic structure and action of the cathode ray oscilloscope in scientifically acceptable ways (CDC, 2015). The cathode ray oscilloscope is very useful in test equipment, radar, television receivers, and computers to present a visual display (William, Trinklein and Metcalfe, 1976; Breithaupt, 1994). Research shows that learners have misconceptions on properties of cathode rays. For example, in New York, Millar (2012) conducted a study to find out what students thought the nature of cathode rays was. The findings show that students had misconceptions about cathode rays. Some thought that cathode rays were particles, others thought they were waves while still others believed that they were both particles and waves. It is true that cathode rays comprise electrons which exhibit both wave and particle behaviour (Wilkinson, 1993), but participants in that study did not give a specific answer. Furthermore, they thought that matter waves were like electromagnetic waves and yet they are not. The Millar (2012) study was similar to the current study in the sense that they both looked at learner misconceptions on cathode rays. However, the difference was that the former only focused on cathode rays while the latter addressed all areas of the first subsection of basic electronics. Furthermore, the two studies were done in different countries.

The second subsection of basic electronics, 'Circuit components', involves: listing basic circuit components such as resistor, potentiometer, diode, capacitor, thermistor, light dependent resistor, reed switch and reed relay; determining resistor values using standard colour codes; describing the action of variable potential divider; explaining the action and application of thermistor and light dependent resistor; describing charging and

discharging of capacitors for variable values of capacitors at low voltage; explaining how a reed switch and reed relay work; demonstrating application of reed switch and reed relay in alarm bells, starter motors and the telephone (CDC, 2000). The researcher found a study which was done by Driver (1994) on the behaviour of a resistor in a series circuit. The results of that study revealed a preconceived notion held by students that, if there is a resistor before a lamp, the resistor will dim the lamp in a circuit, but if the resistor is after the lamp then it will have no effect on the intensity of the light. This showed that the students did not have the understanding that current in a circuit is a flow of charge that is conserved. This study was done in London and indirectly addressed the issue of charge conservation regardless of where the resistor was in a circuit. The current study addressed not only the issue of determining effective resistance of electronic resistors but other areas of the second subsection as well.

Chen et al. (2013) did a study titled "Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model." The study investigated concepts of diodes, which comprised some conceptual contents such as "semiconductor concept of a diode", "feature of diode bias", "simplified model of a diode", and "basic circuit of a diode." Researchers investigated the misconceptions about diodes and related concepts by reviewing the literature and conducting a diagnostic test (Lee and Law, 2001; Engelhardt and Beichner, 2004; Sencar and Eryilmaz, 2004; Periago and Bohigas, 2005; Küçüközer and Kocakülah, 2007). The 40 questions in the diagnostic test provided by researchers and two subject-matter experts were used to collect data on misconceptions about diodes. First of all, 64 sophomores (who had previously studied diodes) were asked to answer some questions. Their answers were then analyzed to summarize all possible misconceptions held by the students.

Results, indicated that there were 7 misconceptions about "semiconductor concept of a diode," 4 misconceptions about "feature of diode bias," 7 misconceptions about "simplified model of a diode," and 10 misconceptions about "basic circuit of a diode" (Chen et al., 2013). Twenty-one of the 28 misconceptions about the concepts of a diode listed were related to semiconductor characteristics, bias types, elementary models, and applicable circuits. Four of them were attributed to incorrect analyses of basic electric current, voltage, and circuit behavior (i.e. "The output current passing through an element

in a circuit is less than the input current", "Incorrect definition of the average output voltage of a rectifier", "Incorrect definition of the RMS (root mean square) output voltage of a rectifier", and "Confusion about concepts of basic series-parallel circuits", while the last three were ascribed to the interaction between fundamental concepts of current (or voltage) and diode (i.e., "No current in parallel resistances when a diode is conducting", "The current passing through a zener diode is equal to the current passing through a load resistance", and "No current passes through a load resistance when the breakdown voltage is applied to a zener diode). These past misconceptions directly affected not only the learning of relevant concepts but also resulted in further misconceptions due to interactions (Chen et al., 2013).

The study by Chen et al. (2013) was very helpful because it brought out a lot of information about diodes. However, it only used a diagnostic test to determine student teachers' misconceptions. The current study used a misconception questionnaire and the results were confirmed by the data obtained from the basic electronics test and an attitude scale. Furthermore, apart from investigating misconceptions on diodes, the current study addressed all other areas of the second subsection of basic electronics while the former only focused on the zener diode. In addition, some of the details on the zener diode which the Chen et al. (2013) study in Japan focused on were not relevant to the Zambian ordinary level physics syllabus. This is why the current study focused on all the relevant knowledge of basic electronic circuit components in the Zambian context.

The area of 'Simple electronic systems' in basic electronics involves: describing the action of a bipolar transistor in electronic circuits; stating in words the action of logic gates: AND, OR, NAND, NOR and NOT (Inverter); deriving the truth tables of logic gates; demonstrating and describing cross-coupled logic gates, as bistable circuit (for memory) and as an astable circuit (for pulse generator); relating qualitatively the frequency of an astable circuit to the values of the resistive and capacitive component (CDC, 2015). Although the current framework pointed to the fact that student teachers of physics had misconceptions about fundamental concepts in physics (Knight, 2002), no literature was found on 'Simple electronic systems' to ascertain the claim both in and outside Zambia. Hence, this study which investigated the conceptions held by physics student teachers about that area of basic electronics as well.

The fourth subsection of basic electronics, which has been a component of the '5054 Physics Syllabus' for many years, but which is now part of the Zambian revised ordinary computer studies syllabus, is "Computers." This section involves: defining a computer; stating the major components of a computer system such as the input devices, CPU and output devices; describing the functions of the main components of a computer system; distinguishing between computer hardware and software. Furthermore, it involves discussing and demonstrating uses of computers in everyday life in word-processing, calculations, data analysis, communication and e-mail. Though the theoretical framework did not consider any area of physics to be free of learner misconceptions, no literature was found both in and outside Zambia to show what misconceptions student teachers of physics had on the named concepts. This is why the current study investigated the misconceptions held by physics student teachers about such concepts as well.

The last subsection of basic electronics, "Impact of electronics on society and industry", involves: discussing the impact of common electronic devices and systems on domestic and industrial activities, with reference to radio, television, telephone, calculators, computers, robots as some examples. From the theoretical framework there was no doubt that student teachers of physics had misconceptions on this subsection of basic electronics as well (Kelly, 1966; Glasersfeld, 1995). However, even in this case no literature was found both in and outside Zambia on misconceptions about the impact of electronics on society and industry.

Therefore, it was clear from the afore review of literature that research does not show misconceptions held by student teachers of physics in basic electronics in the Zambian context. And yet, in Zambia, despite its importance, electronics is rated the most difficult section of the senior secondary school physics syllabus even for the qualified teachers of physics (Haambokoma et al., 2002). Many teachers (65%) rate themselves not confident in teaching electronics and so are least comfortable to teach that section of physics. According to Haambokoma et al.(2002), the major reason given by teachers of physics for such difficulties was that they did not have adequate knowledge in basic electronics. Many Heads of Science Department in Zambia also agreed and suggested that teachers of physics needed help in understanding electronics theoretically and practically.

As a result of teachers' lack of appropriate knowledge of basic electronics, pupils also found among others, electronics, a difficult section to learn in senior secondary physics. Haambokoma et al. (2002) add that in the SMASSE study, carried out in Kenya in 1999, teachers had difficulties teaching and pupils had difficulties learning among other topics, Electronics. In Zambia pupils advanced some reasons for finding electronics difficult to learn. 'One of them was no/or unclear explanation from teachers' (Haambokoma et al., 2002; p. 142). However, it is important to note that although this study identified basic electronics as the most difficult section to teach in Zambia, it was not about misconceptions but just nearer to misconceptions.

The scanty literature on misconceptions in electronics was done outside Zambia and mainly centred on one aspect, the zener diode, which is not relevant to the Zambian secondary physics syllabus. The current study focused on misconceptions in all areas of basic electronics as stipulated by the Zambian ordinary level physics syllabus (CDC, 2000, pp. 36-40) and the revised Zambian ordinary level physics syllabus (CDC, 2015, pp. 1-65). Section 4.1.2 highlights student teachers' misconceptions about electricity which is closely related to electronics. This is because both electricity and electronics require electrons for their operations.

4.1.2 Physics student teachers misconceptions about Electricity

According to Baser (2006, pp.369-370) 'Concepts in direct current electricity are abstract, as a result students develop a wide range of alternative conceptions related to current, potential difference, complete circuit, and power dissipated within circuit elements.' These alternative conceptions have been the focus of many studies in physics education (Lee and Law, 2001; Sencar and Eryilmaz, 2004; Engelhardt and Beichner, 2004; Periago and Bohigas, 2005; Cepni and Keles, 2006). They are common not only to students but also to teachers, and are observed in various countries (Shipstone et al., 1988).

For instance, many students consider that a single wire is enough to carry current from the positive terminal of the battery to a bulb and so the connection of negative terminal of the battery to the bulb is unnecessary (Fredette and Lochhead, 1980). On the other hand, there are students who think that electric currents coming from positive to negative terminal of the battery meet at the bulb, get used up in the bulb and consequently shine it

(Osborne, 1983). In addition, many students believe that current flows in one direction around the circuit and is being used up, and so it is less available to other elements further along in the circuit (Shipstone et al., 1988). One similarity between these studies and the current study is that they all address misconceptions on the direction of flow of conventional current. However, they are different in the sense that they address issues of conservation of charge, which the current study does not do and were done outside Zambia.

On the variation of potential difference across a metallic conductor with resistance of the conductor and current passing through the conductor, most students only rely on current and ignore or underestimate the importance of resistance information (Liegeois and Mullet, 2002). Moreover, many students have the idea that there is no potential difference in an open circuit (Engelhardt and Beichner, 2004). Students also have many difficulties in analyzing electric circuits. For example, if a circuit is modified, they tend to analyze only the modified part of the circuit rather than the whole circuit (Cohen et al., 1983). The resistance information does not only apply to electrical circuits but also those that are electronic. In this regard, the study by Liegeois and Mullet (2002) on variation of potential difference or current with resistance were similar to the current study.

Understanding electric diagrams and interpreting a short circuit are difficult for students. Engelhardt and Beichner (2004) highlight some students' alternative conceptions related to direct current electricity. They explain that some students have difficulties in understanding the induced emf and how it is produced. They further explain that there are students with a misconception that since charges cannot move in an insulator, there is no electric field. All these findings confirm that student teachers of physics have alternative conceptions about electricity.

Therefore, it is true the studies in subsection 4.1.2 that student teachers of physics have misconceptions on electricity which are related to those that they have on electronics. However, none of the studies was done in Zambia to ascertain such misconceptions.

Section 4.1.3 reviews literature on misconceptions about waves, which are also connected to electronics in various ways. For example, though accelerating electrons in basic electronics are not electromagnetic in nature, they exhibit wave properties such as interference and diffraction (Wilkinson, 1993). According to Wilson and Buffa (1997, p.642),

> *Electromagnetic waves are produced by accelerating electric charges, such as an electron oscillating in simple harmonic motion. This could be one of the many electrons in the antenna of a radio transmitter, driven by an electrical oscillator with a frequency of about 10^6Hz. As such an electron moves, it continually accelerates and decelerates, and radiates an electromagnetic wave. The continual oscillations of many such charges due to the alternating current in the transmitter produce time-varying electric and magnetic fields in the immediate vicinity of the antenna.*

A combination of varying electric and magnetic fields results in electromagnetic waves, such as Radio waves, that are used in communication. However, studies show that physics student teachers hold misconceptions on waves as well.

4.1.3 Physics student teachers' misconceptions about Waves, Sound and Light

In South Africa, Coetzee and Imenda (2013) conducted a case study aimed at identifying the most prevalent alternative conceptions relating to interference and diffraction of waves amongst first year physics students at a University of Technology. The research sample comprised 133 students. A questionnaire and a test were used to collect the required data. Although quantitative data were collected, the main thrust of data analysis for this paper was on the qualitative data generated.

The results showed that the students held many alternative conceptions concerning interference and diffraction of waves including the notions that:

> *(a) the principle of superposition applies along both the y and x axes, (b) interference is associated with reinforcement and not destructive interference, (c) interference results in the average effect – hence two identical waves won't have any effect on one another, (d) waves have mass, exert force and occupy space, (e) waves have positive or negative charges, which result in attractive and repulsive forces, (f) amplitude is directly proportional to period, and (g) sound and electromagnetic waves are the same concept (Coetzee and Imenda, 2013; p.1)*

It was further established that students were confused by the different meanings and interpretations of the concepts of in phase, out of phase, constructive and destructive interference, given in literature and different text books (Coetzee and Imenda, 2013). It

was noted that these could have led to the incidence and prevalence of alternative conceptions.

The study by Coetzee and Imenda (2013) yielded very helpful information and it was done in Africa like the current study. However, it used first year students of physics while the current study used students of physics who were about to complete their degree programme. Secondly, the study gathered quantitative data using a test but did not utilize such data much because the thrust of data analysis was on the qualitative data generated. It is true that use of both quantitative and qualitative data analysis could have affected the framework of the study and its methodology. But it could have helped the researcher to achieve an extended understanding that qualitative data analysis alone could not offer.

Houle and Barnett (2008) described the impact of one of the developed modules, on students' understanding of sound. The module incorporated a technology-rich scientific investigation with traditional, well-established sound learning activities. Their findings suggest that 'While the investigation was successful, students' understanding of the properties of sound were mixed.' (p. 242). Duit's (2007) misconception database, lists nearly 7,700 studies that examined students and teachers understanding of scientific concepts. These studies found that from an early age, students strive to understand the natural world and in the process develop their own theories and mental models to explain their experiences and observations. In general, these studies reported that students' theories and models are contrary and in conflict with currently accepted theories and models of the scientific community. A good number of these studies addressed sound (Linder 1987; Linder and Erickson 1989; Borstad 1989; Linder, 1992/1993; Maurines 1993; Barman 1996; Mäzens 1997; Rosser, 1998; Leite and Afonso 2001; Hrepic et al. 2002; Mäzens and Lautrey, 2003; Eshach and Schwartz, 2006). From these studies, two major misconceptions regarding sound emerged from the literature. The first major consensus across the studies suggests students tend to hold a materialistic view of sound. Students view sound as a substance with the physical properties of matter rather than as a process of energy transmission through a substance. This misconception has been found in young children, as well as college and university undergraduates (Linder and Erickson 1989; Mäzens and Lautrey, 2003).

A study examining ten middle school students' conceptions of sound found that sound was perceived as a "sort of material" which is pushable, frictional, containable and transitional (or able to move or be moved) (Eshach and Schwartz, 2006). That study also found that students' conceptions of sound lacked internal consistency. A second theme emerging from the literature suggests confusion regarding students' written representations of sound as a transverse wave. Linder (1992) suggests ' the pictures and schematic representations of sound commonly used in textbooks and lectures may not only be misleading but also false' (p. 263). In other words, sound is often portrayed as a sinusoidal wave. While these waveforms may be useful in discussing the characteristics of waves, sound actually travels as a compression wave. Furthermore, Eshach and Schwartz's (2006) interviews suggest the vernacular usage of the word "waves" in "sound waves" evokes images of water waves and further supports the misconception of sound waves as a transverse wave.

On light there were students who believed that we see because light shines on things and brightens them (Janet et al., 1984). This is why Bendall et al. (1993) believed that most of the older students have the idea that the eye plays an active role while the object has a passive role in vision**.** Such students did not realise that we see because the light shining on objects is reflected off them to our eyes. Therefore, they are not aware of the role that bouncing or reflected light plays in seeing. The descriptions of how our eyes work also depend on the understanding that we see the light that is reflected off objects to our eyes, rather than the objects themselves (p.367).

These are very interesting findings about alternative conceptions held by students on waves, sound and light. They confirm the fact that student teachers in Africa hold similar misconceptions like colleagues in other countries in the world. However, they focused on the nature and properties of waves while the current study focused on basic electronics in general including the nature of cathode rays. In addition, unlike the current study which was done in Zambia, all the studies above were done in other countries.

Subsection 4.1.4 addresses misconceptions on other areas of ordinary level physics which apply to basic electronics in one way or another. For example, in thermionic emission we need to know the mass of an accelerating electron and its speed, in order to determine its kinetic energy at any given point in a CRO. Therefore, knowledge of physical quantities such as: mass, weight, distance covered, speed, velocity and acceleration of moving

electrons is very important. Student teachers of physics also need to have a good understanding of quantities like work to determine the energy needed to free an electron from a given material, heat to determine the temperature required for thermionic emission to take place and kinetic energy in order to determine the amount of light that may be produced when accelerating electrons strike the screen of a CRO. Therefore, these quantities are very important serve as a pre-requisite to the understanding of basic electronics. However, student teachers of physics have several misconceptions about such quantities which make it difficult for them to understand the work on basic electronics. These misconceptions are outlined in the section that follows.

4.1.4 Physics student teachers' misconceptions about other areas of ordinary level physics which apply to basic electronics

Gonen (2008) conducted a study in Turkey, whose aims were considered under three headings. The first was to elicit misconception that pre-service science student teachers held about the terms, "inertial mass", "gravitational mass", "gravity", "gravitational force" and "weight". The second was to understand how prior learning affected their misconceptions, and whether teachers' misconceptions affected their students' learning. The third was to determine the differences between science student teachers' understanding levels related to mass and gravity, and between their logical thinking ability levels and their attitudes toward physics lessons.

A total of 267 science student teachers participated in the study. Data collection instruments included the physics concept test, the logical thinking ability test and physics attitude scale. All instruments were administered to the participants at the end of the 3rd semester of their university years.

The results revealed that science student teachers held several misconceptions concerning fundamental physics concepts. The inertial mass, the gravitational mass, the gravitational force, gravitational acceleration and weight were among such concepts. For example, the findings revealed that 'mass is the force of a body exerted on earth' (Gonen, 2008; p.76).

These concepts are basic to scientific concepts and play a pivotal role in the understanding of other concepts in different disciplines of natural sciences including electronics. Therefore, where student teachers misunderstand such fundamental physics

concepts, it is not likely that they will find knowledge of basic electronics, such as the behaviour of cathode rays in intense gravitational fields easy to comprehend.

In basic electronics, student teachers of physics deal with motion of electrons as already. Sometimes they need to determine the distance covered, velocity or acceleration using equations of motion or graphically because graphs of kinematics variables are a staple of physics. Unfortunately, student teachers have several misconceptions on kinematics graphs. McDermott, Rosenquist, and van Zee (1987) found that students, even those in the honors section of a calculus-based university physics course, had trouble interpreting kinematics graphs. Common problems include discriminating between the slope and height of a graph (Bell and Janvier 1981; McDermott, Rosenquist and van Zee, 1987; Clement 1989) and relating one type of graph to another (Brasell 1987; McDermott, Rosenquist, and van Zee 1987). Students often expect the distance-time graph of an object to be similar to the velocity-time graph of the object (Brasell, 1987, p.415). That is why Hale (2000) asserts that 'Students come to the mathematics classroom with their own understandings of velocity, acceleration, and distance that are based on their personal experiences.

This view is shared by Stepans (1994), who contends that:

> *Beliefs resulting from personal experience, intuition, and 'common sense' lead students to form their own ideas and models, often well before formal instruction. These experiences and feelings seem to contradict what students read in their textbooks and/or are taught by their teachers. Worse still, even with instruction, it is often difficult for students to give up these ideas, or they may revert to them later even though it appears they may have learned the correct ideas in class* (p.1).

A good understanding of the concept of energy enables learners to understand thermionic emission, kinetic energy of electrons and production of light on cathode ray screens. However, research shows that student teachers have misconceptions about energy. Trumper (1998) conducted a 'Longitudinal Study of Physics Student teachers' Conceptions on Energy in Pre-Service Training for High School Teachers'. The energy conceptions of the Physics students were analyzed by means of a two-part written questionnaire that was presented to the same group on their first day of class for four years running.

The most important findings of this study can be summarized as follows.

> *Despite their pre-service training, future physics high school teachers: Hold a number of different alternative conceptual frameworks when describing physical situations, instead or besides the accepted scientific concept; Mostly think that energy is a concrete entity and not an abstract idea; Mostly do not accept the idea of energy degradation; Mostly confuse the concepts of energy and force and hold, at some extent, two intuitive conceptions: a) energy is only present if there is movement, and b) energy is needed to be doing something (p. 317).*

Therefore, there is no doubt that physics student teachers construct thoughts, expectations, and explanations about natural phenomena to make sense of their everyday experiences. Unfortunately, their explanations often differ from scientific views and this is why they are referred to as misconceptions, alternative conceptions, or alternative framework (Kyle and Shymansky, 1989; Knight, 2002).

Heat is also a very important concept not only in other disciplines of physics but also basic electronics. For example, the amount of heat falling on a thermistor can vary its temperature, thereby changing the resistance of the electronic component. If the thermistor is part of a complete electronic circuit, variations in its resistance causes variations in the current flowing in the circuit. Unfortunately, research shows that there are common student misconceptions about heat, caused by text books. Some of them are that heat is synonymous with the movement of molecules; that heat is caused by friction between molecules; that heat is created when molecules bounce off each other and that heat is the amount of energy in a substance (Day et al., 2010). As a result of such misconceptions, comprehension of other important concepts such as Thermionic emission in basic electronics become difficult for learners.

There are several other studies in physics to do with student teachers' misconceptions (Blosser,1987; Yip et al., 1998; Groves and Pugh, 1999; Papadimitriou ,2004). Perhaps the study of Elementary Pre-Service Teacher Perceptions of the Green House Effect by Groves and Pugh (1999) yield some of the most fruitful findings about the misconceptions related to Green House Effect. This study employed the Environmental Issues Questionnaire which was developed by Boyes, Chukran, and Stanisstreet in 1993. The instrument was administered to 330 college students from the colleges of Education, Pure and Applied Sciences, Pharmacy and Health Sciences, and Liberal Arts at a

Regional University, as a partial replication of the Boyes et al. (1993) study. The study used senior students who had received a substantial portion of the science coursework required by their respective programs and had completed their science methods course. The questionnaire consisted of 36 statements divided into three subgroups: the first 12 statements dealt with consequences of the green house effect; the second set of 12 statements dealt with causes of the green house effect; while the last 12 statements focused on ways to alleviate the green house effect. A Likert scale was used and it had five steps ranging from "I am sure this is right" to " I am sure this is wrong." Demographic data included gender, college assignment, teaching background and grade result average (GRA). Data were analysed by Scheff ANOVA software. The results of the study were that elementary education majors held many misconceptions about environmental issues, which misconceptions could affect their teaching of the topics in elementary classes.

Groves and Pugh (1999, p.76) 'agreed with researchers who expressed concern about the ability of teachers with misconceptions to instruct their students correctly since they, themselves, did not have proper understanding of how the world works.' This is mainly because both theory and common sense support the argument that teachers' inadequacy in subject content knowledge will affect teaching performance as well as pupils' learning (Ball and McDiarmid, 1989; Haambokoma et al., 2002). The complexity and multiplicity of a lesson event, such as selecting suitable content, planning and conducting productive learning activities, asking meaningful questions, answering unprepared questions, diagnosing learning difficulties, and assessing students' progress demand teachers to have a good command of subject knowledge (Yip et al., 1998). This is why Shulman (1987), advised teachers not only to be capable of defining for students the accepted truths in a domain but that they must also be able to explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other prepositions.

Papadimitriou (2004) conducted an interesting study on 'Prospective Primary Teachers' Understanding of Climate Change, Greenhouse Effect, and Ozone Layer Depletion', whose aim was to take findings into account for teaching student teachers about these issues. Participants in the study were 174 prospective primary school teachers in their 1st year of study over two consecutive years. An open-ended questionnaire was used in order to gain a more comprehensive understanding of their thought, by obtaining their

spontaneous responses without imposing answers as it happens by using close ended questionnaires. From their answers it appeared that the students believed that climate change was under way and based their beliefs on their own experience. They were unaware of the proper actions to be taken for slowing down the climate change; they also held the misconception that ozone depletion, acid rain, and pollution in general influenced climate change. They confused greenhouse effect with ozone depletion as far as the mechanisms through which they occurred were concerned and the causal compounds.

Another striking study about student teacher misconceptions was done by Yip et al. (1998), on 'The Subject Matter Knowledge in Physics Related Topics of Hong Kong Junior Secondary Science Teachers.' The subject matter competence in physics related topics of 147 in-service Junior secondary science teachers in Hong Kong was identified using a true-or-false questionnaire based on a framework conceptualized by the authors. The physics part of the questionnaire consisted of 36 true-or-false (T-F) items of which 26 were false statements and 10 were true statements. The T-F format was employed because it was the most efficient means to review areas of incompetence. Teachers went through the questionnaire and decided on the correctness of each statement. The findings of this study showed that in-service teachers were weak both in factual knowledge and conceptions in these topics.

The findings in the study above agree with those of Lawrenz (1986), who investigated in-service elementary school teachers' understanding of some elementary physical science concepts. She developed a questionnaire using items from the physical science test questions given to 17-year-old students as part of the National Assessment of Educational Progress science studies. She found that 11 of the 31 items were answered correctly by 50 percent or fewer of the 333 teachers surveyed but the rest were not answered correctly. Lawrenz concluded that some of the errors were due to lack of content knowledge, but that others were indicative of serious misconceptions. She wondered how teachers who did not understand elementary physical science concepts, could teach their students.

Therefore, although the studies above used a variety of instruments and samples, the results obtained in all cases showed that student teachers of physics had misconceptions in the areas which were investigated in various ordinary level physics topics. The studies

of Yip et al (1998), and Groves and Pugh (1999) were good because they involved more than one investigator and so the data and impressions of one researcher could serve as a cross-check for the data and impression of the other. However, some researchers only used one instrument for data collection (Lawrenz ,1996; Trumper,1998; Papadimitriou, 2004). It could have been much better if they had used multiple data collection strategies, and/or data sources. That approach could have given a more complete picture of what was studied. It was also noted that all the studies were conducted outside Zambia. This information is important if researchers and educationists have to take measures to dislodge misconceptions so as to enhance the teaching and learning of physics in general and basic electronics in particular, which is currently, our area of concern. The section that follows presents the review of literature on the second research question.

4.2 What is the correlation between such misconceptions and performance of physics student teachers in basic electronics content?

It well established from the previous studies that learners come to physics lessons with a wide range of some already strongly held ideas, which may differ from the theories the educator may wish to develop (Knight, 2004). According to Halloun and Hesten (1985b), misconceptions do not spare anyone but are common to all categories of learners including school pupils, college or university students, as well as adults. These conceptions, once formed, influence the sense learners make of further learning and make a considerable number of learners hold on to certain intuitive notions despite formal science education they receive (Driver, 1983).

Quite often, students with misconceptions reject what they are taught and so find it difficult to learn (Sewell, 2002). This view is shared by Kyle and Shymansky (1989) who claim that misconceptions interfere with learning because students resist change. Chen et al.,(2013) also add that past misconceptions on basic electronics directly affect not only the learning of relevant concepts on electronics but also result in further misconceptions due to interactions. Indeed, these experiences and feelings seem to contradict what students read in their textbooks and/or are taught by their teachers (Driver et al.; 1994).

Therefore, there is no argument that student teachers of physics have misconceptions on basic electronics which is part of the ordinary level physics syllabus. Secondly we cannot

deny the fact that misconceptions have a negative effect on physics student teachers' learning of basic electronics. However, previous studies do not specify such misconceptions on basic electronics in the Zambian context. Furthermore, they do not show any correlation between the misconceptions they found and performance of student teachers in ordinary level topics. All they say is that misconceptions have a negative effect on learning. Knowing the correlation (and if it is causal) is very important because based on this knowledge, researchers can make an informed decision whether to labour to continue looking for ways of dislodging the misconceptions or not. It was in view of this that the current study sought to determine the correlation between misconceptions that would be revealed (if any) and performance of student teachers in basic electronics content in senior secondary physics. If no misconceptions would be found or the correlation would be positive, there would be a good reason to celebrate. However, if misconceptions would be revealed and the correlation would be negative and significant, it would suggest a lot of work for researchers and physics educators. This is because they should verify the findings and find ways to solve the problem so as to enable student teachers of physics to join the teaching profession with no misconceptions about basic electronics. Section 4.3 presents a review of literature on the third research question.

4.3 How do these misconceptions affect the teaching of basic electronics by student teachers in senior secondary physics?

According to Knight (2002), misconceptions have a negative effect on the teaching of physics. This is supported by Tytler (2002), who contends that " Students' alternative conceptions have proved surprisingly difficult to shift, and can offer a serious barrier to effective teaching" (p.3). Therefore, those who undergo a physics teacher training course but still hold on to misconceptions about fundamental physics concepts cannot teach physics effectively (Yip et al., 1998). No wonder Groves and Pugh (1999) expressed concern about the ability of teachers with misconceptions to instruct their students correctly since they, themselves, did not have proper understanding of how the world works. This is because both theory and common sense support the argument that teachers' inadequacy in subject content knowledge will affect teaching performance as well as pupils' learning (Ball and McDiarmid, 1989; Haambokoma et al, 2002). (Yip et al., 1998) clarify this argument by saying that the complexity and multiplicity of a lesson

event, such as selecting suitable content, planning and conducting productive learning activities, asking meaningful questions, answering unprepared questions, diagnosing learning difficulties, and assessing students' progress demand teachers to have a good command of subject knowledge. This is why a student teacher of physics with misconceptions on what he or she is going to teach, cannot be expected to present the lessons on such topics effectively.

Therefore, it is clear from section 4.3 that misconceptions have a negative effect on teaching of physics. However, the literature does not specify ways in which misconceptions negatively affect the teaching ordinary level physics in general and basic electronics in particular. This is why the current study sought to address this gap in knowledge. Subsection 4.4, presents the literature review on the last question of the study.

4.4 What effect does the 'BE' Education Resource have on physics student teachers' misconceptions and performance in basic electronics?

All the previous studies have clearly indicated that misconceptions have a negative effect on physics student teachers' learning and teaching of physics in general. Therefore, unless their misconceptions are changed or dislodged, student teachers may not find it easy to learn and later teach the concepts on basic electronics effectively. This is why Knight (2002, pp.42-45) encourages physics educators to alter or dislodge student teachers' misconceptions using the following steps:

i. Keep students actively engaged and provide rapid feedback.

Active engagement helps students to build their mental models rather than receive them from the instructor using: Interactive demonstrations, nearest neighbour discussion activities, collaborative group activities, microcomputer-based laboratories or other guided-discovery laboratories and take-home experiments.

ii. Focus on phenomena rather than abstractions

Mathematics and other abstractions are important and useful tools, but they are just that, tools. If we want students to reason correctly about physical processes and to develop physical intuition, instruction must remain focused on the phenomena by using: experimental laboratories, where possible, to provide familiarity with basic phenomena, working inductively from concrete to the abstract and asking students to explain the

outcome of experiments by using qualitative reasoning with no equations (unless, it is absolutely necessary).

iii. Deal explicitly with student alternative conceptions

The learning cycle which appears to be most effective is:

- Ask students to make a prediction about something and to be explicit about their reasoning. This forces them to use their mental model, rather than just guess.
- Then allow them to do an experiment or a demonstration.
- Explore the fact that many predictions were wrong. This cannot be glossed over quickly. There will be a conflict between their prediction and reality. Help them so that gradually they accept reality.
- Reiterate. Students' alternative conceptions are highly resistant to change. They need to see repeatedly that their conceptual model fails, when put to the test, but that an alternative model succeeds.

iv. Teach and Use Explicit Problem-solving skills and strategies.

A major goal of the science courses is for students to learn more sophisticated problem-solving skills. To succeed, we must:

- Teach students the specific skills needed to solve complex problems. These include interpretation skills, pictorial skills, graphical skills, and reasoning skills.
- Show students how those skills are assembled into a powerful problem-solving strategy and demonstrate their use, in detail, in the example you work in class.
- Make explicit the assumptions, decisions, and reasoning that are part of an expert's problem-solving strategy but which usually go unsaid.

v. Write homework and exam problems that go beyond symbol manipulation to engage students in the qualitative and conceptual analysis of physical phenomena.

Students certainly must practice to build problem-solving skills. But they must engage in the right kind of work, using the right kind of practice. When they spend hours floundering, what they really practice is floundering. Appropriate homework and example problems need to:

- Emphasize reasoning, de-emphasize formulas and equations
- Deal directly with phenomena and observations.

This is not to say that students should not or will not learn to solve quantitative problems. The point is that problems should focus students' attention on interpretation, on analysis, on reasoning, that is, on doing physics rather than just on getting a number.

While this steps are so good, studies do not recommend a particular Education Resource as a solution to the problem of misconceptions about basic electronics. This is why the current study decided to test the 'BE' Education Resource to see if it could help minimise any misconceptions about basic electronics. This resource was not new material or teaching approach, but contained relevant material on basic electronics from the two recommended textbooks by Wilkinson (1993) and Nelkon (1981). The only difference was that it contained improvised practical demonstrations to clarify abstract concepts such as: Thermionic emission, cathode rays, waves and few others. Section 4.5 is a summary of the literature reviewed and it shows all the gaps revealed by the literature.

4.5 Summary of the Literature reviewed

It is clear from the literature reviewed that just like pupils, student teachers of physics have misconceptions about their pedagogical content knowledge and such misconceptions do have negative effects on their performance in content and teaching. The literature is however limited, for seven reasons.

First, all the literature found is completely based on studies conducted outside Zambia. This means that so far there has been no study in this country on the topic in question, and yet Zambia has its own education system. Therefore, it is difficult to replicate the findings in this country.

Connected to the above, is the fact that though ***misconceptions*** have been reported on several topics in senior secondary physics, research does not show misconceptions held by student teachers in basic electronics in the Zambian context. And yet, in Zambia, despite its importance, basic electronics is rated the most difficult section of the senior secondary physics to teach (Haambokoma et al., 2002).

Next, the scanty literature about misconceptions in electronics (found elsewhere) did not focus on the whole section of basic electronics but, the diode. This is negligible (about 5%), compared to the remaining material on basic electronics (95%) that has not been exploited.

Fourth, the literature found was centred on a Zener diode which is not covered in the Zambian ordinary level physics syllabus. The current study looked at the normal (p-n) diode which is part of the Zambian secondary school syllabus.

Fifth, some of the studies used one or two research instruments, questionnaire and a pupils' test, to collect data. This resulted in lack of triangulation and consequently it could not be easy to assess the validity and reliability of the data obtained by cross-checking the information. The current study used four instruments to collect data so that the results could be triangulated.

Sixth, the literature reviewed did not show any ***relationship*** between student teachers' misconceptions and their performance in basic electronics content. Therefore, it was not clear whether more misconceptions resulted in worse or better performance or there was no relationship at all.

Finally the literature reviewed did not did not recommend a particular Education Resource as a solution to the problem of misconceptions about basic electronics.

In order to address the concerns above, the current study done in Zambia, investigated misconceptions on all sections of basic electronics, used four different methods of data collection (questionnaire, test, observation schedule and an attitude scale for reasons of triangulation) investigated the correlation between student teachers' misconceptions and their performance in basic electronics, established ways in which misconceptions affected the teaching of basic electronics and tested the 'BE' Education Resource to see if it could help to solve the problem of misconceptions about basic electronics. The chapter that follows describes the research design and methodology of the study.

CHAPTER 5

RESEARCH DESIGN AND METHODOLOGY

5.0 Introduction

This chapter describes the research design and methodology of the study. It has 18 sections arranged as follows: 5.1, Description of the Research Design; 5.2, the Basic Correlation Research Design; 5.3, the True Experimental Design of the type Pretest-Posttest Control Group; 5.4, Study area; 5.5, Study population; 5.6, Sample size; 5.7, Sampling procedure; 5.8, Instruments used for data collection; 5.9, Validity and Reliability of the instruments used in the study; 5.10, Validity and reliability of qualitative research; 5.11, Validity of the findings; 5.12, Data collection; 5.13, Data analysis; 5.14, Limitations of the study; 5.15, Delimitation of the study; 5.16, Reflection on Ethical issues and 5.17, the chapter summary. Below is the first section.

5.1 Description of the Research Design

Kumar (1999) defines a **research design** as a procedural plan that is adopted by the researcher to answer questions validly, objectively, accurately and economically. In other words "It is a basic plan for a piece of empirical research, which should include the strategy, framework, who or what will be studied and the tools and procedures to be used for collecting and analyzing empirical materials" (Punch, 2002; p.52). White (2005) highlights two important things that should be included in the description of a research design. He says,

> *When describing the research design, the researcher should attend to two aspects, the **research approach** as well as the **research method** to be implemented. The research approach means the qualitative or quantitative paradigm (or a combination) to be used in a study. The research method refers to methods such as experimental, ex post facto, ethnographical, or action research, et cetera (p.80).*

Quantitative research is ' The collection of numerical data in order to explain, predict and/or control phenomena of interest, while qualitative research is the collection of extensive narrative data on many variables over an extended period of time, in a naturalistic setting, in order to gain insights not possible using other types' (Gay, 1996; p. 623). The two approaches are based on the 'purpose of research, "different ontological,

methodological and epistemological views", research methods, typical studies, the researcher's role and the importance of context in the study (White, 2005; p. 63). Therefore, before describing the designs which were used, this study first distinguishes between the two paradigms above, in terms of the six aspects that have been stated.

- **Research purpose**

Quantitative research seeks to establish relationships (if…..then) and to determine causes of changes in measured social facts (White, 2005). In view of this, 'It has a hypothesis, the most specific statement of a problem, which states the researcher's expectations concerning the relationship between the variables in the research problem or questions concerning the current status of the subjects of the study' (Gay, 1987; p.10). On the other hand, 'Qualitative research is more concerned with understanding social phenomena from the perspectives of the participants. This happens through the researcher's participation in the daily life activities of those involved in the research or through historical empathy with participants in past social events' (White, 2005; p 81).

- **Ontological view (The nature of reality and human behavior)**

In quantitative research, reality is viewed as objective, out there and independent of researcher (White, 2005). Therefore, in quantitative research it is possible to measure something objectively by using a research instrument such as a test. Furthermore,

> *Quantitative research is usually based on what is called the **positivist philosophy**, which assumes that there are social facts with a single objective reality which is separated from the feelings and beliefs of individuals. This objective reality can be explained, controlled and predicted by natural (cause/effect) laws. Human behavior can thus be explained in causal ways and people can be manipulated and controlled (White, 2005; p. 81).*

On the contrary, in qualitative research, the only reality is the one constructed by the individuals involved in the research situation. Therefore, multiple realities exist in any given situation such as that of the researcher, those individuals being investigated and the reader or audience interpreting the study (White, 2005). The qualitative researcher needs to report these realities faithfully and to rely on sources and interpretations as obtained from informants. 'Qualitative research is based more on Interpretivist philosophy, which

assumes that multiple realities are socially constructed through individual and collective definitions of the situation' (White, 2005).

- **Methodological view**

In quantitative studies there is an established set of procedures and steps which guide the researcher and so the quantitative researcher will begin with a hypothesis and then seek to verify it through empirical testing, or questions concerning the status of the subject that are later answered by the study (Gay, 1996; Gay, 1997). Researchers arrange methods as part of a pre-established design before data collection.

In contrast, in qualitative studies there is greater flexibility in both the methods and the research process. Typically, a qualitative researcher uses a design that is not established before the research starts; He or she makes decisions about the data collection strategies during the study (Bryman, 2004). Furthermore, the qualitative methodology is interpretative and constitutes an interactive dialogue. 'During the process of interaction between the researcher and the subject, the subject's world is discovered and interpreted by means of suitable methods' (White, 2005; p.82).

- **Epistemological view (The relationship of researchers to reality and the road they will follow in search of the truth).**

The quantitative approach demands that the researcher should remain distant and independent of what is being researched. Thus the researcher selects a systematic sample in surveys and experiments, and remains objective in addressing a situation. In fact, the ideal quantitative researcher is detached from the study in order to avoid bias. He or she is able to be objective as one sees oneself detached from, and not part of the object that one is studying. The researcher neither influences nor is influenced by the object under study (White, 2005).

The qualitative research approach is different in the sense that the researcher interacts with participants that one is studying, whether this interaction assumes the form of living with or reserving informants over a prolonged period of time, or actual collaboration (White, 2005). In short the researcher tries to minimize the distance between him/herself and those being researched. White (2005, p.83) adds that, 'Qualitative researchers

become part of the situation, present or past, and the phenomena being studied. For example, ethnographers assume interactive local roles in which they record observations and interviews with participants.'

- **Typical studies**

While in quantitative studies an **experimental** or **correlation design** is used to reduce error, bias and the effect of extraneous variables, the classical qualitative study of ongoing events is an **ethnography**, which makes readers understand the multiple constructions of reality (White, 2005). "Furthermore, whereas quantitative research seeks to eliminate subjectivity through design, qualitative research seeks to take subjectivity into account in data analysis and interpretation" (p. 83).

- **Context of the study**

'The quantitative research attempts to establish universal, context-free generalizations so that findings are not valid only in a specific environment but anywhere, irrespective of time and place (White, 2005; p. 83).' For example, if a researcher, through experimental research, finds that a problem – based approach leads to better results in mathematics in Pretoria, the same success should be attained in London when the same approach is applied. In contrast, the qualitative researcher believes that human actions are strongly influenced by the settings in which they occur. It is believed that the researcher cannot understand human behavior without understanding the framework within which the subjects interpret their thoughts, feelings and ideas (White, 2005). It is for this reason that qualitative research develops context-bound generalizations. The survival skills of a street kid in Congo DR may differ totally from that of street kids in Algeria.

Despite the differences in the aspects above, it is important to note that many of the distinctions between quantitative and qualitative research are not absolute when conducting research or reading a completed study. 'Researchers can and do combine both quantitative and qualitative research methods in a single study in order to investigate a particular problem' (White, 2005; p. 84). Therefore, since this study generated quantitative and qualitative data, a ***mixed-methods approach*** was used to investigate the issues involved. According to Creswell and Garret (2008, p.322), 'Mixed methods is an approach to inquiry in which the researcher links, in some way (e.g. merges, integrates, connects), both quantitative and qualitative data to provide a unified understanding of a research problem.'

Specifically, the current study used the ***concurrent nested strategy*** to mix qualitative and quantitative methods. This involves simultaneous collection of qualitative and quantitative data but with either the qualitative methods or the quantitative methods being dominant and thus guiding the study (Creswell, 2003). In the current study, the quantitative methods were dominant because the study dealt with data that were principally numerical (Leedy, 1993). The method entails a deductive approach to determine the relationship between theory and research; It has incorporated the practices and norms of the natural scientific model and embodies a view of social reality as an external, objective reality (White, 2005).

On the other hand, qualitative research was used because whatever the researcher studied was happening in the real world of participants. Therefore, respondents were expected to describe their every day experiences relating to their understanding of basic electronics. Where need was, the researcher interacted with the participants to present the questionnaire, administer tests, present the treatment and evaluate lessons during peer-teaching. The combination of the two research paradigms (quantitative and qualitative) was very helpful in getting sufficient information that would enable the researcher to understand the research problem better (Creswell, 1994).

The research strategy used can be represented diagrammatically by an inner and an outer rectangle as shown below (Creswell, 2003).

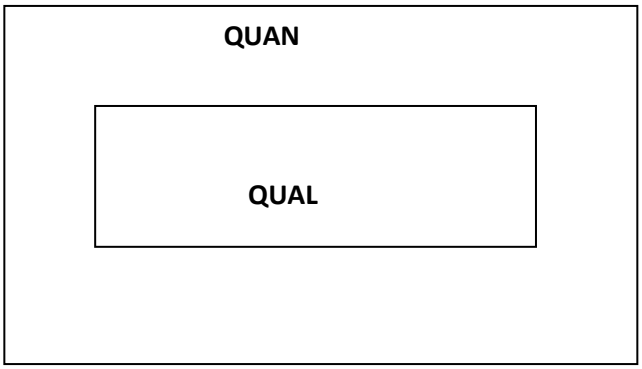


Fig. 5.1 : Concurrent Nested Mixed Methods Strategy with Quantitative Methods Dominant (Creswell, 2003).

Here, the outer rectangle represents the dominant set of methods, that is, the quantitative methods indicated by the letters QUAN, while the inner rectangle the less dominant qualitative methods, denoted by the letters QUAL. This approach to research generally

follows philosophical and methodological pragmatism with a very broad and inclusive ontological realism (Maxcy, 2003).

The mixed methods strategy above has some advantages: it makes it possible to gain perspectives from different research methods and allows the researcher to collect quantitative and qualitative data simultaneously in a single data collection phase (Creswell, 2003). Despite this, the strategy is limited in the sense that there isn't enough literature to explain how to integrate the data within the analysis phase of the study or how to resolve discrepancies that might occur between qualitative and quantitative data (Creswell, 2003). However, it is not necessary to worry about such limitations because as Ritchie (2003) explains, the purpose of mixing qualitative and quantitative methods is not to get the same results from different angles, but " to achieve an extended understanding that neither method alone can offer. It is then up to the researcher to explain why the data and their meaning are different" (p. 43). This is why Darlington and Scott (2002) advise that obtaining such discrepancies should be viewed as an opportunity rather than a constraint, as it may simply indicate that further work is required to understand what is going on, work that can lead to more interesting findings. In short, discrepancies should be expected but what matters is how a researcher responds to them.

As for **research methods** (also commonly known as research designs), this study worked within the framework of two designs to arrive at the results. The first was the **Basic Correlation Research design**. This was used because it was the only design that would help to determine whether there was a relationship (and to what degree that relationship existed) between physics student teachers' misconceptions and their performance in basic electronics in senior secondary physics. After that, the study used the **true experimental Design**, to find out if misconceptions had an effect on physics student teachers' performance in basic electronics.. This design was used because the former (Correlation design) only went as far as helping the researcher to determine the relationship and the degree to which that relationship existed but not the cause of the relationship. On the other hand, though the latter design (Experimental) did not help to determine the relationship, it was one of the best designs in cause-effect relationships and so helped to determine the cause of the relationship. Section 4.2 describes how the Basic Correlation Research design was used in the study.

5.2 The Basic Correlation Research Design

This study employed the Basic Correlation Research Design, which is a research design used to describe the statistical association between two or more variables (Gay, 1996). "It describes in quantitative terms the degree to which variables are related" (p. 296).

In the study, two pairs of scores were obtained for each of the respondents in the experimental and control groups. These were the number of misconceptions (**X**) held by a respondent as revealed by the questionnaire (Appendix 'A') and the score obtained in electronics content (**Y**) as revealed by the test (Appendix 'B'). The data obtained were used to complete Table 5.2.1

Table 5.2.1 Scores obtained by participants in the experimental and control groups in basic electronics content.

Respondent	Number of misconceptions **(X)**	Score obtained in the basic electronics content test **(Y)**
E1		
"		
E30		
C1		
"		
C30		
N= 60	**∑X**	**∑ Y**

The letter **'E'** in the table represented a participant in the experimental group while **'C'** represented a participant in the control group. After getting all the data, the information in table 5.2.1 was used to determine the Pearson's Product Moment Correlation Coefficient, using the Statistical Package for Social Sciences (SPSS).

After that, two other pairs of scores were obtained from the same participants. These were the number of misconceptions (**X**) held by each participant as revealed by the questionnaire (Appendix 'A') and participant's score (**Z**), in peer-teaching of basic electronics, as revealed by the Teacher Evaluation Form (Appendix 'C'). The data obtained were used to complete table 5.2.2. There were a total of sixty participants.

Table 5.2.2 Scores obtained by participants in the experimental and control groups in the teaching of basic electronics

Respondent	Number of misconceptions **(X)**	Score obtained after teaching basic electronics. **(Z)**
E1		
"		
E30		
C1		
"		
C30		
N=60	**∑X**	**∑ Z**

The data in table 5.2.2 was also used to determine the Pearson's Product Moment Correlation Coefficient, r, using the Statistical Package for Social Sciences (SPSS).

The resulting Pearson's 'r' in both cases indicated the degree of relationship between misconceptions and performance of physics student teachers in basic electronics content and in the teaching of this section of physics respectively. The Pearson's correlation coefficient was used because it was the most stable measure. Furthermore, the

relationship between the variables to be correlated was linear and the sets of data to be correlated represented interval scales.

At this stage it is important to mention that, participants' pre and post test scores in various elements of effective lesson presentation on basic electronics, were also recorded and later used to show if there was a significant difference between the two groups, in teaching basic electronics. Section 5.3 describes how the experimental design was also used in the study.

5.3 The True Experimental Design of the type Pretest-Posttest Control Group

According to Gay (1996),

> *An experimental design is one in which the researcher manipulates at least one independent variable, controls other variables, and observes the effect on one or more dependent variables. By the independent variable we mean that activity or characteristic believed to make a difference while the dependent variable refers to the change or difference that occurs as a result of manipulation of the independent variable (p. 396).*

The study used the Pretest-Posttest Control Group Design as illustrated below.

R O_1 X O_2 (Experimental group)
R O_3 O_4 (Control group)

R implies that the participants were randomly assigned to the groups. This was done by first assigning all the sixty participants numbers one to sixty. Then, all the old numbered participants formed the experimental group while the even numbered participants formed the control group. Randomization ensured the greater likelihood of equivalence, that was, apportioning of the experimental and control groups of any factors or characteristics of the subjects which might conceivably affect the experimental variables in which the researcher was interested (Cohen and Manion, 1990). Since the groups were made equivalent, if there were any clouding effects, they were present in both groups. For example, If the mental ages of the subjects in the experimental group increased, so did the mental ages of the control group; If something happened to affect the experimental

subjects between the pretest and posttest, this same thing also affected the subjects of the control group (Cohen and Manion, 1990). The **Os** in the design referred to measurement or observation in sequential order for each group. **X** represented the treatment, which in this study were the lessons in Basic Electronics.

The design involved two groups (experimental and control), both of which were randomly assigned. At the beginning of the study, the groups answered the questionnaire and were administered a pretest of the dependent variable. After that, all respondents did peer-teaching on basic electronics. Next, the experimental group received a treatment (lessons in basic electronics) for about a month. Meanwhile the control group did other lessons in physics which were not related to basic electronics for the same period. The groups were informed that after a month they would swap the lessons so that those who began with basic electronics would do other lessons done by the friends and vice versa. After one month, both groups were post tested and they did their peer-teaching for the second time. Posttest scores were directly compared using a t-test because from the pretest results, it was clear that the two groups were essentially the same on the dependent variable. If they weren't (random assignment could not have guaranteed equality), posttest scores could have been analyzed using analysis of covariance (ANCOVA).

At this stage it is important to mention that in the experimental design (quantitative research), there were several threats to internal validity. Therefore, Sub-section 5.3.1 describes a number of extraneous variables that threatened the validity of the above experiment and how the design controlled for such.

5.3.1 Internal validity of quantitative research

"Internal validity is the degree to which the design of an experiment controls extraneous variables. Experiments are more or less internally valid depending on how well **extraneous variables** have been controlled by the researcher" (White, 2005; p.193). An extraneous variable is one that influences the results of a research project but has nothing to do with the experimental treatment (p. 193).

Gay (1996) contends that:

> *Any uncontrolled extraneous variables affecting performance on the dependent variable are **threats** to the validity of an experiment. An experiment is valid if results obtained are due only to the manipulated independent variable, and if they are generalizable to situations outside of the experimental setting. The two conditions that must be met are referred to as internal validity and external validity. Internal validity refers to the condition that observed differences on the dependent variable are a direct result of manipulation of the independent variable, not some other variable. In other words, the outcome of the study is the result of what the researcher did, not something else"(p. 346).*

Below is a description of the extraneous variables that threatened the **internal validity** and each one is accompanied by a description of how it was controlled.

- **History:** 'This refers to the occurrence of any event which is not part of the experimental treatment but which may affect performance on the dependent variable'(Gay, 1996; p.347). The longer a study lasts, the more likely it is that history may be a problem. Events (including current events) in a country such as Analogue to Digital migration are examples of history. In the current study, to control for history, both groups were pre and post-tested at the same time and in same settings. Second, the period between pre and post-tests was reasonable (not long or short, considering the treatment participants had); Third, the post-test was given shortly after the treatment. Fourth, while the experimental group received a treatment, the control group was kept busy with other topics which were equally important as they were part of their curriculum. Furthermore, if at all there were any factors which could still cause a problem, those were controlled in that the general **history events** which might have contributed to the $\mathbf{O_1}$ and $\mathbf{O_2}$ effects would also produce the $\mathbf{O_3}$ and $\mathbf{O_4}$ effects because the experiment was run in a specific manner.
- **Maturation: '**This refers to physical or mental changes that may occur within the subjects over a period of time'(Gay, 1996; p.347). These changes may affect the subjects' performance on the measure of the dependent variable. This is common in studies which take too long because subjects may become older, more coordinated, unmotivated, anxious, or just plain bored (White, 2005). In this study maturation was controlled in that it manifested equally in both treatment and

control groups. Furthermore, the period between pre and post-tests was not too long.

- **Testing**: 'Testing also known as **pre-test sensitization** refers to improved scores on a post-test resulting from subjects having taken a pre-test' (Gay, 1996; p.347). According to White (2005), in many educational experiments a pre-test is administered, followed by the experimental treatment and then a control. If the two tests are similar, subjects may show an improvement simply as an effect of their experience with the pre-test, that is, they have become 'test-wise. In other words, they remember some of the issues or items being tested in the first test. Therefore, taking a pre-test may improve performance on a post-test, regardless of whether there is any treatment or instruction in between. Testing is more likely to be a threat when the time between tests is short.

  However, in this study, the time between pre and post tests was reasonable (not long or short). Furthermore, if at all there was any testing effect, it was controlled in that it manifested equally in both the experimental and control groups.

- **Instrumentation**: 'This refers to unreliability, or lack of consistency, in measuring instruments which may result in an invalid assessment of performance' (Gay, 1996; p. 348). It may occur in several different ways. For instance, if two different tests are used for pretesting and post-testing, and the tests are not of equal difficulty, instrumentation may occur; if the post-test is more difficulty, it may fail to show improvement which is actually present, where as if the post-test is less difficult, it may indicate an improvement that is not present. On the other hand, if data are collected through observation, observers may not be observing or evaluating behaviour the same way at the end of the study as at the beginning. In fact, if they are aware of the nature of the study, they may unconsciously tend to see and record what they know the researcher is hypothesizing. If data are collected through the use of a mechanical device, such as a scale, it may be suffering from some malfunction resulting in inaccurate measurement. White (2005) adds that "An apparent learning gain may be observed from pre-test to post-test because the nature of the measuring instrument has changed" (p. 195).

Therefore, in this study, to control for instrumentation, the same test was used for pre and post testing. Second, no mechanical device was used. Third, data were collected through various ways: questionnaire, test, teacher evaluation form and Likert scale and later the results were triangulated. Fourth, students who participated in peer-teaching were kept ignorant of the purpose of the experiment to prevent them from seeing and recording what they knew the researcher was hypothesizing. Furthermore, the researcher cautioned observers so that they could evaluate performance of participants in the same way at the end of the study as at the beginning.

- **Statistical regression:** According to Gay (1996, p.348), 'Statistical regression usually occurs when subjects are selected on the basis of their extreme scores. It refers to the tendency of subjects who score highest on a pre-test to score lower on a post-test, and of subjects who score lowest on a pre-test to score higher on a post-test.' The tendency is for scores to regress, or move toward, the mean (average) or expected score.

  In this study **regression** was controlled by the mean differences regardless of the extreme of scores or characteristics. The experimental and control groups were randomly assigned from the same extreme pool. Therefore, both groups regressed similarly, regardless of treatment.

- **Differential selection of subjects:** According to Gay (1996), this occurs when already formed groups are used. 'It refers to the fact that the groups may be different before the study even begins, and this initial difference may at least partially account for post-test differences' (p. 349).

  In this study, to avoid this threat, there were no already formed groups. Groups were selected which were as similar as possible from the same extreme pool and a pre-test was administered to check for initial equivalence.

- **Mortality:** This is also known as **Attrition** and it normally occurs in longer studies. Mortality refers to the fact that 'subjects who drop out of a group may share a characteristic such that their absence has a significant effect on the results of the study' (Gay 1996, p. 349). Subjects who drop out of a study may be less

motivated, for example; this is especially a problem when volunteers are used. Volunteers rarely drop out of control groups because few or no demands are made on them. Volunteers may, however drop out of an experimental group if too much effort is required for participation. The experimental group that remains at the end of the study may as a whole represent a more motivated group than the control group. On the other hand, the experimental group might end up looking pretty good when compared to the control group simply because many of the good students dropped out of the control group.

In this study, all the subjects were students of the named institution and so were expected to participate in all activities without being forced to do so, as some of the work was not only used for research but also for their continuous assessment before the final examinations. Therefore, none of them dropped out but willingly stayed on.

- **Selection-Maturation Interaction: '**This means that if already formed groups are used, one group may profit more (or less) from a treatment, or have an initial advantage, because of maturation' (Gay, 1996; p. 350). This threat was controlled for by randomly assigning subjects into experimental and control groups and none of the two groups were given any initial advantage that would lead to post-test differences, rather than the independent variable. The results of the pre-test which was administered confirmed the groups' initial equivalence.
- **Subject effects**

According to White (2005; p.195),

> *In ideal research the subjects behave and respond naturally and honestly. However, when people become involved in a study they often change their behavior simply because they understand they are 'subjects' and these changes may affect the results. Subject effects refer to subject changes in behavior, initiated by the subjects themselves, in response to the research situation. If subjects have some idea of the purpose of the study or the motivation for doing well, they may alter their behavior to respond more favourably*.

Therefore, in order to avoid this effect, participants were kept ignorant of the main purpose of the experiment, and the motivation for doing well was to complete their degree programme, which everyone wanted.

In summary, ‘ The validity of an experiment (in quantitative research), is a direct function of the degree to which extraneous variables are controlled’ (Gay, 1996, p. 357). If such variables are not controlled, it is difficult to evaluate the effects of an independent variable and the generalisability of effects. In this study randomization was used to attempt to control the extraneous variables all at the same time, regardless of what they were. The design had a combination of random assignment and the presence of a pretest and a control group which served to control for nearly all sources of internal invalidity.

Gay (1996, p. 403) argues that:

> *The combination of random assignment and the presence of a pretest and a control group serve to control for all sources of internal invalidity. Random assignment controls for regression and selection factors; the pretest controls for the mortality; randomization and the control group control for maturation; and the control group controls for history, testing, and instrumentation. Testing, for example, is controlled because if pretesting leads to higher post-test scores, the advantage should be equal for both the experimental and control groups).*

The factors described so far had to do with internal validity of the experiment. However, in the same design, the researcher also anticipated threats to **external validity** (also called **interaction effects** because they involve the treatment and some other variable, the interaction of which cause the threat to validity). But unlike internal validity, external valid was not easy to control. However, some effort was made to do so, as described in section 5.3.2.

5.3.2 External validity of quantitative research

External validity refers to the generalisability of the treatment/condition outcomes (Cohen and Manion, 1990). It concerns whether the results of the research can be generalized to another situation, population, different subjects settings, times and occasions. Even if an experiment has internal validity, it may not be generalisable to other situations due to threats to external validity (White, 2005). The following were the

anticipated threats to external validity in the current study and below each threat is an explanation of how it was controlled for:

- **Pretest-Treatment interaction**

  This occurs when subjects respond or react differently to a treatment because they have been pretested. A pretest may sensitize or alert subjects to the nature of the treatment (Gay, 1996, p. 350). Thus it becomes difficult to generalize the results to a given population.

  However, in this study the pre-tested candidates were pretty dense not to see a connection between the pre-test and the treatment. Furthermore, the time between pre and post-tests was reasonable, about a month (not too long or too short).

- **Multiple-Treatment Interference**

  This can occur when the same subjects receive more than one treatment in succession. 'It refers to the carry-over effects from an earlier treatment which make it difficult to assess the effectiveness of a later treatment' (Gay, 1996, p. 351).

  In this study, this was not a problem because each group received only one treatment. Although subjects in the control group later benefited from the lessons on basic electronics, that was after the required data had been collected from the experimental group. What the two groups did after the posttest was not meant for the study but purely for academic purposes. Furthermore, all subjects who took part in the study had not participated in some other study.

- **Selection-Treatment Interaction**

  'This is similar to the "differential selection of subjects" problem associated with internal invalidity and also occurs when subjects are not randomly selected for treatments' (Gay, 1996, p. 352). Therefore, in this study, the threat above was controlled for by randomly selecting the subjects for treatments. Furthermore, the population which was studied did not reject the invitation.

- **Other subjects**

  External validity may be affected if the researcher chooses to use what he or she considers to be the most convenient sample, like students in a specific institution. However, in this study though participants from only one institution were used, they were tested on the knowledge of basic electronics which they had acquired in ordinary level physics from various senior secondary schools throughout the country. Furthermore, all of them had benefited equally (in basic and higher level electronics) from the first year lectures delivered at the University of Zambia which included electronics, before the study began and so were representative of the broadest population possible.

- **Other times**

  When a given experiment is conducted at two or more different times, it is likely that it may not produce the same results, as conditions may change (White, 2005). In this study, participants did their work on Monday and Thursday of every week from 14:00h to 17:00h which were laboratory periods. Furthermore, an effort was made to ensure that conditions in the lab remained the same, that is, in terms of, sitting arrangement, laboratory facilities, laboratory technician and researchers.

- **Other settings**

  A pervasive problem that can hinder external validity, involves the question of how the phenomenon observed in one laboratory can be related to a similar phenomenon observed in another laboratory or in the real world (White, 2005; p. 196). In this study, that was not an issue because participants were tested on what was in their minds about basic electronics and not what they saw in the laboratories at the time of the experiment. Therefore, under normal circumstance, their performance in any other setting should have been more or less the same.

- **Specificity of variables**

  Like Selection-Treatment Interaction**, specificity of variables** is also a threat to generalizability regardless of the experimental design used (Gay, 1996). “It refers to the fact that a given study is conducted (i) with a specific kind of subject; (ii) based on a particular operational definition of the independent variable; (iii) using specific measuring instruments; (iv) at a specific time; and (v) under a specific set of circumstances” (p. 353).

In order to deal with the threats associated with specificity, (i) the variables were operationally defined in a way that had meaning outside of the experimental setting and (ii) the conclusions and generalizations were carefully stated.

Experimenter Effects:

According to Gay (1996, p. 354),

> *There are several ways in which the experimenter may unintentionally affect execution of study procedures, the behavior of subjects, or the assessment of their behavior, and hence the results. Possible biasing effects may be passive or active. Passive elements include characteristics or personality traits of the experimenter such as sex, age, race, anxiety level, and hostility level. These influences are collectively referred to as experimenter personal-attributes effect (Rosenthal, 1966). Active bias results when the researcher's expectations affect his or her behavior and hence outcomes. Such behavior on the part of the researcher is referred to as the experimenter bias effect.*

Therefore, the way an experimenter looks, feels or acts may unintentionally affect study results, typically in the desired direction.

In this study the experimenters made sure they looked, felt and acted in the same and acceptable way. Furthermore, the effect was avoided by not communicating the outcome expectations to any personnel connected with the study.

- **Reactive arrangements: '**This refers to a number of factors associated with the way in which a study is conducted and the feelings and attitudes of the subjects involved; It refers to the artificiality of the experimental setting and the subject's knowledge that he is participating in an experiment (Gay, 1996; p.355). Examples are: the Hawthorn effect, which is any situation in which subjects' behavior is affected not by the treatment per se, but by their knowledge of participation in a study; the John Henry effect, which is a situation whereby for any reason control groups or their teachers feel threatened or challenged by being in competition with a new program or approach and so, outdo themselves and perform way beyond what would normally be expected-even if it kills them (Saretsky, 1972). When this effect occurs, the treatment under investigation does not appear to be

very effective since post-test performance of experimental subjects is not much (if at all) better than that of control group (Gay, 1996). A similar phenomenon in medical research is the "Placebo effect", which refers to 'The discovery in medical that any "medication" could make subjects feel better, even sugar and water' (Gay, 1996, p. 623).

Therefore, in this study, to avoid any reactive arrangements, when the experimental group was receiving lessons on basic electronics, the control group had lessons on other topics starting with Conservation laws, which appeared in their course outline but were not related to the purpose of the study. The subjects in the control group were told that they would do the lessons on basic electronics after completing the section they were doing and their friends would switch on to Conservation laws, for academic purposes. Therefore, all the subjects were kept busy and did not concentrate on what friends in other groups did.

Before leaving this section it is also important to make a comment on the so called the '**novelty effect'**. This refers to increased interest, motivation, or participation on the part of subjects simply because they are doing something different (Gay, 1996, p. 357). In other words, a treatment may be effective because it is different, not better per se.

In the current study, novelty was not an issue because the activities in the treatment were similar to the subjects' usual routine. Furthermore, the study was conducted over a number of weeks sufficient to allow the 'newness' (if any) to wear off.

5.4 Study area

The study area was the University of Zambia in Lusaka province. The decision to conduct the study at this University was based on the fact that it had the required type of student teachers of physics (pre-service and in-service) from all over the country who were expected to be very conversant with basic electronics, and so this would increase the chance that the findings of the study would be generalisable to those who were being trained by the University of Zambia to be teachers of physics in Zambia.

5.5 Study population

According to McMillan and Schumacher (2001, p.169), 'A population is a group of elements or causes, whether individuals, objects or events, that conform to specific

criteria and to which we intend to generalize the results of the research. The population for this study were one hundred and ninety one (191) 3rd and 4th year Bachelor of Science with Education (BSc.Ed) and Bachelor of Education in Mathematics and Science (BEdMAS) student teachers of the University of Zambia from all provinces of Zambia. Some of those students formed the study sample, because at that level they were considered to be conversant with basic electronics content and science teaching methods. Among them were in-service and pre-service teachers of physics pursuing a teaching degree programme in physics.

5.6 Sample size

A sample refers to a group of subjects or situations selected from a larger population (White, 2005). In the current study, the sample comprised sixty (60) student teachers of physics. This number of participants (60) was twice the recommended minimum number, in this case, thirty (30), for a study of this nature to yield valid results (Gay, 1996). According to Gay (1996), the question of when the sample size is 'too small' or becomes 'large enough' does not have an easy answer.

He argues:

> *In most cases the researcher does not have access to many subjects. In fact, obtaining permission to involve students in a study, or finding adults willing to participate in a study, is generally not an easy task. Usually the problem is too few subjects rather than too many. …. In general the minimum number of subjects believed to be acceptable for a study depends upon the type of research involved. For correlational, causal-comparative, and experimental research, some experts consider the magic "general guideline" to be 30. Thus, for correlational studies at least 30 subjects are needed to establish the existence or non existence of a relationship. For causal-comparative studies and many experimental studies, a minimum of 30 subjects per group is recommended (Gay, 1996; 123).*

Experimental studies with tight experimental controls, however, may be valid with as few as 15 subjects per group (Roscoe, 1975). Of course, the "minimums" discussed here are just that, "minimums". 'If it is possible to use more subjects, one can do so, though size alone does not guarantee representativeness. Even large samples can lead to erroneous conclusions if they are not well selected' (Gay, 1996; p. 129).

5.7 Sampling procedure

The total population of student teachers who had done Basic Electronics at school and 1st year University level was 191. Only student teachers of physics were selected using simple random sampling to provide the best information to address the purpose of the research. Those who took other sciences were left out because they had forgotten some of the concepts in basic electronics which they did at school and first year University level.

The key steps in devising the simple random sample were as follows:

- First the population was defined. It was decided that this would be all the 3rd and 4th year BSc.Ed and BEDMAS students at the University of Zambia. They were over 200.
- Next, a comprehensive sampling frame was selected or devised. The Department of Mathematics and Science Education (MSE) kept records of all BSc.Ed students and those records enabled the researcher to exclude those student teachers who did not meet the criteria for inclusion i.e. those who did not have enough knowledge of basic electronics.
- All the student teachers in the population were listed and assigned consecutive numbers from 1 to N, where N was 191.
- Using a table of random numbers in the appendices of statistics books (Gay, p. 601) and later (a computer program that could generate random numbers), the researcher selected n(60) different random numbers that lay between 1 and N(191).
- The students to which the n (60) random numbers referred constituted the sample.

Using this process, there was almost no opportunity for human bias to manifest itself. Students were not selected on such subjective criteria as whether they looked friendly and approachable. The selection of whom to use in the study was entirely mechanical. Second, the process was not dependent on the students' availability. They did not have to be walking in the researcher's proximity to be included in the sample. The process of selection was done without their knowledge. It was until they were contacted by the researchers that they knew that they were to be part of the study if they were willing.

5.8 Instruments used for data collection

The following research instruments were used: questionnaire, test, observation schedule, and a Likert scale. 'A questionnaire is a written list of questions, the answers to which are recorded by respondents' (Kumar, 1999; p.110). The questionnaire was used to identify and verify physics student teachers' misconceptions in basic electronics. The reason for starting with a questionnaire was that it was the most appropriate way to get the information that would help to answer the first research question.

'A Test is an examination of somebody's knowledge or ability, consisting of questions for them to answer or activities for them to perform' (Hornby, 2010, p. 1543). This instrument was used because it was going to provide information that would help to check participants' performance in basic electronics content in senior secondary physics and in turn help to answer the second and third research question.

An 'Observation is a purposeful, systematic and selective way of watching and listening to an interaction or phenomenon as it takes place' (Kumar, 1996, p. 105). The observation schedule (Teacher Evaluation Form) was used mainly to evaluate students' performance in the teaching of basic electronics in senior secondary physics. This was because it was only by careful observation of lessons that presenters (in this case student teachers of physics) would be properly evaluated in the teaching of basic electronics. Therefore, this instrument provided information that would help to answer the last research question.

5.9 Validity and Reliability of the instruments used in the study.

'Validity is an attempt to check out whether the meaning and interpretation of an event is sound or whether a particular measure is an accurate reflection of what you intend to find out, while reliability refers to the consistency of a measure, score or rating' (Renuka and Jonathan, 2003, p. 32).

5.9.1 Validity of instruments used in the study

'A valid measuring instrument is that which does what it is intended to do, measuring what it is supposed to measure and yielding scores of which differences reflect the true differences of the variable being measured rather than random or constant errors' (White, 2005, p. 196). This definition has two parts; The first one is that the instrument actually

measures the concept in question. Second, the concept is measured accurately. The following classification scheme attempts to categorize the common validities underlying measurement, namely: face, and content.

Face validity is the idea that a test should appear to any person to be a test of what it is supposed to test. In other words, it is the researchers' subjective assessments of the presentation and relevance of the measuring instrument as to whether the items in the instrument appear to be relevant, reasonable, unambiguous and clear (Golafshani, 2003).

In the current study, to ensure that the test had face validity, the following were done: all questions in the test were on basic electronics and came from the school certificate pure physics past examination papers. They were based on the Zambian Senior Secondary School Physics Syllabus (5054). These questions were prepared by experts in physics who set, proof read and marked physics papers at the Examinations Council of Zambia. Furthermore, questions in the questionnaire came from the syllabus above, on basic electronics. The questionnaire was prepared by turning all the twenty objectives on basic electronics in the syllabus into questions for participants to answer. Therefore, it had all the validities. The teacher evaluation form had elements of effective teaching which were produced by the University of Zambia, School of Education and was used by the staff in the School to train future secondary school teachers. Items in the Likert scale were statements, related to nothing else but the treatment that was given to the experimental group and so, the instrument had face validity as well.

Content validity refers to the degree to which a test measures an intended content area (Gay, 1996; p. 159). It samples the range of behaviors presented by the theoretical concept being measured. In order to ensure that the tests had content validity, questions were at different levels of difficult and measured: general knowledge, verbal ability, spatial ability and various process skills that were expected of a physics student. Furthermore, the instruments were piloted, and only the questions that gave the type of answers that we found useful in the study were maintained.

5.9.2 Reliability of the instruments used in the study

According to Gay (1996, p.145), the term 'Reliability refers to the degree to which a test consistently measures whatever it measures.' In order to determine the **internal reliability** of the instruments, the study used the following methods:

- **Test-Retest**, in which the test on basic electronics was given to 5 physics student teachers of UNZA one day, who were not part of the sample and then administered to them again a week later. The two sets of scores were correlated in Excel to get a coefficient of stability.
- **Spearman-Brown's two equivalent half dividing method** and **Cronbach's Alpha** were used to determine the reliability coefficients of the Teacher Evaluation Form, Likert Scale and the Participant's Questionnaire.
- **Interrater reliability** (Cohen's Kappa) was used to examine the agreement between the two observers during Peer teaching sessions.

The reliability coefficients were found to be 0.80 for the Basic Electronics Test, 0.85 for the Teacher Evaluation Form, 0.82 for the Likert scale, and 0.90 for the Participant's Questionnaire. The interrater reliability for the raters was found to be Cohen's Kappa= 0.81 with $p < 0.005$ (95% CI).

The correlation coefficients were between 0.8 and 1, indicating minimum error variance. In other words the effect of errors of measurement (random errors) resulting from a variety of causes had been reduced and so the reliability of each instrument was acceptable (Bryman, 2004). All the information above had mainly to do with the quantitative aspects of the study.

5.10 Validity and Reliability of qualitative research

Since the study was not only quantitative, but also embraced **the qualitative paradigm**, there was need to address issues of validity and reliability of the qualitative side as well.

5.10.1 Internal validity of qualitative research:

'Internal validity is validity of the research study (White, 2005; p. 201). It can also be defined as 'The degree to which the research findings can be distorted by extraneous variables' **(**Borg and Gall, 1989; p. 405). Different strategies are used to deal with threats to internal validity of qualitative research. This is because ' It is not fair to measure the validity of qualitative research using the quantitative research yardstick' (p. 406). In the current study,

- **Content and concept validity** were achieved by : preparing a comprehensive record of categories of data established to be used during data analysis, establishing member checks and audit trails to make corrections to categories and concepts formed, guarding against bias and perspectives that the researcher might instill in the participants, as well as their prejudices that might influence their responses and indicating whether the researcher's attitude had changed through exposure to the research.

- **Logical validity** (which depends on the logic of the research framework) was attained by: Creating a balance between 'letting the object speak for itself ' and using abstracted categories for analysis and interpretation; Gathering data until the point of theoretical saturation had been reached. This meant that the gathering of data was continued until no new affirmative or contrasting information was obtained. At this stage the number of participants was the final number and the process of data gathering was terminated; Comparing data and indicating differences and similarities in the data.

5.10.2 External validity of qualitative research

This refers to 'the degree to which the findings can be generalized to the population from which the participants were drawn' (Borg and Gall, 1989; p. 404). Put differently, 'It is the validity of the research results regarding the intended object of study' (White, 2005; p. 202).

Since external validity relates to the validity of research results, the researcher ensured that there was external validity of qualitative research by taking the following measures: Giving an accurate description of the research process, reasons for the choice of methods, the circumstances under which, and context in which the research was conducted; and providing a 'thick' description of the research situation and context so that others could ascertain whether and to what extent the research results were valid or could be useful in their own situation or context" (White, 2005; p. 202).

5.10.3 Reliability of qualitative research

Like validity, reliability can also be divided into **Internal reliability** and **external reliability**. Internal reliability refers to the reliability during the study while external

reliability is the verification of the findings of the research, if the same research would be conducted by independent researchers under the same circumstances and using the same participants (White, p. 201)

The study accounted for **internal reliability** of the results using: Triangulation, Cross-examination (comparing the current findings with those of other researchers), Returning draft reports to respondents for accuracy checks (member checks), participants' open discussions regarding the findings to reach consensus, thorough selecting and training of research assistants and observers to ensure that people who assisted the researcher were competent, and mechanization (i.e. using computers for data processing).

In order to ensure that there was **external reliability**, a thick description of aspects such as the status and the role of the research subjects the researchers used, relevant characteristics of the participants, concepts that were used, theoretical ideas and methods of research were made available and clear. Furthermore, an exposition of the theoretical starting points and arguments underlying the various choices made in the research were included in the report (White, 2005; p. 201).

It is important to mention that high reliability does not guarantee valid results. For example a scale can measure the mass of a pupil as 60kg on three different days, although the correct mass could be 61kg. This scale is reliable, although not valid.

5.11 Validity of findings

In addition to validity of the research design, instruments and of qualitative research, the study also considered the validity of findings by triangulating the results. White (2005) sees triangulation as a method that may be used to combine qualitative and quantitative research. It provides a means by which researchers can test the strength of their interpretations to establish validity and reliability in their research findings (p. 89). Thomas and Nelson (1996) identify three types of triangulation. These include: *Theory triangulation*, which involves the use of several frames of reference (theories) or perspectives in the analysis of the same set of data. The current study used two theories of learning, Glasersfeld's Radical constructivism and Kell's Cognitive constructivism; Second is *Data triangulation*, which refers to data sources such as oneself, informants,

interviews, observations, questionnaires and documents. The current study gathered information through the use of a variety of sources, namely: questionnaires, Tests, observations and Likert scale, to ensure that a theory was tested in more than one way. The inclusion of multiple sources of data in this research increased the reliability of the observations as well. The last one is *Investigator triangulation*, which is the use of multiple observers, coders, interviewers and/or analysts in a particular study (White, 2005). In this study, two observers particularly during peer teaching, and two analysts were used to ensure that the scores obtained by participants and their final results were valid and reliable. In addition the study considered rival explanations for the same issues or questions.

5.12 Data collection

This section describes how access to the research site was gained and the procedures which were employed to collect the data needed to answer the research questions.

5.12.1 Negotiating Access to the Research Site

The researcher obtained permission from the Dean, School of Education, to conduct the study in the School of Education, Department of Mathematics and Science Education (MSE). After that he approached the Head, MSE, to present the letter from the Dean and explained what he intended to do. With the Head's permission, he met the staff in the Department of MSE, discussed the issue with them and arranged to start work. Using the MSE student departmental records/lists, he first selected the required student teachers (by simple random sampling). Then, he met the required student teachers and asked them if they were willing to participate in the study. He assured them that participation or non-participation in the study had no effect on their course grade in their degree programme. Therefore, participants were given an invitation to take part in the study (Appendix E on p.311). They also completed the consent form (Appendix F on page 231) before completing any of the data collection instruments. Only participants who agreed to participate in the study were given the questionnaire to complete.

5.12.2 The Pilot Study

Five university physics student teachers, who were not included in the study, participated in the pilot study. Though conversant with basic electronics, the students were not full

time and so did not mix with the subjects who were to participate in the main study. They were given the questionnaire, test, teacher evaluation form and Likert Scale.

The content and face validity of the tests were established in two different ways. First, early versions of the tests were examined by two physics educators, two teachers and ten graduate students, and their suggestions were incorporated into the final version. Second, the test was administered to five undergraduate physics students and it was determined that they all agreed on the correct answer to each question.

The reliability of each instrument (Test on Basic Electronics, Teacher Evaluation form, Likert Scale and the Participants's Questionnaire) was calculated through Spearman-Brown's two equivalent half dividing method and Cronbach's alpha on an excel spread sheet. The reliability coefficients were found to be 0.80 for the Basic Electronics Test, 0.85 for the Teacher evaluation form, 0.82 for the Likert scale, and 0.90 for the Participant's Questionnaire. According to Bryman(2003, p. 72), 'The figure

The pilot study was useful for a number of reasons. First, feedback from the small pilot study was used to revise questions in the instruments which were apparently unclear, did not solicit the desired information, or produced negative reactions in subjects. Second, it allowed the researcher to determine the adequacy of instructions to respondents who were to participate in the test and complete the Likert scale and the self-completion questionnaire. Furthermore, the pilot study determined whether the resulting data could be quantified and analyzed in the manner intended. The section that follows describes how data was collected from various instruments.

5.12.3 Procedure for data collection

A questionnaire was administered to the respondents by the researcher. The purpose of the questionnaire was to find out what **misconceptions** student teachers of physics had in basic electronics in senior secondary physics. Second, a test was administered to see what results participants would get in basic electronics content in senior secondary physics. The test comprised two sections, namely: multiple choice and structure questions. This type of test was used not only to cover all areas of basic electronics but also to avoid any subjectivity in marking. The test was followed by peer-teaching observations (which

were done by the researcher with assistants) to see if the participants' teaching in basic electronics was effective or not. The results obtained in the test and peer-teaching were later compared with student misconceptions to see what correlation existed between them. After that, participants in the experimental group were given the treatment while those in the control group did some other content mainly on conservation laws. That stage was followed by a post-test for all participants on basic electronics. Finally, a Likert scale was given to the experimental group to get their views about misconceptions and the treatment they were given. Data collection from all the instruments took about two months.

5.13 Data analysis

This study generated both quantitative as well as qualitative data. The data was analyzed as described in the following subsections.

5.13.1 Analysis of quantitative data

(a) Analysis of quantitative data from pre and post tests

Quantitative data analysis is the process of presenting and interpreting numerical data. This type of analysis often contains descriptive and inferential statistics. Descriptive statistics includes among others, measures of central tendency (averages - mean, median and mode) and measures of variability about the average (range and standard deviation). These give the reader a 'picture' of the data collected and used in the research project. Inferential statistics are the outcomes of statistical tests, helping deductions to be made from the data collected, to test hypotheses set and relating findings to the sample or population (Gay, 1996). The coefficients were determined using the Statistical Package for Social Sciences (SPSS) computer software.

This study began with **descriptive statistics** by determining the Pearson's Product Moment Correlation Coefficients (for pre and post test scores) to see what correlation existed between the physics student teachers' misconceptions and their performance in basic electronics.

After finding 'r', **Inferential statistics** was used to determine if there was statistically significant correlation between misconceptions held by participants and their

performance in basic electronics content. Therefore, the researcher embarked on finding out if the value of the Pearson's Product Moment Correlation that was obtained in the study represented a true relationship, that is, if it was significantly different from 0.00 and reflected a true relationship not a chance relationship. In order to do that he used a reference table, A.2, from Gay (1996) on page 606, which indicated how large ' r' needed to be in order to be significant, given the number of subjects available (60) and the level of significance (0.01) at which he worked. He compared the Pearson r to the table value and the former was bigger than the latter. The table did not know or care whether r was positive or negative. It only showed how big r needed to be in order to indicate a relationship significantly different from 0.00, a true relationship (Gay,1996).

After determining the correlation above, there was need to find out if misconceptions were the cause of that correlation or not. The only way to do so was to use inferential statistics to compute a **t-value** for two independent samples**.** This parametric test was used because the number of participants in each of the two groups was 30, which was a threshold number of participants for parametric tests (Gay, 1996) and all other assumptions for use of parametric test were met. The t-test was done using the computer software SPSS.

(a) Analysis of quantified data from the Teacher Evaluation Form (appendix 'C'), which was used during peer teaching of basic electronics.

First, pre- and post-test scores obtained by participants in various elements of effective lesson presentation on basic electronics, were recorded and summarized. Next, the sums, means and percentages of the scores were determined using Excel. After that, graphs of Score by experimental group Vs Score by control group before and after treatment were plotted to see clearly the difference in performance between the two groups in teaching basic electronics. Finally, a t-test was done on the post-test scores of the two independent samples to see if there was a significant difference between the post-test scores of the two groups in teaching.

(b) Analysis of quantitative data from the Likert scale.

There are various kinds of rating scales used to measure attitudes directly (i.e. the person knows their attitude is being studied). These are the Likert scale, semantic differential

scale, Thurstone scale and the Guttman scale (Gay, 1996). Among these, the most widely used is the **Likert Scale** (McLeod, 2008).

Likert-type or frequency scales use fixed choice response formats and are designed to measure attitudes or opinions (Bowling, 1997; Burns and Grove. 1997). These ordinal scales measure levels of agreement/disagreement. A Likert-type scale assumes that the strength/intensity of experience is linear, that is, on a continuum from strongly agree to strongly disagree, and makes the assumption that attitudes can be measured. Respondents may be offered a choice of five to seven or even nine pre-coded responses with the neutral point being neither agree nor disagree. In its final form, the Likert scale is a five (or seven) point scale which is used to allow the individual to express how much they agree or disagree with a particular statement.

The current study used a Likert scale with five responses, each of which had a numerical value that was to be used to measure the attitude under investigation. Data analysis was done by :

- first determining the mode for each item (lesson element), then,
- displaying the distribution of observations in a bar chart.

According to McLeod (2008), Likert Scales have the **advantage** that they do not expect a simple yes / no answer from the respondent, but rather allow for degrees of opinion, and even no opinion at all. Therefore **quantitative data** is obtained, which means that the data can be analyzed with relative ease.

However, like all surveys, the validity of Likert scale attitude measurement can be compromised due to the **social desirability**. This means that individuals may lie to put themselves in a positive light. Paulhus (1984) found that more desirable personality characteristics were reported when people were asked to write their names, addresses and telephone numbers on their questionnaire than when they were told not to put identifying information on the questionnaire. Therefore, in this study, participants were told not to indicate their details such as names, computer numbers etc on the questionnaire but ;.just a symbol that was used to distinguish each participant from others.

5.13.2 Analysis of qualitative data

'Qualitative data analysis is the process in which we move from the raw data that have been collected as part of the research study and use it to provide explanations, understanding and interpretation of the phenomena, people and situations which we are studying.' (Strauss and Corbin, 1990, p.61). Qualitative data to be analysed in this case were descriptive answers to twenty questions in the questionnaire (Appendix 'A') on the following concepts: Thermionic emission; Action of resistor, potentiometer, thermistor, diode, light dependent resistor, capacitor, reed switch and transistor in electronic circuits; logic gates; action of bistable; action of astable circuits; and computer hardware and software. Participants wrote a brief description of each concept, from which their misconceptions were revealed. Therefore, to analyse the data the study used the Constant Comparative Method as described below (Glasser, 1965; Bryman, 2004).

First, the researcher read each text (description or answer given by each participant per question) more than once and as he did so, took down any impressions he had which he thought would be useful later. Next**,** he identified the first key question of the study which he wanted the analysis to answer (Glasser, 1965). That identification in turn helped to review the purpose of the evaluation and what he wanted to find out (Strauss and Corbin, 2008). Then, he focused on the analysis to see how all subjects responded to each of the twenty questions. Data for each question were put together so that it would be easy to identify consistencies and differences. Later the researcher explored the connections and relationships between the data (Powell and Renner, 2003; Bryman, 2004).

After that, he categorized the information. Some people refer categorizing information to as **coding** the data or **indexing** the data (Strauss and Corbin, 1990). However, categorizing in this case did not involve assigning numerical codes. In order to bring meaning to the words before him, the researcher identified themes or patterns (ideas, concepts, terminologies or phrases) used and organized them into coherent categories that summarized and brought meaning to the text (Strauss and Corbin, 1990).

A descriptive label (**name**) was provided for each category he created. He made sure he was very clear about what he included in the category and what he excluded. As he categorized the data, he identified other themes that served as subcategories and so he continued to categorize until he had identified and labelled all relevant themes (Strauss

and Corbin, 1990). Main categories were broken into subcategories to ensure that the data were in smaller and more defined categories so as to allow for greater discrimination and differentiation (Powell and Renner, 2003; Bryman, 2004). He continued to build categories until no new themes or subcategories were identified. As many categories as possible were added to reflect everything in the data and to interpret data clearly. He read and re-read each text to ensure that the data were correctly categorized. Data that were not suitable were not coded (Strauss and Corbin, 1990).

After that, he wrote a summary for each category showing key ideas (misconceptions) being expressed within a category, including any similarities and differences in the way the subjects responded (Powell and Renner, 2003). Where need was, larger categories were created to see how the parts related to the whole. In order to show which categories appeared more important he counted the number of times a particular theme came up, or the number of unique respondents who referred to certain themes. That information was put in a table and a graph was plotted. The counts provided a very rough estimate of relative importance but were not suited to statistical analysis, though they revealed general patterns in the data (Strauss and Corbin, 1990; Bryman, 2004; Strauss and Corbin, 2008).

Finally, the themes and connections were used to explain the findings. A list of key points or important findings was developed as a result of categorizing and sorting the data. An outline was developed for presenting the results. Quotes were included to illustrate the points and bring the data to life.

It should be mentioned that after defining categories and labeling data, grouping the data into categories involved some form of cutting and sorting. Each text was cut out of the printed page and sorted into different piles. Each pile represented a category and had a name. An identifier was kept (source of data) with the data so he knew where the text came from. Therefore, when cutting and sorting, the researcher kept track of the source of the data (Bryman, 2004; Strauss and Corbin, 1990; Strauss and Corbin, 2008).

In summary, the method involved making three main passes through the data. The first, called **open coding** required reading through the data carefully and noting the themes or categories (also called codes) which might have been there. The second pass through the data, called **axial coding**, involved seeing how the categories already identified were related, so that major categories and subcategories could be identified. While the final

one, called **selective coding**, was intended to bring together the themes identified in the data to determine how they were connected to each other (Strauss and Corbin, 1990; Powell and Renner, 2003). Data were read again a number of times to identify sections which appeared to relate to different themes. Thereafter, categories were defined and data were labeled and grouped into categories after cutting and sorting. Each pile represented a category and had a name. The researcher made sure that the names represented the main themes that he earlier identified. The themes identified were used to structure the presentation and discussion of results.

5.14 Limitations of the study

Gay (1996, p. 96) defines a limitation as 'Some aspect of the study that the researcher knows may negatively affect the results or generalizability of the results but over which he or she probably has no control; In other words, something is not as good as it should be but the researcher cannot do anything about it.' This research worked within three limitations. Firstly, only 60 student teachers of physics were used because that was the maximum number the researcher could get, following the sampling method that was used. This might have affected the generalizability of the study. Secondly, access to respondents was limited to the time when they did their peer teaching. All other times, the students were busy with their academic work and so could not be reached for this purpose. Therefore, time was not enough for the researchers to do as many observations as possible for the same issues and this might have affected the validity of the findings.

Third, searching for a suitable theory or theories of learning that could constitute the theoretical framework was problematic due to the current debate between constructivists and other learning theorists on philosophical perspectives. This made it difficult to arrive at the best research design for the study. The fourth one was the use of a Likert scale. The instrument limited participants' responses only to the choices they were given. Therefore, the researcher could not be sure that the individuals were expressing their true attitudes rather than "Socially acceptable" attitudes. Therefore, the validity of the study was affected because it was directly related to the validity of the responses made by individuals in the sample.

5.15 Delimitation of the study

The term delimitation is used to address how the study is narrowed in scope. Delimitations are factors that affect the study over which the research generally does have some degree of control (Creswell, 1994). They differ from limitations (over which the researcher has little or no control) in the sense that in this case (delimitations), the researcher has control. In this study, though there were many students of physics at 1st and 2nd years who had done basic electronics and some of whom had a teaching experience (in-service teachers); the study was restricted to 3rd and 4th year students to avoid clashes in the time table.

5.16 Reflection on Ethical Issues

The term "Ethics or ethical refers to principles of conduct that are considered correct, especially those of a given profession or group" (Ranjit, 1999, p. 10). White (2005; p. 210) adds that Ethics is:

> *A set of moral principles which is suggested by an individual or group, is subsequently widely accepted, and which offers rules and behavioural expectations about the most correct conduct towards experimental subjects and respondents, employers, sponsors, other researchers, assistants and students*.

Certain behaviors' in research such as causing harm to individuals, breaching confidentiality, using information improperly and introducing bias are unethical. Therefore, in the current study, respondents remained anonymous in the sense that they did not use their names but symbols (a letter each with a number as a subscript), for record purposes. As a result, no one could easily identify a response with a given respondent. No information from respondents was made public as there was confidentiality. Privacy, defined by White (2005) as " that which normally is not intended for others to observe or analyze" (p. 210), was respected. Participants had a right to decide when, where, to whom, and to what extent their attitudes, beliefs and behaviors would be revealed. Information was given anonymously to ensure that there was privacy. All possible methods of protecting the respondents were applied. They were also informed that participation or non-participation in the study had no effect on their course grade in their degree programme.

Furthermore, no information was revealed that would embarrass participants or endanger their academic performance. They were informed of safety regulations in the laboratory where the study was conducted and none of them was injured in any way. The researcher ensured that no participant experienced mental or physical discomfort. Researchers took the study in which they were skilled. No value judgements were made under any circumstances whatsoever on the cultural aspect of communities. Informed consent was obtained after placing a lot of emphasis on accurate and complete information so that subjects fully understood and consequently were able to make a voluntary, thoroughly reasoned decision about their possible participation but the researcher also made sure that this did not affect the internal validity of the experiment. Therefore, participants were not forced to take part in the study but did so willingly. They were aware of their entitlement to refuse any stage for whatever reason and to withdraw data just supplied. All the questionnaires and test scripts were issued and collected by the researcher. Finally, there was no deception, that is, representing the research as something other than what it was, not only because it was undesirable, but also because of the question of professional self interest (Bryman, 2004).

5.17 Chapter Summary

This section was on the design and methodology of the study. The study employed a mixed methods approach (quantitative and qualitative), the Correlation research design, and the True experimental Design of the type Pretest-Posttest Control Group. The Study area was the University of Zambia. The study population comprised 191 BSc. Ed and BEdMAS students from whom 60 subjects formed a sample using Simple Random Sampling. Instruments used were the questionnaire, test, teacher evaluation form and attitude scales. Although the issues of validity and reliability were addressed, the study still experienced some limitations. Ethical issues were addressed accordingly. The chapter that follows presents the findings of the study.

CHAPTER 6

FINDINGS ON THE MISCONCEPTIONS HELD BY PHYSICS STUDENT TEACHERS

6.0 Introduction

This chapter presents the findings on the **first research question** of the study. It has two Sections, 6.1 and 6.2. Section 6.1 presents the misconceptions held by student teachers of physics in basic electronics, as revealed by the study. Section 6.2, presents the chapter summary.

6.1 Misconceptions held by physics student teachers in Basic Electronics.

Here the research question to be answered was ***'What misconceptions do student teachers of physics have about basic electronics in senior secondary physics, as they finish their training?'***

Participants were given a questionnaire (Appendix A, p. 286) containing 20 items and were asked to write what they knew about each item. From the answers they gave, several misconceptions were revealed as described stated in statements (i) to (xx) that follow.

(i) Thermionic emission is loss of heat by materials

When asked to describe "Thermionic emission", in question 1, a number of participants, 15 (25%) made statements which implied that Thermionic emission is loss of heat by materials. Some of these participants were E2, E6, E21, C3, C4 and C29. E2 said 'This is the emission or transmission of thermal energy', while E6 said 'This is the emission of heat by a particle it could be an electron.' According to C3, 'It is the loss of heat by heated electrons', while E21 said 'Not sure but involves the emission or loss of heat by a body.' C4 said 'Thermionic emission is the emission of heat by good conductors of heat.' E14 added 'This is the emission of heat by some substances which involves the process…. For example when an electron which is accelerated is suddenly blocked it losses energy....this energy is released as heat and light.' When asked for more reasons

why they thought thermionic emission was loss of heat by a body, C29 said, 'the term "Therm" is associated with heat, and the term "ionic" is associated with ions while emission means losing. Therefore, Thermionic emission is the losing of heat by hot particles such as ions in a body.' It was clear from all the above responses from participants that a good number of them had an erroneous idea (misconception) about thermionic emission.

(ii) Cathode rays are electromagnetic waves that travel at the speed of light

In question 2 of the questionnaire, participants were asked to state four properties of cathode rays. Several participants, 19 (32 %) indicated that cathode rays were waves that travelled at the speed of light. Among them were C2, C9, and E10. C2 said 'They are waves.' C9 said 'They are electromagnetic in nature' while E10 said 'Since they are rays, they are waves as well and they have speed of light;' Others were E1, E5, E7, E8, E14, , C1, C3,C9 and C10 who also indicated that cathode rays travel at the speed of light. When asked why participants thought cathode rays were waves, C17 and C23 substantiated their claim by saying that a ray is associated with some form of energy, that is, light ray, heat ray etc. Therefore, cathode rays were waves in nature since they (cathode rays), according to the participants, were in form of energy. Furthermore, since they were waves, they travelled at the speed of light. Their ideas suggested that cathode rays are electromagnetic in nature, which is a fallacy.

(iii) Conventional current (is the same as convection current and so it) has no specific direction

Here, the question to be answered by respondents was " Is there any difference between the direction of flow of electrons and the flow of conventional current." Some participants refused entirely, 8(13%). C1 said 'There is no difference because in any case, current moves from a higher potential to a lower one, electrons move from less attractive to more attractive, conventional currents move from more heated to less heated areas.' C12 said 'There is no difference since they both refer to the flow of electrons' and C14 said 'No, this is because electrons flow in the positive direction and also conventional current flows in the positive direction.' Furthermore, there were participants who thought that conventional current had no direction because it was the same as convection currents in air or water (C16, C25 and E29) which have no specific direction. Therefore, some participants, did not distinguish between direction of electron flow and that of

conventional current. In other words the concept of conventional current was not clear to some participants.

(iv) Applications of cathode rays are similar to those of electromagnetic waves such as X-rays

In question 4, participants were asked to state four applications of electron beams. C1 said 'In the cure of cancer, knowing of broken bones, knowing of cracks.' C28 said in welding, C7 said in the detection of fracture and C8 expanded on the answers given by saying:

> E*lectron beams i.e X-rays are used in treatment (medicine) to see internal wounded or broken bones; Also used to see through metals so as to determine a metal has internal cracks or not; electron beams are used in lighting.*

Therefore, such participants, 14(23%) believed that cathode rays could be used exactly as x-rays because according to them cathode rays were electromagnetic in nature like X-rays, which was a misconception.

(v) (a)The Cathode ray oscilloscope (CRO) has one X and one Y- plate that form a deflecting pair

In the fifth question, participants were asked to describe the basic structure and action of the cathode ray oscilloscope. E12 said 'Cathode ray oscilloscope contains two plates that is the X-plate and the Y-plate. X-plate deflects the beams horizontally, Y-plate deflects the beams vertically.' E10 said 'Cathode ray oscilloscope has a source of light/heat, X-plate and Y-plate.....' C2 also said 'It has the X-plate and Y-plate.' According to C4, ' It has the X and Y plate for emission of electrons.' C9 said 'X-plate cause horizontal deflection of electrons and Y- plate cause vertical deflection.' C10 said 'Y-plate for vertical; X-plate for horizontal.' These responses from participants, 6 (10%) implied that the cathode ray oscilloscope comprised only two plates, X and Y as a pair. That kind of thinking gave the impression that participants misunderstood the action of X and Y plates in the Cathode Ray Oscilloscope and so they had a misconception about how a cathode ray oscilloscope operates.

(b) In a CRO the heater produces light, which is deflected by X and Y plates

On the same question (V) above, some participants, 3(5%) indicated that the heater in a CRO produces light and not heat and that the light produced was deflected by X and Y plates. Among them were C2, C21 and C4. According to C4 and C21, 'In a CRO, the heater produces light which is deflected by charged plates.' C2 added that 'The CRO has.....source of heat which produces beams of light and light is accelerated and controlled by X-plate and Y-plate.'

Therefore, when participants saw a spot of light moving either vertically or horizontally on the CRO screen, they were made to believe that light can be deflected by charged plates, which is not viable. On the other hand, after further cross examination, some participants said that the light seen on the screen were beams of electrons. This implied that electrons could be seen, which also was wrong. It was clear from that kind of thinking that some participants had a wrong conception regarding how light came about on the Cathode Ray Oscilloscope screen.

(vi) Intergrated circuits, Amplifiers, Logic gates, transformers are some of the basic components in electronics

Question 6 required participants listing 8 basic electronic circuit components. According to the Zambian senior secondary school syllabus (CDC, 2000; 2015), the expected answers were: resistors, potentiometers, capacitor, thermistor, light dependent resistor, reed switch and reed relay. Some of these were listed by participants. But some participants added: Intergrated circuits, Amplifiers, logic gates and transformers. This clearly showed that those participants, 6 (10%) like C2, C5,C14, E10, E12 and E14, did not understand what the syllabus meant by basic electronic circuit components.

(vii) All band values must be added to find resistance of band resistors

Here, participants were asked to describe how to determine resistor values using standard color codes. C1 wrote: 'Determining resistor values. Each resistor has colors in it and each color has a code. To know resistor value get value on the first color followed by other colors and so forth. Triple the value of the last color taken.' According to C4, to determine resistor value, 'You note the colors that a resistor has, each color represents a different value. After noting those colors add their value and the answer you get gives

you the value of such a resistor.' E6 stated that 'the colors correspond to a specific number, hence we add the number corresponding to colors starting from the left to the right.' E7 added, 'Since each code represents a certain amount of resistance by the transistor, so adding the color codes, will give the total resistance of the resistor. Hence the resistor value.'

Therefore, a number of subjects, 6(10%) thought that to determine the effective resistance of a band resistor, one should just add up all the band values. But in general, if the resistance of a band resistor were calculated that way, the answers would be wrong.

(viii) A potentiometer acts as an ammeter, detects resistance and measures resistivity of wire

The question that followed was number 8, in which participants were asked to describe the action of the potentiometer. Although many of the responses from participants were satisfactory, some 4(7%) weren't. C1 said 'A potentiometer can act both as an ammeter and a resistor. C7 said 'The potentiometer detects the resistance of the substance being measured say water, when put on the metal strip the voltmeter deflects which shows the resistance of the substance.' C3 and C30 said 'A potentiometer will measure resistivity of a wire.' Therefore, some participants had a misconception about the action of a potentiometer.

(ix) Half Wave Rectification produces an output which is partly DC and partly AC; Full Wave Rectification produces an output which is completely DC.

Participants attempted question 9, in which they were asked to distinguish between half wave and full wave rectification. Many of them, 23(38%) stated that Half Wave Rectification produces an output which is partly AC and partly DC. while Full Wave Rectification produces an output which is completely DC. Some among them responded as follows: C1, 'Half Wave changes AC to DC but leave pulsating wave forms in their output as there is still a degree of alternating current in output while full wave changes AC to DC completely.' E1 said, 'in a half wave rectifier it is not pure direct current but there is some component of alternating current in the output whilst in the full wave rectifier the output is pure direct current (if alternating current present is small).

According to E3, ‘Half Wave rectification is the production of voltage or current which is partially AC while full wave produces DC voltage or current.’

Therefore, participants believed that in half wave rectification, part of the output still remained AC. In other words, the concept of rectification was misunderstood.

(x) A Thermistor changes heat energy to electrical energy and detects temperature

In question 10, participants were asked to explain the action of a thermistor. Some, 6(10%) indicated that a thermistor changes heat energy to electrical energy. For example, according to E11, ‘It is a device that is used to convert heat energy into electrical energy.’ But if it were so, the thermistor could serve as a power supply in a circuit. Therefore, some participants had a wrong conception about the action of a thermistor.

(xi) Light Dependent Resistor (LDR) depends on light to measure resistance

In question 11, participants were asked to explain the action of a Light Dependent Resistor (LDR). Participant E5 stated that ‘light dependent resistor, becomes active to measure the resistance when it gains more energy from light, but it fails when there is no enough light, therefore it depends so much on light for it to operate.’ C7 stated that ‘ The light dependent resistor is one that depends on light for it to measure resistance.’ E25 expressed the same sentiment as others. A number of them, 8(13%), believed that Light Dependent Resistor (LDR) depends on light to measure resistance. It was clear from this that such participants misunderstood the action of an Light Dependent Resistor in an electronic circuit.

(xii) Capacitor discharges whenever it is disconnected from a power supply/circuit

In question 12, participants were asked to describe the charging and discharging of capacitors. Here it was worrying to note that several participants, 20(33%) believed that a capacitor discharges completely when it is not part of a complete circuit. Among the statements made by participants were the following:

‘C3 said when a capacitor is connected to the power source, it gets charged by storing charges and when immediately disconnected it starts discharging by releasing out charge.’ C4 said ‘this topic confuses me.’ But C8 said ‘a capacitor when connected in a

circuit with a certain potential across it, gets induced, meaning that while still connected in a circuit potential is induced into the capacitor, then when it is disconnected it loses this induced potential gradually or slowly till it goes back to its original state.' According to C9, 'Charging a capacitor involves the inducing of a charge on a capacitor so that it can be stored. The capacitor is connected to a circuit so that when the circuit is on, charge passes and is stored in a capacitor. When the capacitor is disconnected charge stops flowing and the capacitor starts losing what it stored. This is called discharging.' C10 said 'When a capacitor is connected to a power source it allows voltage to flow while storing some. When the power source is removed the capacitor will start releasing energy slowly.' E2 said 'I don't understand this topic.' E3 said 'When current passes through a capacitor, it charges and when current stops passing through a capacitor, it discharges.' E5 said 'When a capacitor is connected to the circuit, it takes a bit of time to be active, and hence it becomes charged but when it is removed from the circuit again it becomes discharged.' E6 added, 'When one of the sides of the capacitor is connected to the power supply it begins to charge (stores charge). When it is full it discharges the charge through the other side to the point of need.' E7 said 'As current passes through a capacitor, a charge is stored between the dielectric as the capacitor is disconnected, the charge from the dielectric is released, hence discharging.' E8 said 'for a charging capacitor, when time is zero the charge is also zero, now after t seconds the capacitor has charged and when the Q max is attained the current is zero and if the supply is removed the capacitor begins to discharge to zero.' E9 said 'A capacitor is made of two parts of different charges. When placed in the circuit it begins storing charge to its full capacity before passing to other components of the circuit. This is called charging. When it is full it releases the charge and this is called discharging.' E10 said 'charging of the capacitor occurs when the current flows in the circuit while discharging when the circuit is not conducting.'

These statements implied that a capacitor discharges whenever it is disconnected from a power supply/circuit. In other words the participants meant that a charged capacitor which is not connected to any circuit gradually loses all its charge, which is a worrying misconception.

(xiii) A reed switch operates on the principle of induced current and regulates voltage

In question 13, participants were asked to explain how a reed switch works. Many of them said they were not sure. But some participants, 4(7%) such as E8 and C13 gave interesting answers. E8 said 'A reed switch operates on the principle of induced current. When a current is induced into a plate closer to another plate depending on the charge on the plates they may attract or repel.....' C13 said 'Reed switches are used to regulate voltage but only allow certain amount to pass or the current breaks completely.' These conceptions of some participants about the action of reed switches in a circuit were fallicies.

(xiv) A reed relay uses temperature changes to control current

In question 14, participants were to explain how a reed relay works. Again many said they were not sure. Among those who gave answers, was C13 (2%). He responded that 'Relay switches are self regulated switches, when temperature increases it slowly goes off or reduces the current flow and then opens again.' This answer gave an impression that the participant thought that a relay switch operated on the principal of expansion and contraction, like a bimetallic strip, which was not correct.

(xv) Bipolar transistor is made up of two transistors; When one is on, the other is off; so it acts as a switch.

In question 15, participants were asked to explain how a bipolar transistor works as a switch.

Some subjects, 8(13%) believed that a Bipolar transistor is made up of two transistors; When one is on, the other is off; This is how it acts as a switch. For example C2 said 'Bipolar transistor has two transistors, It works in such a way that when voltage on one of transistors goes on, the other one goes off.' E6 said 'It has two transistors, hence when one is conducting the other is turned off after a while, the one that was off is turns on and the one that was on is turned off.' But E2 said he did not understand that topic. It was clear from these statements that some participants had a wrong conception about the action of a transistor as a switch.

(xvi) Bipolar transistor is made up of two transistors; This enables it to amplify

In question 16, participants were asked to describe the action of a transistor as an amplifier. Some participants, 8(13%) were under the impression that a Bipolar transistor is made up of two transistors and this is what enables the transistor to amplify. For

example, C2 said ‘Since the bipolar has two transistors connected opposite to each other in the circuit this increases its advantage of amplifying.’ This clearly indicated that the concept of the action of a transistor as an amplifier was erroneous to such participants.

(xvii) In all cases NAND outputs are opposite to NOR outputs

In question 17, participants were asked to distinguish between the action of NAND and NOR gates. Some of them, 7(12%) said that in all cases NAND outputs were opposite to NOR outputs, which is not true. Among them were C6, E8 and E10 who verbally stated that the output of NAND were opposite to the output of the NOR gate. Like several others, these participants had challenges with truth tables.

(xviii) 0+0 = 1 and 1+0 = 0 for AND gate

Here, participants were asked to derive the truth table for AND, OR, NAND, NOR and NOT gates. Generally speaking they did well on this question except for few who had difficulties like C1, 1(2%), who gave the truth table for the AND gate as shown in the following table.

Input A	Input B	Output
0	0	1
1	0	0
0	1	1
1	1	1

The participant had a wrong idea about the action of the AND gate.

(xix) Astable circuit has one stable state.

In question 19, participants were asked to describe the use of Bistable and Astable circuits. Some participants, 10 (17%), said that an Astable circuit has one stable state. For example, C2 said ‘Bistable, it is a multivibrator which has two capacitors for its works and two transistors. In a circuit when switched on, the transistor will be in a 2 stable state at high voltage. But the capacitor present charges and then forces one transistor to go low

depending on where current is conducted first. While the Astable one has only one stable state.' C4 said 'Bistable circuit has two stable states and an Astable circuit has one stable state. Bistable circuits are needed in the electrical machines, that is, on robots to change colours. They result in stable and unstable states.' C13 said 'The bistable circuits have two stable states because both transistor conduct and allow both outputs to be high, the Astable circuit has one stable state as one transistor conducts the other does not conduct hence only allowing one output to be high.' E8 said 'Bistable circuit has two stable states while Astable has only one stable state.' Therefore, several participants had the idea that an Astable circuit has one stable state, which was not viable.

(xx) Computer hardware as wares that are external while computer software are wares that are stored in a computer

On the last question, number 20, participants were asked to distinguish between computer hardware and software. Many performed well on this question. They referred computer hardware to as the physical components of a computer while computer software meant programs in a computer. However, some participants, 7(12%) gave strange answers. For example, C1 said 'Computer hardware are wares that are external while software are stored wares in the computer.' C3 said 'Hardware is the make up and the components of the computer. Software is the inner make up that makes the computer to be operational.' E5 and few others admitted that they were not sure about the difference between computer hardware and software. These ideas indicated that some participants were not very clear about the distinction between computer hardware and software and so needed more clarification on those terms. All the misconceptions revealed by the study were as shown in the table below.

Table 6.1.1 Summary of physics student teachers' misconceptions as revealed by the study

S/NO.	Sub-topic	Misconception/s	Frequency	%
1	Thermionic emission	Thermionic emission is loss of heat by materials	15	25
2	Cathode rays	Cathode rays are waves; travel at speed of light	19	32

3	Conventional current	Conventional current (is the same as convection current and so it) has no specific direction	8	13
4	Applications of electron beams	Application of cathode rays are same as those of electromagnetic waves	14	23
5(a)	Basic structure and action of cathode rays	The CRO has one X and one Y- plate that form a pair.	6	10
(b)	Basic structure and action of cathode rays	In a CRO the heater produces light which is deflected by X and Y plates	3	5
6	Basic circuit components	Intergrated circuits, Amplifiers, Logic gates, transformers are some of the basic components in electronics.	6	10
7	Determining resistor values using standard colour codes	All band values must be added to find resistance of band resistors	6	10
8	Variable potential divider	A potentiometer acts as an ammeter, detects resistance and measures resistivity of wire	4	7
9	Action of a diode	Half Wave Rectification produces an output which is partly DC and partly AC. Full Wave Rectification	23	38

		produces an output which is completely DC.		
10	Action of a thermistor	A Thermistor detects temperature	6	10
11	Action of a light dependent resistor (LDR)	LDR depends on light to measure resistance	8	13
12	Action of a capacitor	Capacitor discharges whenever it is not part of a complete circuit	20	33
13	Action of a reed switch	A reed switch operates on the principle of induced current and regulates voltage	4	6
14	Action of a reed relay	A reed relay uses temperature changes to control current	2	3
15	Action of a bipolar transistor	Bipolar transistor is made up of two transistors; When one is on, the other is off; so it acts as a switch.	8	13
16	Action of a bipolar transistor	Bipolar transistor is made up of two transistors; This enables it to amplify.	8	13
17	Logic gates	In all cases NAND outputs are opposite to NOR outputs.	7	12
18	Logoc gates	**0+0 = 1 and 1+0 = 0 for AND gate**	1	2

19	Action of astable and bistable circuits	Astable circuit has one stable state	10	17
20	Computer hardware and software	Computer hardware as wares that are external while computer software are wares that are stored wares the a computer	7	12
Total Number of participants			**N= 60**	**100%**

After the summary in Table 6.1.1, the **number of misconceptions held by participants** per topic were presented graphically in fig. 5.1.1, in order to show clearly the sub topics in which participants had more misconceptions.

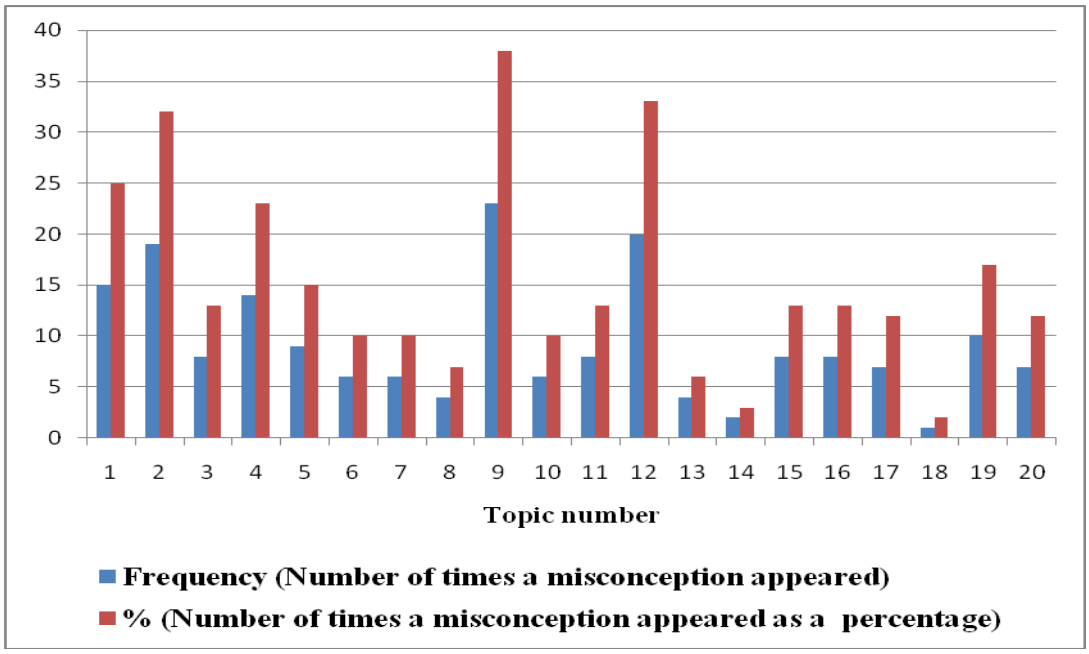


Fig. 6.1.1 Number of times a misconception appeared Vs Topic Number

6.2 Chapter Summary

The results in Table 6.1.1 and Fig. 6.1.1 show that participants had misconceptions in all topics. Most misconceptions were on topics: 2 (32% - Cathode rays are electromagnetic waves that travel at the speed of light, 9(38% - Half Wave Rectification results in an output which is partly DC and partly AC and 12(33% - A capacitor discharges completely when it is disconnected from a circuit.

CHAPTER 7

FINDINGS ON THE CORRELATION BETWEEN PHYSICS STUDENT TEACHERS' MISCONCEPTIONS AND PERFORMANCE IN BASIC ELECTRONICS CONTENT

7.0 Introduction

This chapter presents the findings on the correlation between physics student teachers' misconceptions and performance in basic electronics content. The research question to be answered was***, "What is the correlation between such misconceptions and performance of student teachers in basic electronics content in senior secondary physics?"*** This was the second research question and it was asked in an effort to determine whether, and to what degree, a relationship existed between the physics student teachers' misconceptions and their performance in basic electronics content. The relationship did not imply that one variable was the cause of another, but it could be useful for prediction purposes.

The chapter has nine Sections, 7.1 to 7.9. Section 7.1 presents the findings on the correlation of the experimental group before the treatment. Section 7.2 presents the findings on the correlation of the experimental group after the treatment. Section 7.3 compares results of the experimental group before and after treatment. Then, section 7.4 presents the findings on the correlation of the control group before the treatment. Section 6.5 presents the findings on the correlation of the control group after the treatment. Section 7.6 compares results of the control group before and after the treatment. Section 7.7 presents the findings on the correlation of both groups before the treatment. Section 7.8 presents the findings on the correlation of both groups after the treatment. Section 7.9 presents the chapter summary. The results were mostly presented graphically, using the data from appropriate tables in **appendix E**. This was done so that it could be easier to understand the findings.

7.1 Correlation of the experimental group before the treatment

The pre-test results of participants in the experimental group were presented graphically as shown in Fig. 7.1.1. The letter **E** represented a participant in the experimental group.

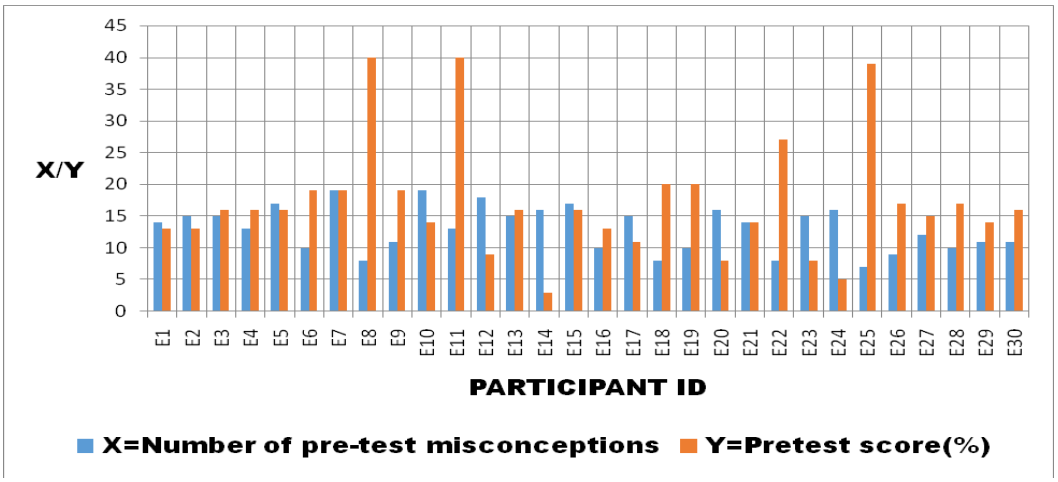


Fig. 7.1.1 Pre-test misconceptions Vs Pre-test scores for Experimental group

Careful examination of the graph above indicates that participants with fewer misconceptions performed better than those with more misconceptions and vice versa. Following this, misconceptions in Fig. 7.1.1 were correlated with their corresponding scores and the graph in Fig. 7.1.2 was produced.

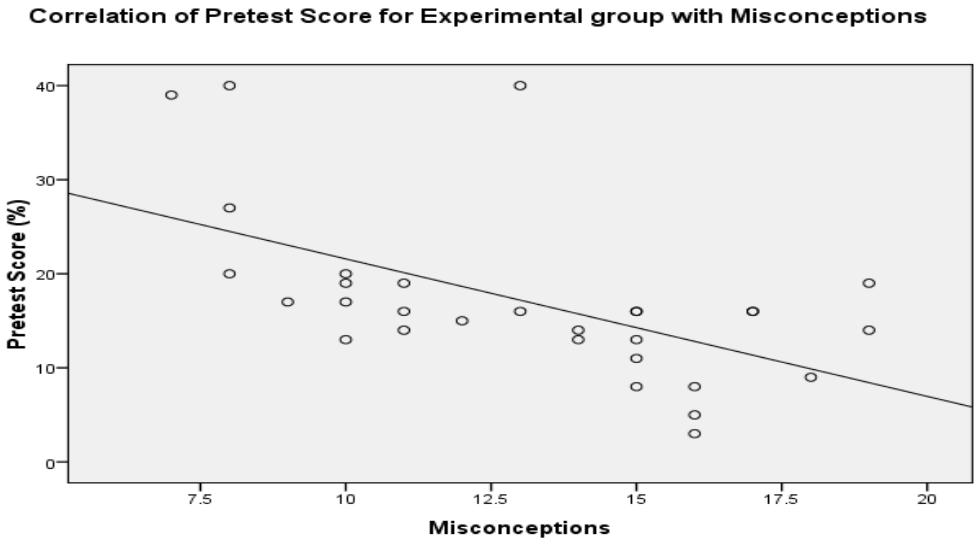


Fig. 7.1.2 Correlation of Pre-test Results for the Experimental group

The graph has a negative gradient, which confirms that there was a negative correlation between participants' pre-test misconceptions and their performance in basic electronics. The study went further to determine not only the descriptive statistics but also the actual

correlation that existed between the two variables above. The values were as shown in Tables 7.1.1 (a) and (b).

Table 7.1.1 Pearson's Product Moment Correlation for pre-test scores for Experimental Group

(a) Descriptive Statistics

	Mean	Std. Deviation	N
Pretest score	17.1	9.0	30
Misconcep	13.1	3.5	30

(b) Correlations

		Pre-test score	Misconcep
Pretest score	Pearson Correlation	1	-0.6**
	Sig. (2-tailed)		.001
	Sum of Squares and Cross-products	2358.7	-517.2
	Covariance	81.3	-17.8
	N	30	30
Misconcep	Pearson Correlation	-0.6**	1
	Sig. (2-tailed)	.001	
	Sum of Squares and Cross-products	-517.2	353.7
	Covariance	-17.8	12.2
	N	30	30

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

Therefore, before treatment, the value of Pearson's Product Moment Correlation for the experimental group was **– 0.6** to one decimal place.

7.2 Correlation of the experimental group after the treatment

The post-test results of participants in the experimental group were presented as shown in Fig.7.2.1.

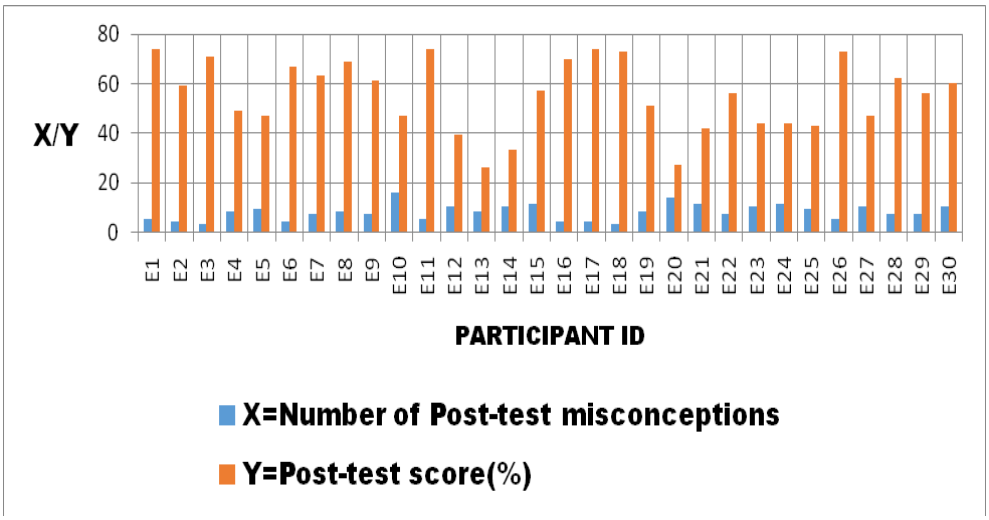


Fig. 7.2.1 Post-test misconceptions Vs Post-test scores for Experimental group

The graph in Fig. 7.2.1 shows that even after the treatment, as misconceptions of each participant in the experimental group decreased, participants' performance in the post-test was better than before. This finding pointed to a negative relationship and so the variables were correlated, resulting in Fig. 7.2.2.

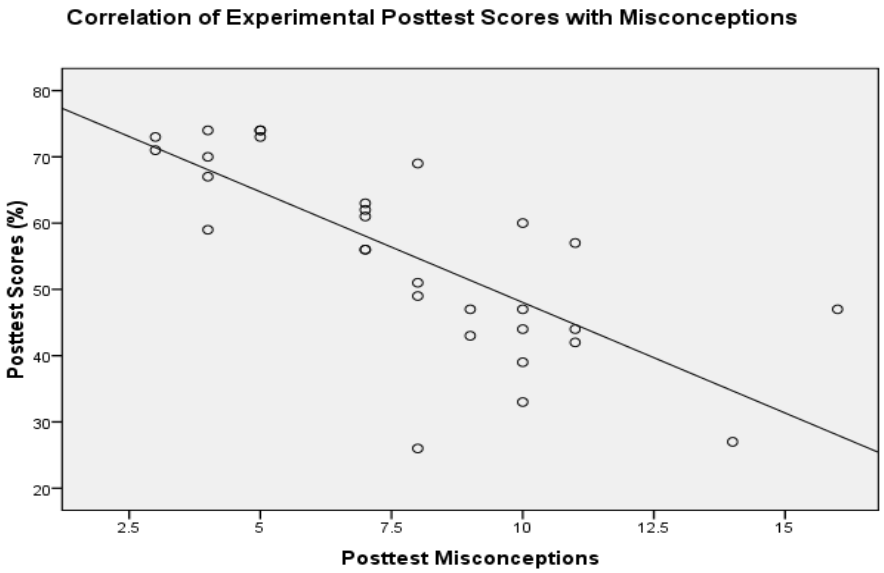


Fig. 7.2.2 Correlation of Post-test Results for the Experimental group

The graph in Fig. 7.2.2 confirmed a negative correlation of post-test results for the experimental group. In view of this confirmation, using SPSS, the current study went further to determine the descriptive statistics and the actual correlation as shown in Table 7.2.1.

Table 7.2.1 Pearson's Product Moment Correlation for post-test scores for Experimental group.

(a) Descriptive Statistics

	Mean	Std. Deviation	N
Posttest score	55.3	14.3	30
Misconcep	7.8	3.2	30

(b) Correlations

		Posttest score	Misconcep
Posttest score	Pearson Correlation	1	-0.8**
	Sig. (2-tailed)		0.000
	Sum of Squares and Cross-products	5909.9	-981.7
	Covariance	203.8	-33.9
	N	30	30
Misconcep	Pearson Correlation	-0.8**	1
	Sig. (2-tailed)	0.000	
	Sum of Squares and Cross-products	-981.7	294.2
	Covariance	-33.9	10.1
	N	30	30

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

Therefore, after the treatment, the value of Pearson's Product Moment Correlation for the Experimental group was – 0.8.

7.3 Correlation of the Control group before the treatment

The pre-test results of participants in the control group were presented as shown in Fig. 7.3.1.

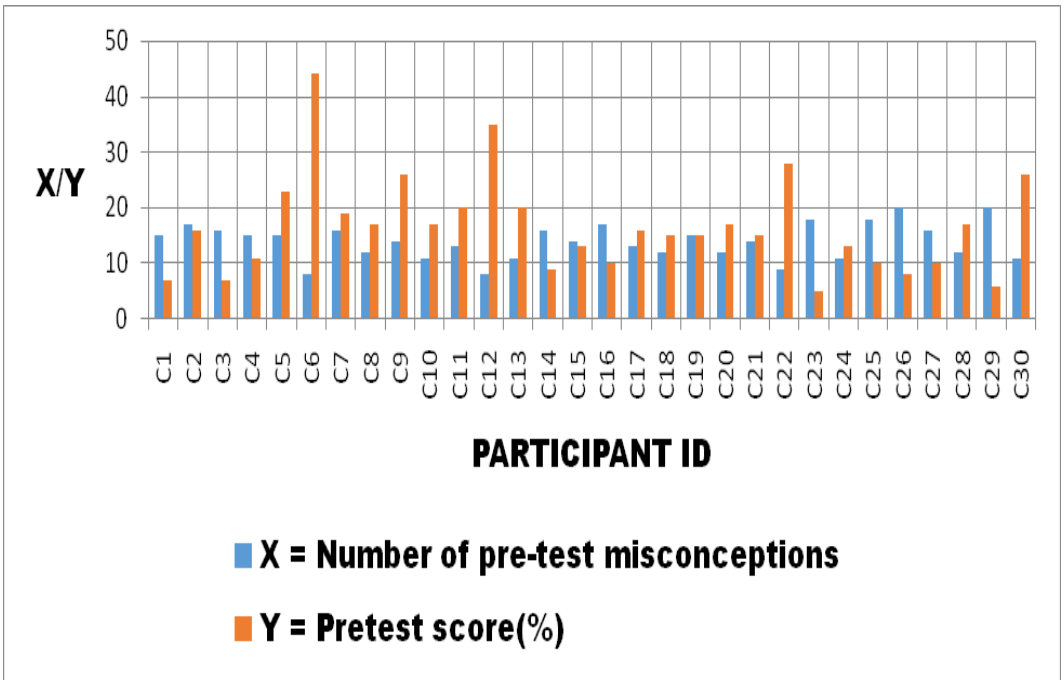


Fig. 7.3.1 Pre-test misconceptions Vs Pre-test scores for Control group**.**

The graph indicates that participants with fewer misconceptions achieved more than those with more misconceptions, which in turn shows that the **relationship** between participants' misconceptions and their performance in basic electronics was **negative**. The data were correlated and the graph in Fig. 7.3.2 was produced.

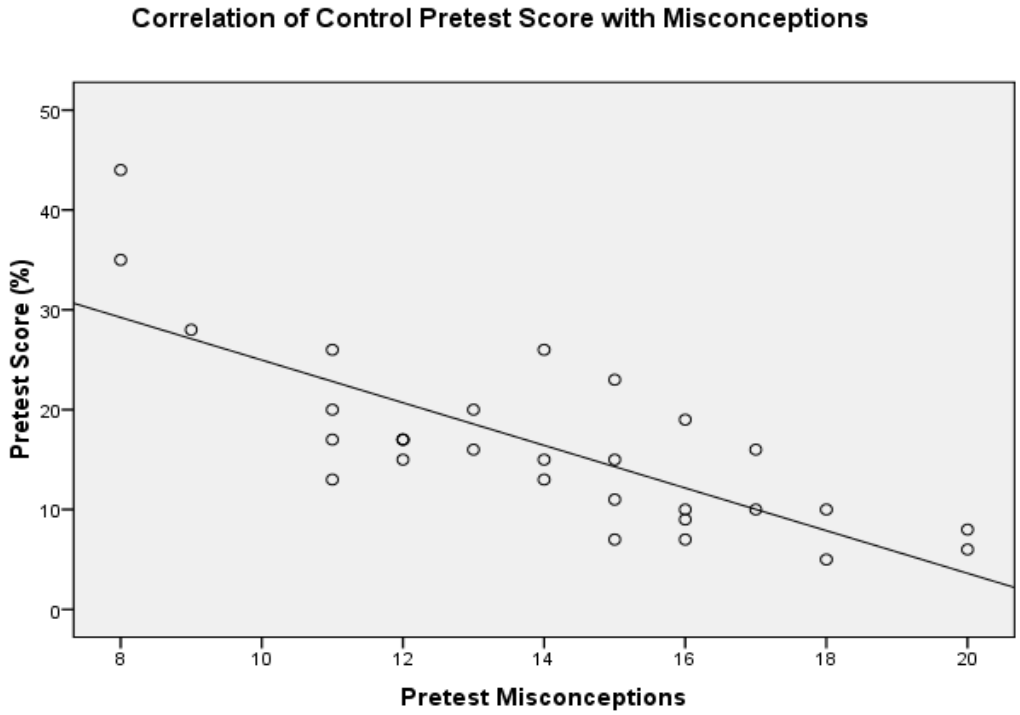


Fig. 7.3.2 Correlation of Pre-test results for the Control group

The graph has a negative gradient showing a negative correlation between the variables involved. Using SPSS, the correlation coefficient was determined as shown in Table 7.3.1.

Table 7.3.1 Pearson's Product Moment Correlation for pre-test scores for the Control group

(a) Descriptive Statistics

Descriptive Statistics

	Mean	Std. Deviation	N
Pretest score	16.5	8.8	30
Misconcep	14	3.1	30

(b) Correlations

		Pretest score	Misconcep
Pretest score	Pearson Correlation	1	-0.8**
	Sig. (2-tailed)		0.0
	Sum of Squares and Cross-products	2225.5	-625.5
	Covariance	76.7	-21.6
	N	30	30
Misconcep	Pearson Correlation	-0.8**	1
	Sig. (2-tailed)	0.0	
	Sum of Squares and Cross-products	-625.5	293
	Covariance	-21.6	10.1
	N	30	30

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

Therefore, before the treatment, the Pearson's Product Moment Correlation for control group was -0.8.

7.4 Correlation of the Control group after the treatment

The post-test results of participants in the control group were presented graphically as shown in Fig. 7.4.1.

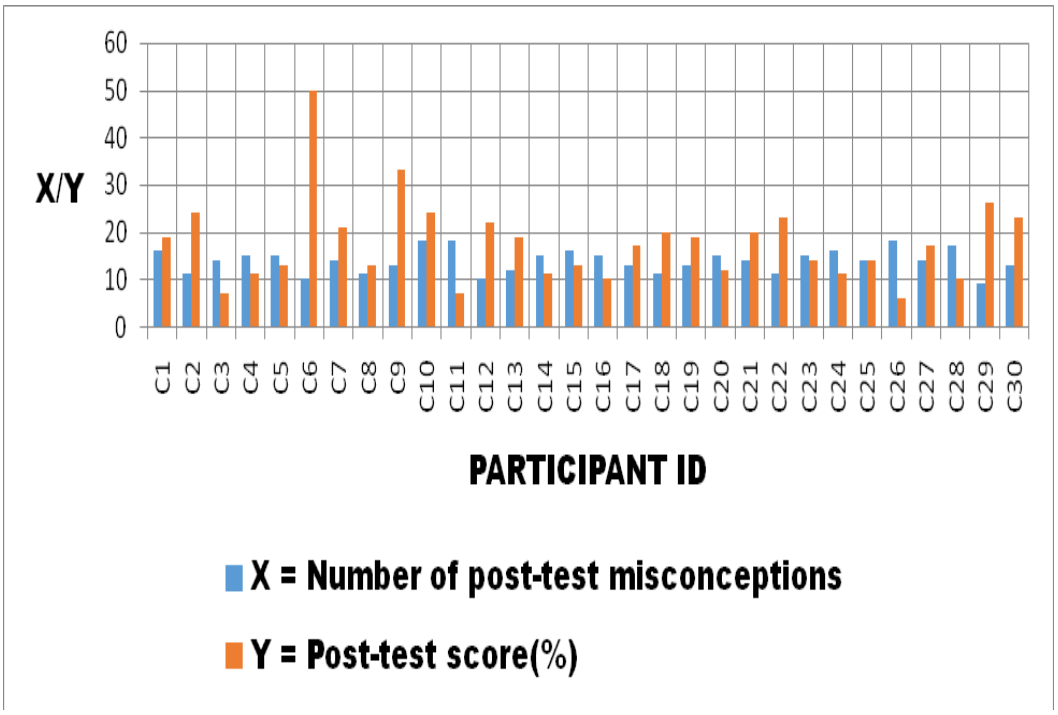


Fig. 7.4.1 Post-test misconceptions Vs Post-test scores for Control group.

The **relationship** between participants' misconceptions and their performance in the post-test was still **negative**. However, both the participants' misconceptions and their performance in the post-test were more or less the same as those of the pre-test. The results were correlated as shown in Fig. 7.4.2.

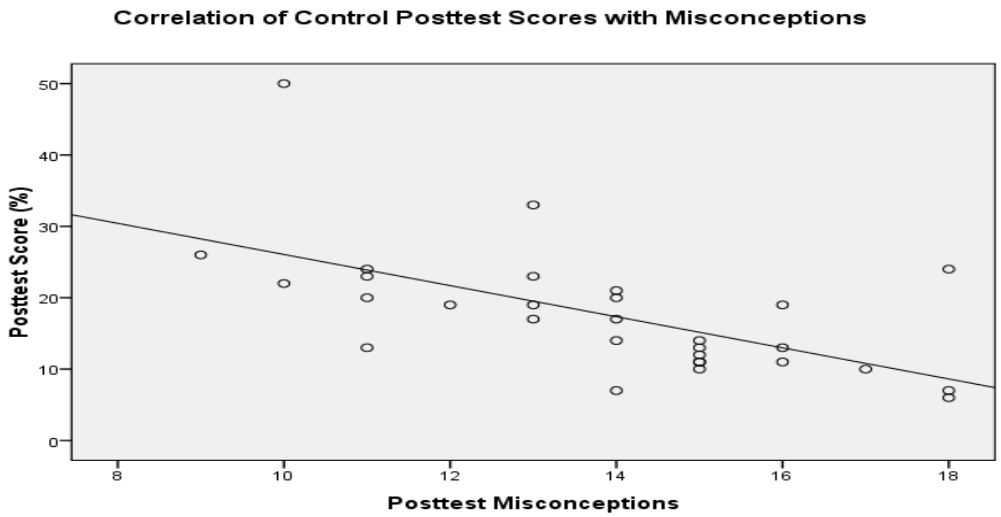


Fig. 7.4.2 Correlation of Post-test Results of the control group

From the graph it was clear that the correlation was negative and the value was as shown in Table 7.4.1.

Table 7.4.1 Pearson's Product Moment Correlation for post-test scores for Control group

(a) Descriptive statistics

	Mean	Std. Deviation	N
Posttest score	17.6	8.9	30
Misconcep	13.9	2.5	30

(b) Correlations

		Post-test score	Misconcep
Posttest score	Pearson Correlation	1	-0.6**
	Sig. (2-tailed)		0.0
	Sum of Squares and Cross-products	2273	-382.5
	Covariance	78.4	-13.2
	N	30	30
Misconcep	Pearson Correlation	-0.6**	1
	Sig. (2-tailed)	0.0	
	Sum of Squares and Cross-products	-382.5	175.5
	Covariance	-13.2	6.1
	N	30	30

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

Therefore, in the post-test, the Pearson's Product Moment Correlation for control group was -0.6.

In **summary**, all the pre and post test results above, for both the experimental and control groups, clearly indicated that there was a negative correlation (negative relationship) between participants' misconceptions and their performance in basic electronics. The findings in Section 7.5 were obtained when the two groups were combined.

7.5 Correlation for both groups before the treatment

The pre-test results of participants in both groups before the treatment were presented as shown in Fig. 7.5.1

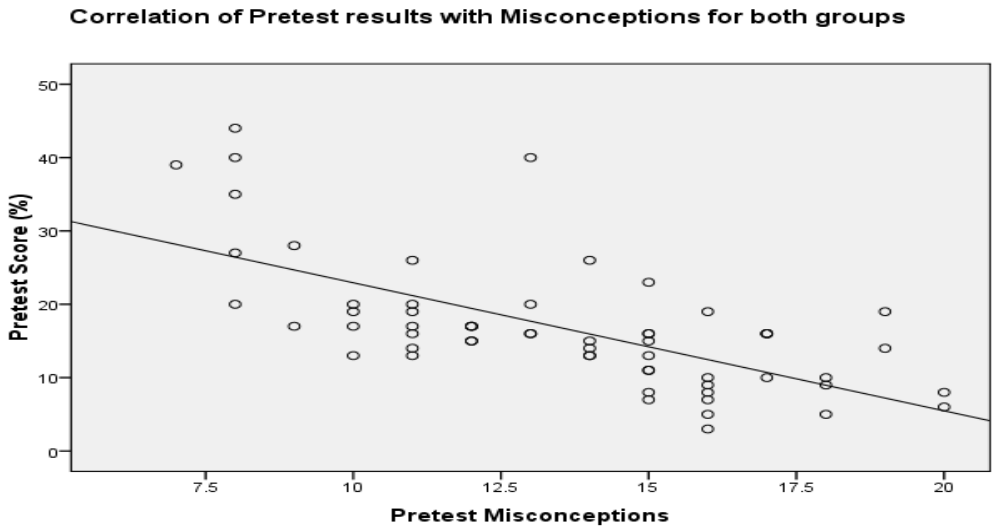


Fig. 7.5.1 Correlation of pre-test Results for both groups

This graph also has a negative gradient, thereby confirming a negative correlation. Using SPSS, the descriptive statistics and correlations were computed as shown in table 7.5.1.

Table 7.5.1 Pearson's Product Moment Correlation for Pre-test scores for both groups

(a) Descriptive statistics

	Mean	Std. Deviation	N
Pretest score	16.8	8.8	60
Misconcep	13.5	3.3	60

(b) Correlations

		Pretest score	Misconcep
Pretest score	Pearson Correlation	1	-0.7**
	Sig. (2-tailed)		0.0
	Sum of Squares and Cross-products	4589.6	-1150.8
	Covariance	77.8	-19.5
	N	60	60
Misconcep	Pearson Correlation	-0.7**	1
	Sig. (2-tailed)	0.0	
	Sum of Squares and Cross-products	-1150.8	659
	Covariance	-19.5	11.2
	N	60	60

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

The Pearson's Moment Product Correlation for both groups before treatment was - 0.7. Section 7.6 presents the findings for both groups after the treatment.

7.6 Correlation for both groups after the treatment

The post-test results of participants for both groups were presented as shown in Fig. 7.6.1

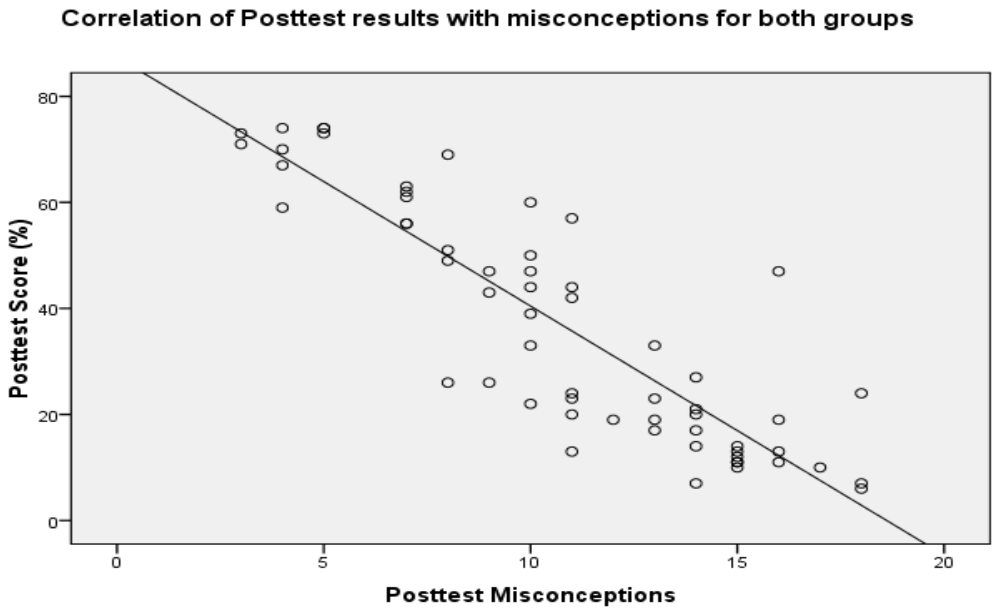


Fig. 7.6.1 Correlation for Post-test scores for both groups

The gradient of the graph was negative, showing a negative correlation between the variables involved. Using SPSS, the correlation coefficient was computed as shown in Table 7.6.1.

Table 7.6.1 Pearson's Product Moment Correlation for Post-test scores for both groups

(a) **Descriptive Statistics**

	Mean	Std. Deviation	N
Misconceptions	10.9	4.1	60
Post test scores	36.4	22.3	60

(b) **Correlations**

		Misconceptions	Post scores
Misconceptions	Pearson Correlation	1	-.9**
	Sig. (2-tailed)		0.0
	Sum of Squares and Cross-products	1015.7	-4770
	Covariance	17.2	-80.8
	N	60	60
Post scores	Pearson Correlation	-0.9**	1
	Sig. (2-tailed)	0.0	
	Sum of Squares and Cross-products	-4770	29426.9
	Covariance	-80.8	498.8
	N	60	60

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

The value of Pearson's Product Moment Correlation for both groups after the treatment was - 0.9.

7.7 Chapter summary

In all cases, results indicated that there was a negative correlation as shown in table 7.7.1.

Table 7.7.1 Summary of coefficients

Group	**Correlation before the treatment**	**Correlation after the treatment**
Experimental	-0.6	-0.8
Control	-0.8	-0.6
Both Experimental and control	-0.7	-0.9

The average value of the correlations in Table 7.7.1 for both groups was -0.8. All the values in the table were significant at 0.01 level (2-tailed). The numbers in the table meant that the more misconceptions a physics student teacher had, the lower was one's performance in basic electronics content and vice-versa. According to Gay (1996, p. 299), 'For 10 participants (df =8), and p=0.01, a coefficient of 0.7646 is required for researchers to be certain that a given coefficient represents a true relationship.' This study used 60 participants and so the researcher was very confident that the decision concerning the relationship was correct.

CHAPTER 8

FINDINGS ON STUDENT TEACHERS' TEACHING SKILLS OF BASIC ELECTRONICS

8.0 Introduction

This chapter presents the findings on the physics student teachers' teaching of basic electronics. It has four main sections, 8.1 to 8.4. Section 8.1 presents findings from Peer teaching sessions before the treatment. Section 8.2 shows findings from Peer teaching sessions after the treatment'. Section 8.3 presents findings from the experimental group about the treatment they had (lessons in basic electronics). The last Section, 8.4 is the chapter summary.

8.1 Findings from Peer teaching sessions before the 'Treatment'

Table 8.1.1 contains information about participants' performance in teaching basic electronics during peer teaching sessions before the treatment.

Table 8.1.1 Findings from peer-teaching sessions for participants in the Experimental and Control groups before the treatment.

S/NO.	ELEMENTS OF EFFECTIVE LESSON PRESENTATION	TALLY	
		Experimental N=30	Control N=30
A	**Lesson objectives** Student teacher ensures that the objectives of the lesson on basic electronics are attainable in the time which is given.	12	13

B	**Lesson introduction** Student teacher ensures that the lesson introduction: i. Is relevant to the topic ii. Attracts learners' attention	 23 15	 25 14
C	**Lesson development** Student teacher: i. Presents the lesson logically	 16	 17
	ii. Involves the class in (a non practical) activity iii. Involves the class in an experiment iv. Allows learners to work on their own	5 0 5	4 0 4
	v. Ensures that learners are engaged and on-Task	5	4
	vi. Does a demonstration while learners watch him/her	10	13
	vii. Uses a demonstration which was used by others on the same topic	10	13
	viii. Uses a demonstration which is suitable for the Class	0	0
	ix. Uses the lecture method and other teaching strategies to present the lesson	30	30
	x. Uses the lecture method (only) to present the whole lesson	20	17
D	**Use of resources** i. Student teacher uses various teaching aids during the lesson	 10	 13

	ii. Uses a teaching aid already used by others	10	13
E	**Use of questioning technique** Student teacher: **i.** Asks question to the whole class and learners chant the answer **ii.** Asks question and invites the learners to discuss the answer with each other **iii.** Encourages learners to put their hands up and chooses one to give an answer **iv.** Asks other learners to comment on the answer given **v.** Allows pupils to express their opinions **vi.** Comments on the answers given by Learners **vii.** Makes right comments all the time	10 5 5 5 5 5 3	9 4 5 5 5 5 5
F	**Attention to individual needs** Student teacher: i. Takes account of the fact that learners work at different rates ii. Expects everyone to work at same rate	6 18	8 12
G	**Summarising the work done** Student teacher:		

	i. Explains how the work covered is relevant to every day life	7	6
	ii. Does not summarise the work done	23	24
H	**Evaluation of the work done** Student teacher:		
	i. Gives open- ended tasks	2	2
	ii. Gives tasks with a single right answer (closed)	10	11
	iii. Does not evaluate the work done	18	17
I	**Class notes** Student teacher:		
	i. Asks class to write their own notes based on the work they have done in the lesson	5	2
	ii. Asks class to copy notes from the chalkboard	7	12
	iii. Does not give notes	18	16

The findings in Table 8.1.1 were summarised as shown in Table 8.1.2. Each element of a lesson had one or more sub elements and each sub element had a total score of 30. Therefore, element ‘A’ which had only one sub element had a total or maximum score of 30 while element ‘C’ which had ten sub elements had a total score of 300.

Table 8.1.2 Summary of total scores per 'Lesson Element' for each group before treatment

Element	Number of sub-elements	Total score	Score by experimental group	Score by control group
A	**1**	**30**	**12**	**13**
B	**2**	**60**	**38**	**39**
C	**10**	**300**	**61**	**59**
D	**2**	**60**	**10**	**13**
E	**7**	**210**	**28**	**29**
F	**2**	**60**	**6**	**8**
G	**2**	**60**	**7**	**6**
H	**3**	**90**	**12**	**13**
I	**3**	**90**	**12**	**14**

Therefore, the total score for all the elements of lesson presentation was 960, out of which the experimental group got 186 (19%), while the control group got 194 (20%). This showed that before the treatment the performance of participants in the teaching of basic electronics was almost the same.

The interrater reliability for the two Observers, A and B who ticked either YES (1) or NO (0) against each of the 32 sub-elements of the lesson while a participant presented a lesson on Basic electronics, was found to be Kappa = 0.81 with $p < 0.005$ (95% CI) as shown in the tables 8.1.3 and 8.1.4.

Table 8.1.3 Cross tabulations

RaterA * RaterB Crosstabulation

Count

		RaterB		
		0	1	Total
RaterA	0	12	1	13
	1	2	17	19
Total		14	18	32

Results in this table show that of 32 cases in which observers were to agree or disagree on performance of the participant in teaching basic electronics, in 12 cases both of them disagreed, that is, felt that the participant did not score on such elements of the lesson, in 17 cases they agreed that the participant had scored. However, there were three cases (2+1) in which the two observers disagreed with each other and so rated the participant differently.

Interrater reliability (Cohen's kappa)

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.808	.105	4.580	.000
N of Valid Cases		32			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Results in the symmetric measures table indicate that there was a good level of agreement between the two observers and so the element of subjectivity in awarding marks to participants was negligible. Table 8.1.4 shows a t-test for pre-test scores in teaching basic electronics

Table 8.1.4 T-test for pre-test scores in teaching basic electronics

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Pre-test score in teaching basic electronics	Experimental group	32	10.0938	7.33247	1.29621
	Control group	32	10.2500	7.38350	1.30523

Here **N** did not represent number of participants, but the total number of sub elements of a lesson, on which participants' teaching of basic electronics was based.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre-test score in teaching basic electronics	*Equal variances assumed*	.052	.820	-.085	62	.933	-.15625	1.83951	-3.83337	3.52087
	Equal variances not assumed			-.085	61.997	.933	-.15625	1.83951	-3.83338	3.52088

The results above showed that before the treatment, there was no statistically significant difference in teaching basic electronics between the experimental and control groups (t = - 0.85, df = 62, p = 0.933, t-tailed).

Fig. 8.11 shows performance of both groups in teaching basic electronics before the treatment.

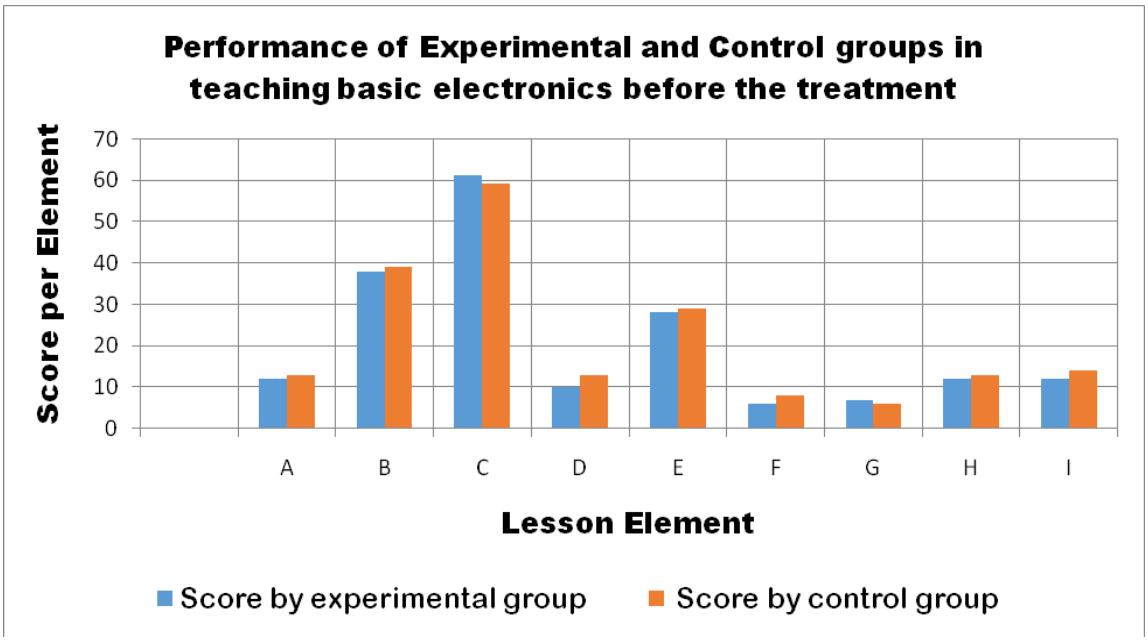


Fig. 8.1.1 Score by experimental group Vs score by control group in teaching basic electronics before treatment.

Indeed, it can be seen from the graph that before the treatment, performance of both groups in terms of the following Elements: [A] writing of lesson objectives, [B] lesson introduction, [C] lesson development, [D] use of the questioning technique, [E] use of resources, [F] attention to individual needs, [G] summarizing of the work done, [H] evaluation of the work done and [I] giving of class notes, was more or less the same and generally poor. However, after the treatment the picture changed completely as shown in Section 8.2.

8.2 Findings from Peer teaching sessions after the 'Treatment'

The information in Table 8.2.1 shows participants' performance in teaching basic electronics during peer teaching sessions after the treatment.

Table 8.2.1 Findings from peer-teaching sessions for participants in the Experimental and Control groups after the Treatment.

S/NO.	ELEMENTS OF EFFECTIVE LESSON PRESENTATION	TALLY	
		Experimental N=30	**Control** N=30
A	**Lesson objectives** Student teacher ensures that the objectives of the lesson on basic electronics are attainable in the time which is given.	25	12
B	**Lesson introduction** Student teacher ensures that the lesson introduction:		
	i. Is relevant to the topic	30	28
	ii. Attracts learners' attention	24	17
C	**Lesson development** Student teacher:		
	i. Presents the lesson logically	29	16
	ii. Involves the class in (a non practical) activity	8	7
	iii. Involves the class in an experiment	12	0
	iv. Allows learners to work on their own	20	7
	v. Ensures that learners are engaged and on-	20	7

	Task		
	vi. Does a demonstration while learners watch him/her	10	13
	vii. Uses a demonstration which was used by others on the same topic	2	13
	viii. Uses a demonstration which is suitable for the Class	8	0
	ix. Uses the lecture method and other teaching strategies to present the lesson	5	7
	x. Uses the lecture method (only) to present the whole lesson	0	23
D	**Use of resources** i. Student teacher uses various teaching aids during the lesson ii. Uses a teaching aid already used by others	30 2	7 13
E	**Use of questioning technique** Student teacher: **i.** Asks question to the whole class and learners chant the answer **ii.** Asks question and invites the learners to discuss the answer with each other **iii.** Encourages learners to put their hands up and chooses one to give an answer **iv.** Asks other learners to comment on the answer given	3 13 27 27	12 8 8 7

	v. Allows pupils to express their opinions **vi.** Comments on the answers given by learners **vii.** Makes right comments all the time	27 27 27 21	7 13 3 2
F	**Attention to individual needs** Student teacher: i. Takes account of the fact that learners work at different rates ii. Expects everyone to work at same rate	 12 18	 10 22
G	**Summarising the work done** Student teacher: i. Explains how the work covered is relevant to everyday life ii. Does not summarise the work done	 25 5	 10 20
H	**Evaluation of the work done** Student teacher: i. Gives open- ended tasks ii. Gives tasks with a single right answer (closed) iii. Does not evaluate the work done	 12 17 1	 3 14 13
I	**Class notes** Student teacher: i. Asks class to write their own notes based on the work they have done in the lesson	 14	 5

	ii. Asks class to copy notes from the chalkboard iii. Does not give notes	14 2	17 8

The results above were summarised as before and recorded in table 8.2.2.

Table 8.2.2 Summary of total scores per 'Lesson Element' for each group after the treatment

Lesson element	Number of sub-elements	Total score	Score by experimental group	Score by control group
A	**1**	**30**	**25**	**12**
B	**2**	**60**	**54**	**45**
C	**10**	**300**	**112**	**50**
D	**2**	**60**	**30**	**7**
E	**7**	**210**	**142**	**41**
F	**2**	**60**	**12**	**10**
G	**2**	**60**	**25**	**10**
H	**3**	**90**	**29**	**17**
I	**3**	**90**	**28**	**22**

This time around, out of a total of 960 scores, the experimental group got 457 scores (48%) in the teaching of basic electronics while the control group got 214 scores (22%), which was very close to what the group got (20%) before the treatment. Fig. 8.2.1 was included to show clearly the change in performance for both groups.

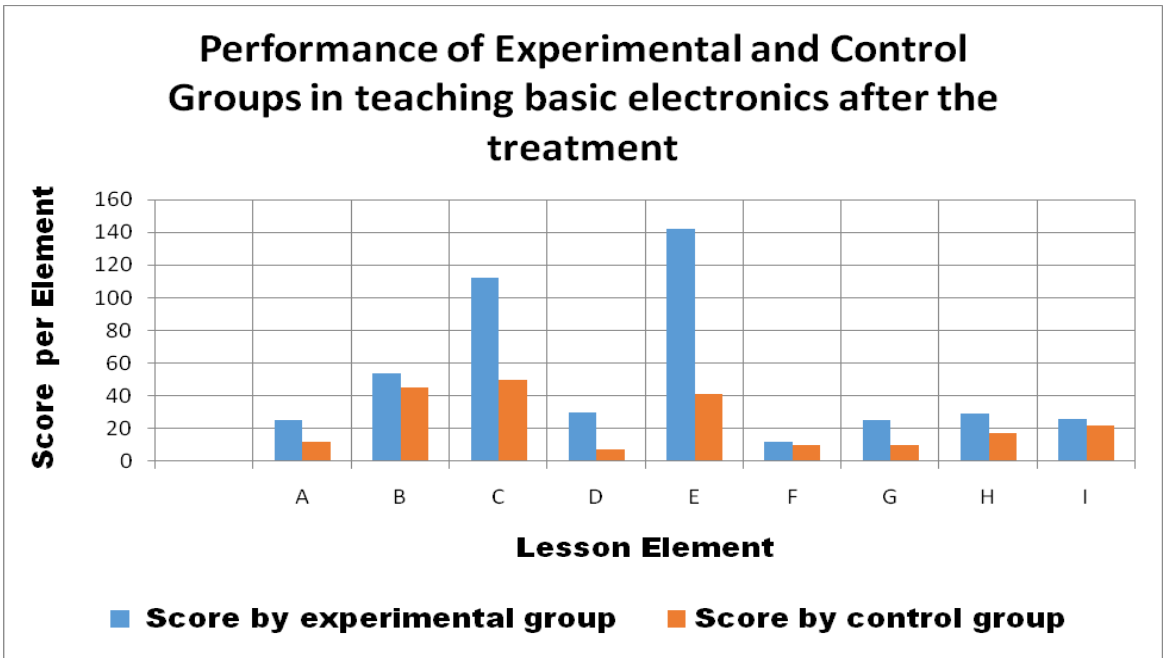


Fig. 8.2.1 Score by experimental group Vs score by control group in teaching basic electronics after the treatment

Fig. 8.2.1 clearly indicates that after the treatment, performance of the experimental group in teaching basic electronics was much higher than that of the control group. This gave the impression that the treatment had enhanced the participants' performance in the experimental group. In other words, the treatment had enabled participants in the experimental group to perform better in the teaching of basic electronics than the control group. An Independent Samples t-test was done to see if the difference in performance was statistically significant. The results were as shown in Tables 8.2.3 and 8.2.4.

Table 8.2.3 Descriptive statistics

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Post-test score in teaching basic electronics	Experimental group	32	16.0938	9.78267	1.72935
	Control group	32	10.5938	6.67619	1.18020

The results in Table 8.2.3 showed that there was a difference in teaching basic electronics between the experimental and control groups.

Table 8.2.4 T-Test on the post-test scores of the two samples

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Post-test score in teaching basic electronics	Equal variances assumed	9.264	.003	2.627	62	.011	5.50000	2.09368	1.31479	9.68521
	Equal variances not assumed			2.627	54.729	.011	5.50000	2.09368	1.30370	9.69630

Equal variances were not assumed because the significant value of 0.003 was less than 0.5. Therefore, the study value used the significant value of 0.011 in the second line which was smaller than the traditional cut off point of 0.05. Hence, there was a statistically significant difference in performance between the experimental and control groups in teaching basic electronics after the treatment.

In summary, after the treatment, performance of the two groups in terms of Elements : [A] writing of lesson objectives, [B] lesson introduction, [C] lesson development, [D] use of the questioning technique, [E] use of resources, [E] attention to individual needs, [F] summarizing of the work done, [H] evaluation of the work done and [I] giving of lesson notes, was not the same. The experimental group performed far much better than the control group. The total score for the experimental group was 257 (48%) while that of the control group was 214 (22%). The mean score for the experimental group was 51 while that for the control group was 24. The t-test indicated that the two sets of scores for experimental and control groups were significantly different. Therefore, performance of the experimental group in the teaching of basic electronics doubled after the treatment. In other words, before the treatment, misconceptions had reduced their performance in

teaching basic electronics by half. Section 8.3 presents the views of the experimental group, about the treatment the Treatment they had ('BE' Education Resource).

8.3 Findings from the Experimental group about the Treatment they had (The 'BE' Education resource).

Here, 18 statements were given and participants responded by either agreeing or disagreeing with the statements given or remaining neutral. A summary of the findings was as shown in the table 8.3.1.

Table 8.3.1 Responses from participants in the experimental group about the treatment (lessons in basic electronics). N=30

S/NO.	Statement	Responses from participants		
		Strongly agreed or just agreed (Yes)	Neutral	Strongly disagreed or just disagreed (No)
1	Before the lessons above , I had misconceptions in basic electronics	30	0	0
2	The misconceptions that I had, negatively affected my performance in basic electronics content	28	0	2

3	The misconceptions that I had, negatively affected my performance in the teaching of basic electronics	18	0	12
4	Due to misconceptions, there were very few topics in basic electronics that I could teach with confidence	19	0	11
5	Because of misconceptions, I did little or no practical work when I taught basic electronics	12	0	18
6	Due to misconceptions, I was not comfortable with questions in basic electronics from the class	14	0	16
7	Due to misconceptions I could not easily think of a variety of class activities in basic electronics lessons	18	0	12
8	Because of misconceptions, I did not use a variety of teaching strategies in basic electronics; I mainly relied on the lecture method	16	0	14

9	Due to misconceptions it was difficult for me to think of teaching/learning aids in basic electronics.	15	0	15
10	Later, the lessons/activities we had in basic electronics (content) during MSE periods were an exciting experience	29	0	1
11	The information on all the topics in basic electronics was clear	25	0	5
12	The amount and quality of materials I covered in basic electronics were right compared with what I knew before.	28	0	2
13	The clarifications made in all topics increased my degree of interest in basic electronics and physics in general	29	0	1
14	The clarifications helped me to be more practical in basic electronics	30	0	0

15	The lessons we had will help me to present basic electronics better than before (to all learners) in or/and outside Zambia	30	0	0
16	After our lessons above, I no longer had misconceptions in basic electronics	24	0	6
17	I suggest that every year, work about basic electronics be clarified to student teachers of physics before they go to teach	30	0	0
18	The University of Zambia should ensure that final year student teachers of physics are conversant with basic electronics content before they join teaching	30	0	0

This information in the table was used to plot the graph in Fig. 8.3.1.

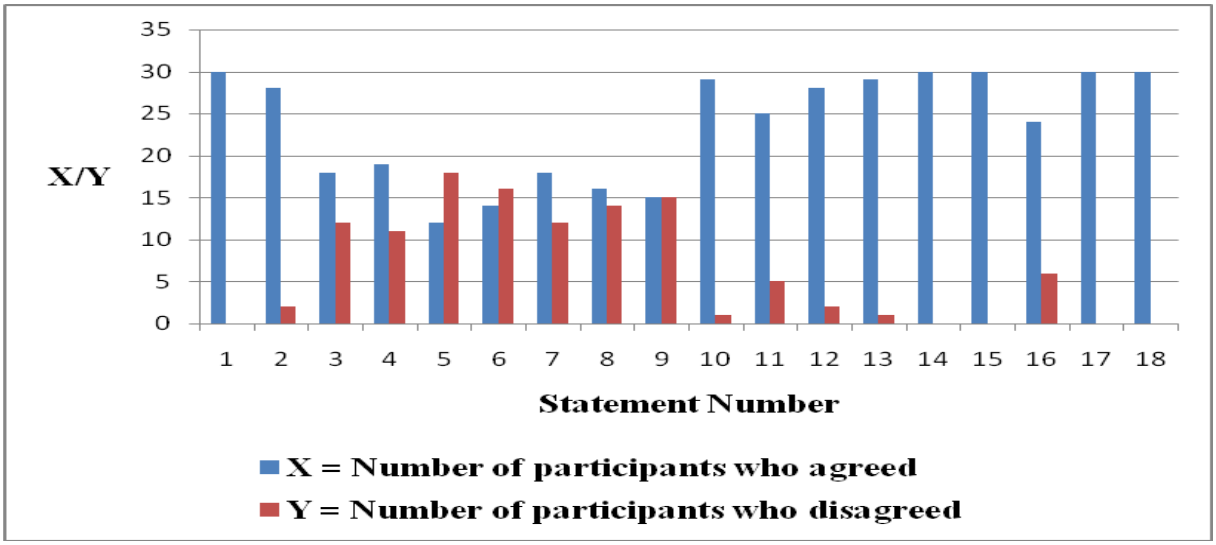


Fig. 8.3.1 Participant responses Vs Statement Number

From the responses in Table 8.3.1, it was clear that: All the student teachers of physics (100%) had misconceptions in basic electronics. These misconceptions affected the

majority of students negatively in content (93.3%) and in teaching of basic electronics in high school physics (60%). Many did not teach basic electronics with confidence (63.3%), failed to vary class activities (60%) and they relied on the lecture method of teaching (53.3%). Only half the number (50%) used a teaching Aid or so in class to simplify work. They admitted that the lessons/activities they had in basic electronics was exciting to them (97%). A good number of them were clear on basic electronics (83.3%). The amount and quality of materials they covered in basic electronics were right compared with what they knew before. The clarifications made in all topics increased their degree of interest in basic electronics and physics in general (97%) and made the students to be more practical (100%). Furthermore, such lessons increased the students' confidence in the teaching of basic electronics in or outside this country (100%). After the lessons above, many felt that they no longer had misconceptions in basic electronics (80%). They suggested that every year, work in basic electronics be clarified to student teachers of physics before they go to teach (100%). They appealed to their institution to ensure that final year student teachers of physics are conversant with basic electronics content before they join teaching because according to them, this cannot easily happen when they have left the institution (100%). Surprisingly, no respondent was neutral on any of the statements. They strongly agreed, just agreed, strongly disagreed or disagreed with the statements which they were asked to respond to but never remained neutral on any statement.

8.4 Chapter Summary

It was confirmed by the last findings that student teachers of physics had several misconceptions in basic electronics which if not checked, they could go with after completing their university education. It was also clear that an intervention, such as the treatment the experimental group had would help change, minimize or possibly dislodge student misconceptions in basic electronics.

CHAPTER 9

FINDINGS ON THE EFFECT OF THE 'BE' EDUCATION RESOURCE AND TEACHING APPROACH ON MISCONCEPTIONS AND PERFORMANCE OF PHYSICS STUDENT TEACHERS IN BASIC ELECTRONICS CONTENT

9.0 Introduction

This chapter presents the findings which sought to answer the fourth research question, that reads: ***'What effect does the 'BE' Education Resource have on physics student teachers' misconceptions and performance in basic electronics?'*** The chapter has six sections, 9.1 to 9.6. Section 9.1 shows the pre-test misconceptions for both groups while 9.2 shows the post-test misconceptions for both groups. Sections 9.3 and 9.4 show the pre-test and post-test scores for both groups respectively. Section 9.5 shows the t-tests for independent samples and section 9.6 is the chapter summary.

9.1 Pre-test misconceptions for both groups

Indeed, having seen (in chapter 7) that with more misconceptions performance of participants was lower and vice-versa, there was need to find out if misconceptions were the cause of that negative relationship and if the intervention ('BE' Education resource) could make a difference. In order to do so, pre-test misconceptions for both groups were first presented graphically as shown in Fig. 9.1.1.

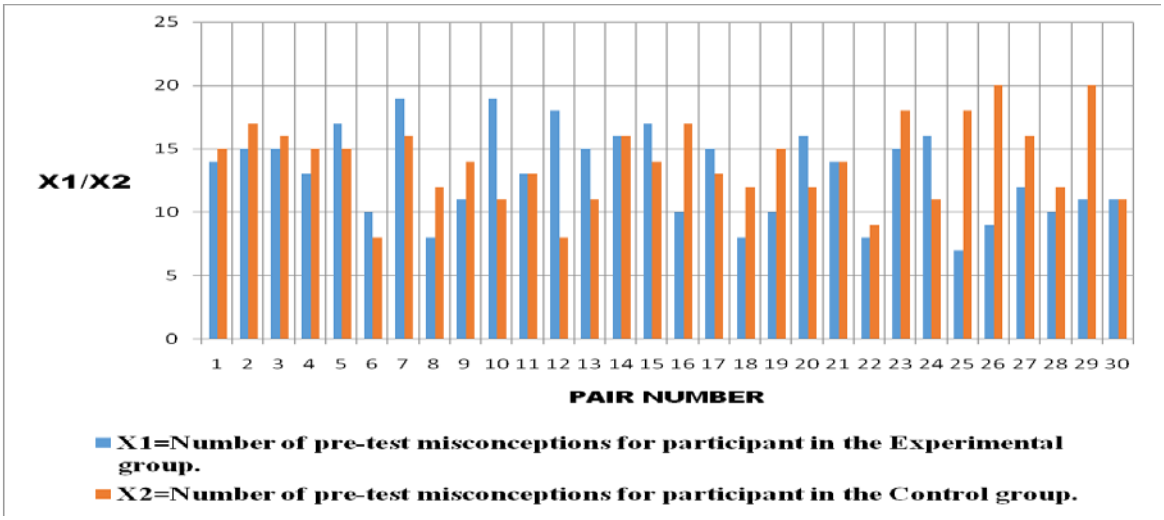


Fig. 9.1.1 Pre-test misconceptions for Experimental and Control groups

The graph in Fig. 9.1.1 shows that before treatment the number of misconceptions held by participants in each group were more or less the same. Their post test misconceptions were compared as shown in Section 9.2.

9.2 Post-test misconceptions for both groups

The findings about the post-test misconceptions for both groups were presented as in Fig. 9.2.1.

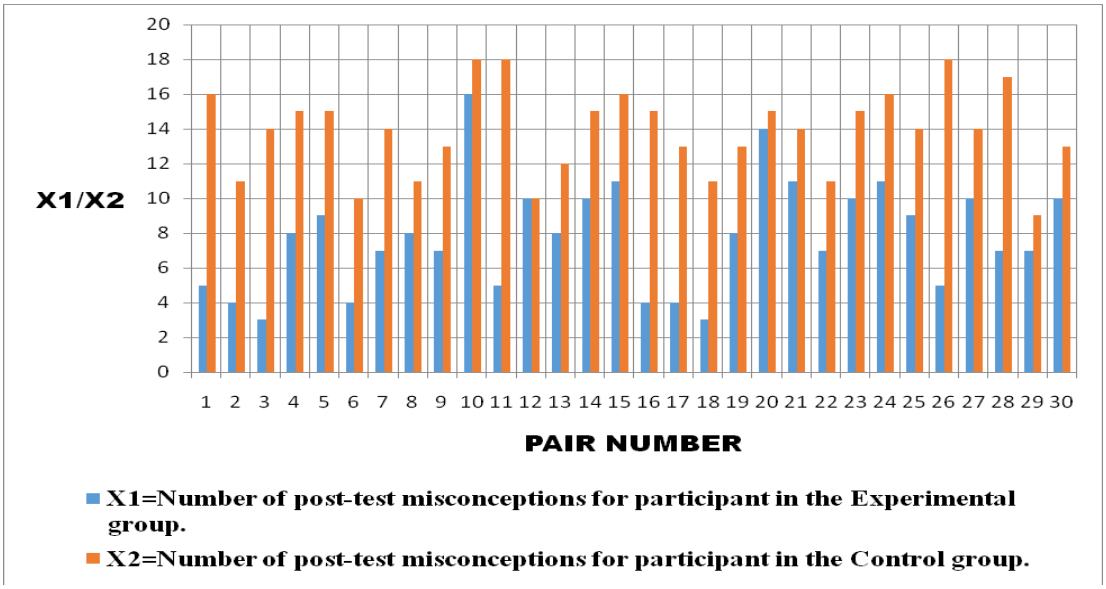


Fig. 9.2.1 Post-test misconceptions for Experimental and Control groups

Here, it was clear that the number of misconceptions held by participants in the Experimental group was lower than that of the misconceptions held by participants in the control group. Pre and post test scores were compared as shown in Section 9.3.

9.3 Pre-test scores for both groups

Pre-test scores for the experimental and control groups were presented graphically as shown in Fig. 9.3.1.

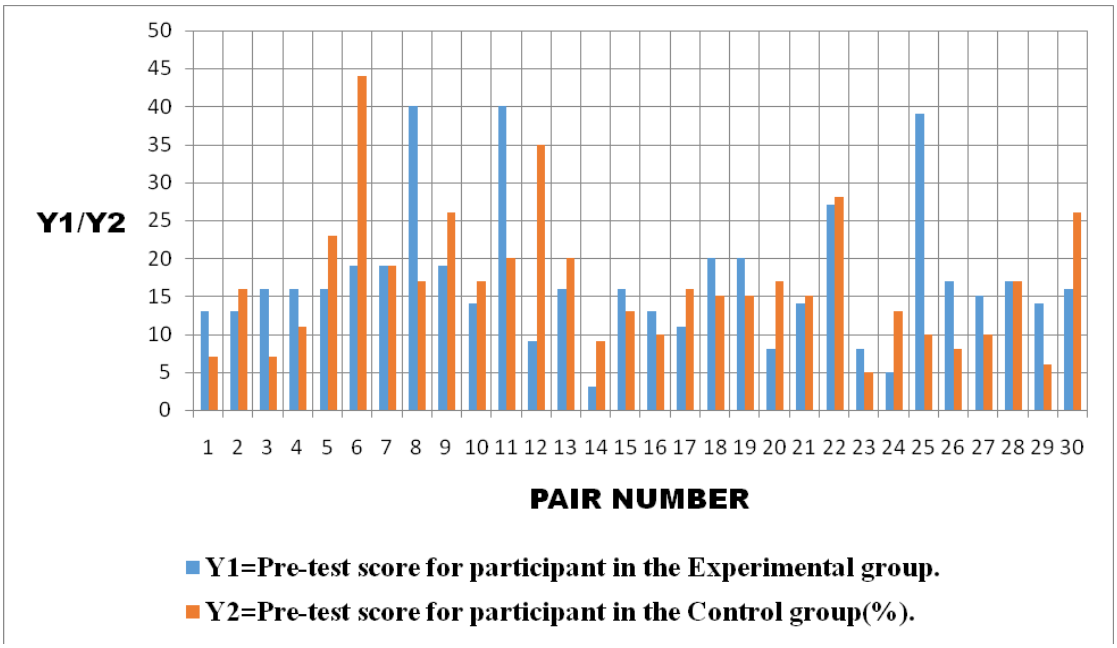


Fig. 9.3.1 Pre-test scores for Experimental and Control groups

The information in the Fig.9.3.1 indicates that before treatment performance of those in the Experimental group was more or less the same as those in the control group. Therefore, before the treatment there was no significant difference between the mean scores of the two groups, indicating that the groups were equivalent in terms of performance. This was supported by descriptive and inferential statistics below.

Table 9.3.1 T-test for both groups before the treatment

Group Statistics

	ParticipantID	N	Mean	Std. Deviation	Std. Error Mean
Pretest score	experimental	30	17.1000	9.01856	1.64656
	control	30	16.5000	8.76022	1.59939

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pretest score	Equal variances assumed	.048	.827	.261	58	.795	.60000	2.29547	-3.99489	5.19489
	Equal variances not assumed			.261	57.951	.795	.60000	2.29547	-3.99497	5.19497

Levene's test for equality of variances gave significance value, .048, which was less than the cut off, .05. This suggested that variances for the two groups were not equal, and the researcher had therefore violated the assumption of homogeneity of variance. Using the set of results for which the assumptions were not violated, it was clear that there was no significant difference in performance of the experimental and control groups before the treatment (t = 0.261, df = 58, p = 0.795, 2-tailed). The information in Table 9.4.1 shows the participants' performance in the post-test.

9.4 Post-test scores for both groups

The post-test scores for both groups were presented graphically as in Fig. 9.4.1

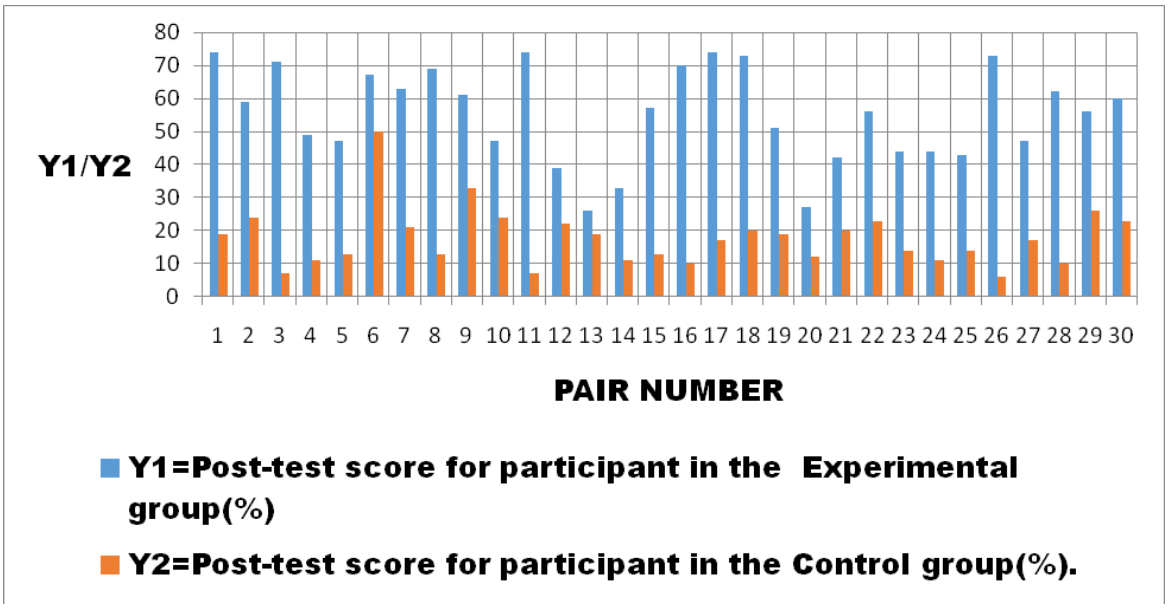


Fig. 9.4.1 Post test scores for Experimental and Control groups

The graph in Fig. 9.4.1 shows that performance of the experimental group in the post test was higher than that of the control group. It was interesting to see how the participants' post test performance changed using the line graphs in Fig. 9.4.2.

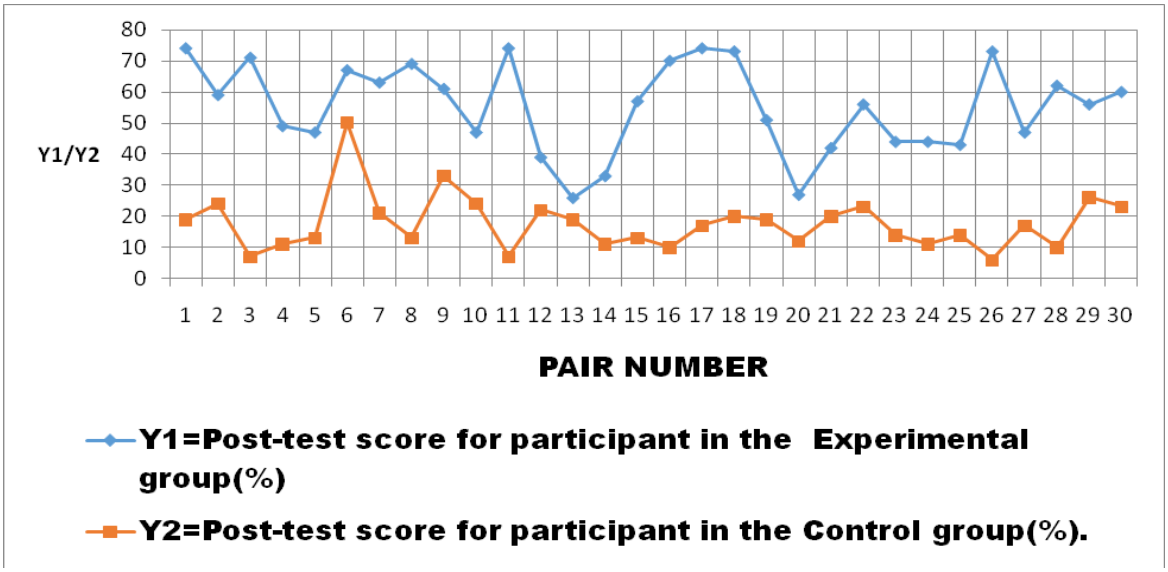


Fig 9.4.2 Line graphs of post-test scores for Experimental and Control groups

The graphs in Fig.9.4.2 clearly indicate that after the treatment performance of participants in the experimental group was far much better than that of the control group.

Therefore, in general results showed that:

i. the experimental group had fewer misconceptions after the treatment than before.
ii. performance of the experimental group was better after the treatment than before.
iii. the control group had more or less same number of misconceptions in the pre- and post-tests.
iv. performance of the control group in the pre- and post-tests was more or less the same.
v. before the treatment, the experimental and control groups had more or less same number of misconceptions.
vi. after the treatment the experimental group had fewer misconceptions than the control group.
vii. pre-test scores for experimental and control groups were more or less the same
viii. post test scores for the experimental group were generally higher than those of the control group

Therefore, there was a difference in performance between the experimental and control groups after the treatment. Following this important finding, the study did a t-test to see if the difference was statistically significant.

9.5 T-test for both groups after the treatment

Here, post-test scores for experimental and control groups were used to compute the t-value for the two independent samples using the Statistical Package for Social Sciences (SPSS). The information in Table 9.5.1 was obtained.

Table 9.5.1 T-test for independent samples (using SPSS)

(a) Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
Scores	Experimental	30	55.3	14.3	2.6
	Control	30	17.6	8.9	1.6

(b) Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Scores	Equal variances assumed	10.1	.002	12.3	58	.000	37.6	3.1	31.5	43.8
	Equal variances not assumed			12.3	48.4	.000	37.6	3.1	31.5	43.8

The results of the t-test for post-test scores for both groups indicates a statistically significant difference in performance between the experimental and control groups (t = 12.3, p = 0.00, 2-tailed).

9.6 Chapter summary

The t-value was found to be 12.3, to one decimal place (df = 58, 2-tailed) at 95% Confidence Interval of the Difference. This indicated that the difference in the post-test mean scores were significant. This meant that misconceptions were the cause of the poor performance of participants in basic electronics. Therefore, the ‘ BE’ Education resource minimised the misconceptions and simultaneously enhanced performance of student teachers of physics in basic electronics.

CHAPTER 10

DISCUSSION OF FINDINGS

10.0 Introduction

This chapter discusses the findings, in line with four research questions which the study sought to answer. It starts with Section 10.1 which discusses the misconceptions that were revealed in basic electronics. Section 10.2 discusses the findings about the correlation between the number of misconceptions and performance of student teachers of physics in basic electronics. Section 10.3 discusses the findings about whether misconceptions were the cause of the revealed negative correlation or not. Section, 10.4 discusses findings that helped to answer the fourth and last research question of the study. The findings discussed were on how misconceptions affected student teachers of physics in the teaching of basic electronics. Section 10.5 discusses views of the experimental group regarding the misconceptions they had before and after the treatment. After that is Section 10.6 which discusses the theoretical implications of the current study. Sections 10.7 discusses the implications for practice while the last Section, 10.8, presents the chapter summary.

10.1 Discussion of findings in Chapter 6, concerning Physics student teachers' misconceptions in basic electronics.

This study sought to find out what misconceptions (if any) student teachers of physics had about basic electronics in the secondary school physics syllabus. The first research question to be answered was '**What misconceptions do student teachers of physics have about electronics in senior secondary physics, as they finish their training?'** The main misconceptions (findings) revealed by the study are discussed in Sections 10.1.1 to 10.1.20.

10.1.1 Thermionic emission is loss of heat by materials

When asked to explain the concept of Thermionic emission before the treatment (lessons in basic electronics), several students (25%) indicated that **Thermionic emission is loss of heat by materials**. They justified this answer by explaining that the term 'thermal' refers to heat, while 'emission' refers to loss. Therefore, thermionic emission should refer

to loss of heat by any material. But the literature reviewed gives a different explanation of this concept (Millman and Halkias, 1972; Nelkon, 1981; Kurup 2013).

Kurup (2013) explains that:

> *Thermionic emission is the emission of electrons from a heated filament or substance. When a filament like Tungsten is heated to a high temperature, some electrons acquire sufficient energy and are able to break away from the surface of the material and go into space. This action is accelerated when the filament is heated in a vacuum by connecting it across a 6-V supply (p.1).*

This view is supported by Nelkon (1981), who says 'In 1902 Richardson found that electrons could escape from some metals such as tungsten when a fine wire of the metal was heated to a high temperature. This is called thermionic emission and the metal is called a hot cathode' (p. 533). Similarly, Millman and Halkias (1972, p. 733), also agree with the scholars above by saying that:

> *When a metal in form of a filament is heated by sending a current through it, thermal energy is supplied to the electrons from the lattice of the heated metal crystal. As a result of this, the energy distribution of the electrons changes, because of the increased temperature. Electrons with the work function (the minimum amount of energy that must be given to the fastest-moving electron at the absolute zero of temperature in order for this electron to be able to escape from the metal) are emitted by the metal.*

What the literature says is considered worldwide as the correct scientific explanation of thermionic emission and is how the Ministry of Education in Zambia expects physics student teachers to understand and teach basic electronics in senior secondary schools (CDC, 2015). Therefore, students' conception that thermionic emission is the loss of heat by a given material, was an alternative conception because it is not acceptable both in and outside Zambia. No wonder before the treatment many participants in this study had a challenge to understand the action of vacuum tubes, such as the cathode ray oscilloscope, which depends on thermionic emission. This agrees with the current theoretical framework which contends that students' prior knowledge and experiences have a powerful influence on their new knowledge and understanding (Osborne & Wittrock, 1983; Gardner,

1993). If their prior knowledge is not viable, even their new knowledge will not be viable and vice versa. The current study used a simple improvised demonstration of boiling porridge on a stove, to clarify the concept of thermionic emission.

10.1.2 Cathode rays are electromagnetic waves that travel at the speed of light

Many participants (32%) claimed that cathode rays are electromagnetic waves that travel at the speed of light. They substantiated their claim by explaining that a 'ray' always has to do with some form of energy, that is, light ray, heat ray and X-ray. Therefore, they thought that cathode rays are waves and not particles because according to them (participants), cathode rays are in form of energy. Furthermore, since light and heat rays are electromagnetic in nature, participants thought that cathode rays are also electromagnetic in nature and travel at the speed of light. But the literature reviewed did not explain cathode rays in that manner. Wilkinson (1993, p.519) explains that 'Cathode rays are a stream of electrons. These rays travel in a straight path but can be deflected by an electric and magnetic field due to their negative charge.' This means that cathode rays cannot be in form of electromagnetic waves because electromagnetic waves have no charge and so cannot be deflected by electric and magnetic fields. Furthermore, since cathode rays are not electromagnetic in nature, their speed, which depends on accelerating potentials is not equal to that of light (Wilson and Buffa,1997).

The finding on the nature of cathode rays is consistent with previously published knowledge on student misconceptions. Millar (2012), conducted a study to find out what students thought the nature of cathode rays was. The findings show that students had mixed feelings about cathode rays. Some thought that cathode rays were particles. Others thought they were waves while still others believed that they were both particles and waves. The differences in the way students construe cathode rays is supported by Kelly's individuality corollary in the current theoretical framework, which contends that 'Persons differ from each other in their construction of events'(Boeree, 2006; p. 10). Since everyone has different experiences, everyone's construction of reality is different (Boeree, 2006**)**. So the way a language is used in science matters a lot, because if scientific terms are understood differently by learners, they can lead to serious learner misconceptions (McCosmas, 2014). In this case, physics educators need to clarify the term 'ray', in order to help student teachers realize that not everything called a ray is electromagnetic in nature. As already said, cathode rays are streams or streaks of moving electrons.

Of course ‘A novel concept of matter was introduced in 1924 by Louis V. de Broglie to the effect that particles of small mass, such as electrons, have a wave character like photons of light energy’ (Hausmann and Slack; 1950, p.759). These so called matter waves have a wavelength of $\lambda = h/mv$, where h is Planck’s constant, and m and v are the mass and velocity of the particle respectively. In 1928 there was enough evidence to confirm the existence of matter waves or de Broglie waves (Wilkinson,1993). However, matter waves, in this case cathode rays are not electromagnetic in nature. Wilson and Buffa (1997, p.867) do not refute this fact but go further to say that ‘ de Broglie waves associated with particles such as electrons and protons are not electromagnetic in nature.’ According to Wilkinson (1993, p.614), ‘Matter waves are not electromagnetic-they are thought of as probability waves.’ Williams,Trinklein and Metcalfe, (1976, p. 649) clarify this further by saying, ‘It must not be assumed, however, that a de Broglie wave is like the physical disturbance of the water in a ripple tank. A de Broglie wave is not a motion of matter, but rather a property.’

The Zambian ordinary level physics syllabus teaches the dual nature of moving particles like cathode rays but does not teach that they are electromagnetic in nature. Therefore, in order to consolidate the fact that cathode rays are not electromagnetic in nature, the current study used a simple demonstration of flowing hot water in a plastic cylindrical pipe, which was open at one end and blocked by a sheet of metal at the other end. Wax stuck on the outer surface of the metal melted. This helped to show that heat, which is in form of a wave can pass through certain materials where water which is in form of particles cannot pass. The demonstration in turn helped learners to accept that there was a difference between electromagnetic waves in general and cathode rays or moving electrons.

10.1.3 Conventional current has no direction

It was interesting to note that some subjects (13%) thought that conventional current has no direction (i.e. does not flow from positive to negative terminal of a power supply) but flows in all directions. The reason they gave was that conventional current is same as convection current, which has no specific direction in a fluid such as water or air. However, literature does not support this (Millman and Halkias, 1972; Pople, 1997).

Convection currents are vertical movements of fluids (liquid or gas) due to heat supplied to them (Pople, 1997). For example, when water in a beaker is heated from the bottom, hot water expands, becomes less dense and rises. Cold water which is dense sinks to the bottom of the beaker and takes the place of the water that has risen. This results in the movement of water from hot to cooler parts thereby forming the so called convection currents. The process, convection, results in heat transfer from hot to cooler parts of the fluid. On the other hand, conventional current is the current which is in the direction opposite to the actual electron flow (Millman and Halkias, 1972). Therefore, conventional current is not the same as convection current and conventional current has a direction opposite to that of electron flow.

The terms conventional current and convectional current look similar and can be quite misleading to learners. This is supported by Krebs (1999) who argues that if the terms used in science are similar, they can lead to confusion and leave learners with misconceptions. According to the current theoretical framework, clarifications of such concepts require the use of the generative learning model (Osborne and Wittrock,1983), of the scientific inquiry type (Schwab, 1982), in which the teacher does not only determine the prior knowledge that students might bring into the learning environment, but also brings students into the scientific process and helps them to collect and analyse data, check out hypotheses and theories, and reflect on the nature of knowledge construction (Joyce and Weil, 1996). Activities of this nature make explicit the range of students' existing beliefs related to the new concept and finally allows students to compare the scientific explanation with their own ideas. Therefore, the model encourages use of simple experiments or demonstrations to help clarify similar concepts such as convection current and conventional current to the learners. This approach to learning is further supported by literature by urging instructors to use the learning cycle below, that is said to be so effective in dealing with students' alternative conceptions:

- Ask students to make a prediction about something and to be explicit about their reasoning (This forces them to use their mental model, rather than just guess).
- Then allow them to do an experiment or a demonstration.
- Explore the fact that many predictions were wrong. This cannot be glossed over quickly. There will be a conflict between their prediction and reality. Help them so that gradually they accept reality.

- Reiterate. Students' alternative conceptions are highly resistant to change. They need to see repeatedly that their conceptual model fails, when put to the test, but that an alternative model succeeds (Knight, 2002, p.43).

Furthermore, literature emphasises that, "Active engagement helps students to build their mental models rather than receive them from the instructor using: Interactive demonstrations, nearest neighbour discussion activities, collaborative group activities, microcomputer-based laboratories or other guided-discovery laboratories and take-home experiments" (Knight, 2002; p.42).

Therefore, the current study involved the experimental group in a simple demonstration of two magnets wrapped in paper and labelled positive and negative to represent two terminals of a power supply while tiny magnets wrapped in paper and labelled either positive and negative charge represented charges. When the magnets were placed close to each other in a suitable runway, charges placed between them moved in different directions. This helped participants to understand that conventional current (positive charges) move in the direction opposite that of negative charge (electrons).

10.1.4 Applications of cathode rays are similar to those of electromagnetic waves

i.e. X- rays

Some subjects (23%) believed that cathode rays can be used exactly as X-rays because they are electromagnetic in nature. Again, as already discussed in section 6.1.2, cathode rays are not electromagnetic in nature but streams of electrons (Wilkinson, 1993). Therefore, there is no way by which cathode rays can be used as electromagnetic waves like X-rays. For example, radio waves pass through all sorts of materials till they are detected by a receiver. Cathode rays cannot penetrate materials as radio waves, infra-red, X-rays and gamma rays do. Furthermore, if cathode rays were forced to pass through human beings as X-rays do, they would cause a lot of harm to living cells. Therefore, such students have an alternative conception about cathode rays and their applications. In the current study, after the treatment participants in the experimental group accepted the fact that cathode rays were not a form of energy and so could not be applied in the same way as electromagnetic waves.

10.1.5 X and Y plates of a cathode ray oscilloscope form a single pair

There were respondents (10%) who said that the X and Y plates of the Cathode Ray Oscilloscope were a single pair. But literature says something different.

According to Wilkinson (1993, p.473):

> *Two pairs of parallel plates are used to deflect or bend the beam. The vertical or X-plates are used to deflect the beam horizontally when a voltage is applied across them. The horizontal or Y-plates are used to deflect the beam vertically. The deflection by the X-plates or the Y-plates is proportional to the applied voltage.*

Therefore, it is not true that X and Y plates are a pair, as each one of them needs a similar plate to form a pair that should deflect the cathode rays either horizontally or vertically. This misconception, is a source of concern because each pair of plates deflects a beam in a particular direction depending on the direction of the electric field between them. The fact that some students thought that X and Y plates were a pair meant that they had an alternative conception about how and why the beam of electrons was deflected in a particular way. Consequently, they could not explain how light covered the whole screen and the uses of the cathode ray oscilloscope in electronic devices such as Television screen.

In the current study, participants used a simple model of a cathode ray oscilloscope to see clearly all the components and the way they are arranged. This is because when you just hear you can easily forget, but not when you physically see the structure of something and how each component behaves.

10.1.6 In a CRO the heater produces light, which is deflected by X and Y plates

Few participants (5%) believed that in a CRO, the heater produced light which was deflected by X and Y plates, and later struck the screen. However, the literature reviewed gave a different explanation of how light is produced on a cathode ray oscilloscope screen. The explanation was that the primary components of a cathode ray oscilloscope are the vacuum tube containing an electron gun and a screen lined with phosphors. Phosphors in a CRO's screen are the materials that directly produce the photons generated by the CRO. These phosphors are struck by incoming electrons from the

electron gun, absorb energy, and then re-emit some or all of that energy in the form of light. That is how light is produced on a CRO screen. It does not come from the heater (Millman and Halkias, 1972).

In addition to the above alternative conception, when the same participants saw a spot of light moving either vertically or horizontally across the CRO screen, they claimed that light was deflected by charged X and Y plates. This meant that participants thought light contained charged particles, which literature does not support. No wonder there has been so much confusion about the nature of light.

Hewitt (1997, p. 597) reports:

> *Isaac Newton believed in a particle model of light. He thought that light was composed of a hail of tiny particles. Christian Huygens believed that light was a wave phenomenon. The wave model was reinforced more than a century later when Thomas Young demonstrated interference. Later, James Clerk Maxwell proposed that light is electromagnetic radiation and a part of a broader electro magnetic spectrum. The wave model gained support when Heinrich Hertz produced radio waves that behaved as Maxwell had predicted. This seemed to verify the wave nature of light once and for all. But Maxwell's electromagnetic wave model was not the last word on the nature of light. In 1905 Albert Einstein resurrected the particle theory of light.*

However, the confusion about the nature of light cannot apply to this study. This is because when scholars suggested that light existed in form of particles, they did not make a claim that the particles were charged. Light has no charge and so cannot be deflected by electric or magnetic fields. This does not suggest that no field in the universe can deflect light. Literature shows that light can be deflected by black holes. According to Wilkinson (1993; p.123), 'A black hole is thought to be a void that remains in the place where a star once existed. Theoretically, the gravitational effect associated with a black hole is so great that nothing, including light and radio waves, can escape from its grip.' Wilson and Buffa (1997, p.867) give a similar explanation that 'The gravitational field of a black hole is so intense that nothing can escape it including light.' All these imply that despite its speed light can be deflected by an intense gravitational field but do not suggest that light has a charge. They only support the particle nature of light.

The current study exemplified the fact that light has no charge by using a simple demonstration, in which a ray of light from a torch in a ray box, passed through a magnetic field undeviated while a tiny magnet covered in paper, labelled either positive or negative and allowed to pass through the same field was made to change direction by the magnetic field. This helped participants in the experimental group to accept the fact that charged particles like cathode rays can be deflected but not electromagnetic waves such as light. Furthermore, it helped them to accept that what the X and Y plates deflected were something else and not light. Finally, they paid attention and understood how light is produced on the CRO screen.

10.1.7 Intergrated circuits, amplifiers, Logic gates, transformers are some of the basic components in electronics.

Participants were requested to list 9 basic electronic circuit components. According to CDC (2000; 2015), the expected answers were: resistors, potentiometers, diode, capacitor, thermistor, light dependent resistor, reed switch and reed relay. Some of these were listed by participants. However, there were few participants (10%) who added: Integrated circuits, amplifiers and logic gates, and yet those were combinations of basic electronic circuit components. The answers from participants gave an impression that they had inadequate knowledge about the named subtopic above. According to literature in adequate knowledge on a concept can be a source of alternative conceptions (Ausubel, 1968).

The current study helped participants to understand what basic electronic circuit components were by physically showing them the actual components, explaining what each one does in an electronic circuit and making it clear that a combination of such components is necessary to produce complex circuits which perform certain functions, that is, an amplifier that enlarges current or voltage in a circuit. This approach of presenting physical reality (visual aids) to learners in the teaching - learning process makes it easier for learners to understand and assimilate or accommodate what they learn (Knight, 2002).

10.1.8 All band values must be added to find effective resistance of band resistors

A number of subjects (10%) thought that to determine the effective resistance of a band resistor, one should just add up all the band values but this is not what literature says.

Nelkon (1981) explains how resistance of band resistors should be calculated using an electronic colour code. The values of many resistors can be recognized from the colour of bands round them. The possible colours and their values are as follows:

Black 0

Brown..... 1

Red 2

Orange.....3

Yellow.....4

Green.....5

Blue.....6

Purple.....7

Grey.....8

White.....9

Bands 1 and 2 show the digits (numbers) of the resistance value and band 3 shows the number of zeros which follow the digits. Band 4 shows the tolerance or accuracy of the values by gold = 5%, silver = 10%, and no colour = 20% (p. 582).

Therefore, looking at the explanation given by some participants it was clear that they did not have adequate knowledge on how to determine values of band resistors.

According to Knight (2004, p. 44):

> *A major goal of the science courses is for students to learn more sophisticated problem-solving skills. To succeed, we must:*
>
> - *Teach students the specific skills needed to solve complex problems. These include interpretation skills, pictorial skills, graphical skills, and reasoning skills.*
> - *Show students how those skills are assembled into a powerful problem-solving strategy and demonstrate their use, in detail, in the example you work in class.*
>
> *Make explicit the assumptions, decisions, and reasoning that are part of an expert's problem-solving strategy but which usually go unsaid.*

In the current study the experimental group learnt how to calculate the resistance using the colour code and the response in the post test was very good.

10.1.9 A potentiometer acts as an ammeter, detects resistance and measures resistivity of wire.

Some subjects (7%) claimed that a potentiometer acts as an ammeter, detects resistance and measures resistivity of wire, but this is not supported by literature. Nelkon (1981, p.421) refutes the claim by explaining that a potentiometer provides an accurate method of measuring emf. This explanation is supported by Hausmann and Slack (1950, p. 412), who report that:

> *The emf of a cell is not given exactly by the reading of a voltmeter connected across the cell terminals, because even a high-resistance voltmeter takes some current. Such emf's can be compared accurately with the known emf of a standard cell by means of a potentiometer. An advantage of the potentiometer method is that the measurement is made when the cell is not supplying any current, and since there is no potential drop in the cell and no polarization, the value measured is truly the emf.*

The explanation above clearly indicates that the potentiometer is not a current measuring instrument. Neither does it detect resistance or measure resistivity of any wire, but measures emf or potential difference across a source or conductor more accurately than a voltmeter. Therefore, some participants did not have viable knowledge about the potentiometer. According to the current theoretical framework lack of viable knowledge cannot result in new viable knowledge but the opposite of this (Kelly, 1966; Glasersfeld, 1995).

According to literature, 'In order to help students reason correctly about physical processes and to develop physical intuition, instruction must remain focused on the phenomena by using: experimental laboratory, where possible, to provide familiarity with basic phenomena, working inductively from concrete to the abstract and asking students to explain the outcome of experiments' (Knight, 2002; p.42). Thus, the current study connected the actual potentiometer in a simple electric circuit and demonstrated how it works. This helped participants to understand the function of a potentiometer in a circuit.

10.1.10 Half Wave Rectification produces an output which is partly d.c and partly a.c. Full Wave Rectification produces an output which is completely d.c.

Many subjects, (38%) stated that Half Wave Rectification produced an output which was partly AC partly DC, while Full Wave Rectification produced full DC, (where AC and represented alternating current and direct current respectively). To participants, this meant that in Half Wave Rectification, half of the AC which entered the diode came out as AC after rectification, which is not supported by literature.

According to Wilkinson (1993), in Half-Wave Rectification a diode removes the negative half-cycles of the ac input to produce a varying but one-way DC output across an external resistor. While in Full Wave Rectification, the bridge rectifier allows both positive and negative half-cycles of the ac input to flow in one direction to produce a varying but one-way dc output across an external resistor. Therefore, it was not right for any participants to claim that AC remained AC after rectification. They did so because they had an alternative conception on the concept of rectification.

Few years ago, there was a study conducted by Chen et al. (2013), on "Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model. The study focused on concepts of the Zener diode, including: some conceptual contents such as "semiconductor concept of a diode", "feature of diode bias", "simplified model of a diode", and "basic circuit of a diode." Results, indicated that there were 7 misconceptions about "semiconductor concept of a diode," 4 misconceptions about "feature of diode bias," 7 misconceptions about "simplified model of a diode," and 10 misconceptions about "basic circuit of a diode." However, the study did not arrive at the finding in the current study, which was that in 'Half Wave Rectification', half the current output is AC while the other half is DC.

Therefore in order to help dislodge this alternative conception, the current study utilised a simple paper model to show how a diode changes ac to dc and it was very helpful. This was in line with the theoretical framework, which encourages the structuring of curriculum materials and learning activities using the constructivist approach that aims at promoting conceptual change and development such as the use of examples and analogies, cognitive conflicts, concept maps, models, demonstrations and student activities (Chen et al., 2013).

10.1.11 A thermistor changes heat energy to electrical energy and also detects temperature

When participants were asked to explain the action of a thermistor in question 10, some of them (10%) indicated that a thermistor changes heat energy to electrical energy and can be used to measure temperature. But if it were so, a thermistor could serve as a power supply in a circuit, but this is never the case. Literature indicates that 'A thermistor is a temperature-sensitive resistor containing semiconducting metallic oxides. The resistance of a thermistor decreases with rise in temperature. Such devices are used for temperature control and compensation in high precision instruments' (Wilkinson, 1993, p. 478). Hillman and Halkias (1972, p. 33) agree with Wilkinson (1993), that 'The conductivity of germanium (silicon) is found to increase approximately 6 to 8 percent per degree increase in temperature; A semiconductor used in this manner is called a thermistor.' This description of a thermistor does not imply that the device changes heat energy to electrical energy. Such an explanation would suit a thermocouple thermometer. Therefore, the response from participants gave the impression that such participants mistook a thermistor for a thermocouple thermometer which uses heat to generate a current and use this property to measure temperature. In other words, participants had an alternative conception about the action of a thermistor, which was in line with the theoretical framework. The current study used a computer simulation to show the behaviour of a thermistor in a circuit and it was very helpful. Literature supports use of microcomputer-based laboratories as they help student teachers of physics to understand abstract concepts better than lecture methods (Knight, 2002).

10.1.12 Light Dependent Resistor (LDR) depends on light to measure resistance

A number of participants, (13%), said that a Light Dependent Resistor (LDR) depends on light to measure resistance, but literature does not support this conception. Nelkon (1981, p. 584) explains that

> *The light dependent resistor (LDR) is a special kind of semiconductor sensitive to changes in light intensity. In the dark it has very high resistance while in the light it has a low resistance of a few hundred ohms. It can therefore be used in circuits where lights are automatically switched on at night-time.*

This explanation does not in any way suggest that the LDR measures resistance. It implies that its resistance varies with the amount of light falling on it. As more light falls on it, the resistance of the LDR decreases and vice versa. Therefore, it was clear from the responses given by participants that they had an alternative conception about the action of the LDR. As such it was difficult for them to understand its action in circuits and appreciate its use. This is in line with the theoretical framework which stipulates that, since misconceptions may differ from accepted scientific views and are resistant to change, they affect how the corresponding scientific explanations are learned (Champagne, Klopfer, and Gunstone, 1982). The current study used computer simulations to help participants understand this concept as well.

10.1.13 Capacitor discharges completely when it is disconnected from a circuit

It was worrying to note that a good number of participants, (33%) said that a capacitor discharges completely whenever it is disconnected from a power supply/circuit. This was worrying in the sense that if this alternative conception is not quickly addressed, our future teachers of physics might cause serious accidents in the physics laboratories by carelessly handling and allowing pupils to handle capacitors that are not connected to power supplies, thinking that the capacitors are discharged and yet they may not be.

Nelkon (1981) describes the action of a capacitor as follows:

> *If the plates of a charged capacitor are joined, a current will flow for a short time. Electrons from the negatively charged plate flow round the circuit to the positively charged plate and the charges neutralize each other. The capacitor is then 'discharged.'* (p. 523)

Nelkon (1981) further states, "If a wire is used to connect [the] charged capacitor plates, a spark may be seen as the plates are joined. When the current has stopped flowing, the capacitor is discharged" (p. 523). This implies that what a charged capacitor requires to discharge is just a conductor across the plates. Since a human body is a conductor, using bare hands or any body parts to join the two plates of a capacitor, makes the capacitor to discharge through the body and if the current is huge, this may lead to loss of life. This is why the alternative conception about the action of a capacitor is so worrying. In the current study, participants in the experimental group charged capacitors using low voltage, 3V – 6V and discharged the capacitors using wires and other conducting

materials. Ammeters and voltmeters were used to show current direction and voltage across capacitors respectively. This helped participants to understand the charging and discharging of a capacitor very well.

10.1.14 A reed switch operates on the principle of induced current and regulates voltage

In question 13, participants were asked to explain how a reed switch works. Many of them said they were not sure. But some participants, 4(7%) such as E8 and C13 gave interesting answers. E8 said 'A reed switch operates on the principle of induced current. When a current is induced in a metallic plate, closer to another metallic plate, depending on the charge on the plates they may attract or repel.....' C13 said ' Reed switches are used to regulate voltage but only allow certain amount to pass or the current breaks completely.' But literature does not support all these conceptions about a reed switch. Wilkinson (1993, p.479), gives a description of a reed switch as follows:

> *A reed switch consists of a glass envelope (tube) with two metal contacts. When a magnet is brought near the reed switch, the metal contacts become magnetized and touch each other. This allows current to flow through the switch. When the magnet is removed, the reed switch opens.*

Therefore, it is not the current which is induced in the reeds, but magnetism. In fact , if current was induced in the reeds, there would be sparks when the reeds touch which could be dangerous to the users as sparks may lead to flames. Furthermore, a reed switch is not a voltage regulator. As the name suggests, its purpose is to complete or incomplete a given circuit. The responses from participants implied that their conceptions about reed switches were not in conformity with the acceptable scientific view points. No wonder Dykstra et al.(1992) said that students come to physics classes with a range of informal ideas about scientific phenomena, based on every day experience. The current study demonstrated practically how a reed switch operates and this made participants understand the concept well.

10.1.15 A reed relay uses temperature changes to control current

In question 14, participants were to explain how a reed relay works. Again many said they were not sure. Among those who gave answers, was C13 (3%). He responded that ' Relay switches are self regulated switches, when temperature increases it slowly goes off

or reduces the current flow and then opens again.' However, literature explains the action of a reed relay in a different way. Wilkinson (1993, p.479), says that, 'A reed switch can also be operated by a coil carrying a current. When a current flows through the coil it behaves like a magnet and closes the switch. This is the principle of the reed relay.' Therefore, the claim that a relay switch is a self regulated switch, when temperature increases it slowly goes off or reduces the current flow and then opens again was an alternative conception. The current study used a visual aid to help participants understand the behaviour of a reed relay.

10.1.16 Bipolar transistor is made up of two transistors; When one is on, the other is off; so it acts as a switch.

Some participants, (13%), claimed that a bipolar transistor was made up of two transistors, so that when one was on, the other was off and that was how the transistor acted as a switch. However, this is not what literature stipulates. Nelkon (1981) explains that if a base current of a transistor which is part of the main circuit changes from practically zero to a small value, the collector current automatically switches from a low value to a high value and vice versa. Therefore, the behaviour of a transistor as a switch is dependent on the base current. If the base is low, the transistor is reverse biased and does not conduct current in the main circuit. But if the base is high, the transistor is forward biased and it conducts a heavy current in the main circuit (Wilkinson, 1993). In this way it acts as a switch. Therefore, the claim made by some participants, of a bipolar transistor being made up of two transistors in order to act as a switch, was an alternative conception. The current study used simulations to assist participants understand the behaviour of transistors.

10.1.17 Bipolar transistor is made up of two transistors; This enables it to amplify.

Some participants, (13%) were under the impression that a bipolar transistor was made up of two transistors, which enabled the transistor to amplify. But this is not what literature says because voltage or current amplification depends on whether the base is low or high. When it is low, no current flows in the main circuit but when it is high, a heavy current flows in the main circuit (Nelkon, 1981; Wilkinson, 1993). Therefore, it was clear from the responses given that some respondents did not have a scientifically acceptable

conception about the action of a transistor as an amplifier. The current study used computer simulations again to show how a transistor acts as a switch.

10.1.18 In all cases NAND outputs are opposite to NOR outputs

Some subjects, (12%) said that in all cases NAND gate outputs are opposite to NOR gate outputs. However, this is not what literature says. Nelkon (1981, p.588) describes the outputs of the two logic gates (NAND and NOR) as follows:

> *A NAND gate is opposite to the AND gate,……A NAND gate is equivalent to an AND gate followed by a NOT gate (NAND = NOT AND). So the output ….. is 1 when A or B or both are 0. A NOR gate (NOT OR) is opposite to the OR gate…….So the output…..is 1 only when the two inputs are 0." The truth tables below for NAND and NOR gates help to clarify this further.*

Truth table for NAND gate

Input A	Input B	Output Q
0	0	1
1	0	1
0	1	1
1	1	0

Truth table for NOR gate

Input A	Input B	Output Q
0	0	1
1	0	0
0	1	0
1	1	0

The outputs for NAND and NOR gates are opposite when the inputs to each gate are opposite, but they are the same when the inputs to each gate are the same. Therefore, it was not true that in all cases the output for NAND gate were opposite to those of NOR gates. That was an alternative conception and it indicated that there were students who at that level were not sure how the logic gates, in particular the ones mentioned in this section operate. The current study designed simple NAND and NOR gates using soft iron metal, connecting wires, power supply and electric bulbs and the gates helped participants to understand the concepts well.

10.1.19 Astable circuit has one stable state.

Some subjects, (17%), were under the impression that an Astable circuit had one stable state. However, this is not supported by literature. Nelkon (1981, p. 590), explains that 'Two cross-coupled NOT gates (or two NAND gates used as NOT gates) can be arranged to generate pulses of voltage at a particular frequency. The circuit used is called an astable since, unlike the bistable, it has no stable states.' Therefore, the claim by some participants that an astable circuit had one stable state, was an alternative conception about the action of an astable circuit. The current study used computer simulations to distinguish the action of an astable circuit from the bistable circuit.

10.1.20 Computer hardware are wares that are external while computer software are wares that are stored in the computer

On the last question (20), participants were asked to distinguish between computer hardware and software. Many (88%) performed well on this question. They referred computer hardware to as the physical components of a computer while computer software meant programs in a computer. However, some participants, (12%) gave strange answers. For example, C1 said 'Computer hardware are wares that are external while software are stored wares in the computer. C3 said 'Hardware is the make up and the components of the computer while Software is the inner make up that makes the computer to be operational.' E5 and few others admitted that they were not sure about the difference between computer hardware and software. C1 probably thought that the inner part of a computer had no hardware. Therefore, although the concepts of computer hardware and software were well known by many participants, there were some, who had alternative conceptions about the concepts in question. Therefore, the current study used the actual

computer (physical) components to demonstrate computer hardware and basic programmes of Word, Excel, Power point, Windows operating system etc to demonstrate computer software.

10.1.21 Summary of Section 10.1

The results in Table 6.1.1 and Fig. 6.1.1 showed that participants had alternative conceptions in all topics (20) of basic electronics which were in sharp contrast with the ideas of physicists. Most misconceptions were that Cathode rays are electromagnetic waves which travel at the speed of light (32%), Half Wave Rectification means that half the current output from a diode is AC while the other half is DC (38%) and that A charged capacitor discharges completely when it is not part of a circuit (33%). This could partly explain why some student teachers and even qualified teachers of physics in Zambia feel that their knowledge of basic electronics is not adequate (Haambokoma et al., 2002). As a result they regard basic electronics as the most difficult section of physics to handle because in many cases their understanding of the concepts on that section of physics is not in conformity with science. Their pedagogical content knowledge on basic electronics requires a lot of refinement in order that they can teach this section of physics effectively. The findings that follow helped to answer the second research question.

10.2 Discussion of findings in Chapter 7, concerning the correlation between physics student teachers' misconceptions and performance in basic electronics content.

This section discusses the findings concerning the correlation between physics student teachers' misconceptions and their performance in basic electronics content. The question which the study sought to answer was, **'What is the correlation between such misconceptions and performance of student teachers in basic electronics content in senior secondary physics?** This was the second research question and it was asked in an effort to find out if more misconceptions lowered, enhanced or did not change students' performance in basic electronics in any way. The section starts by discussing the findings about the experimental group in Sections 7.1, 7.2 and 7.3 of the study. Next, it discusses findings about the control group in Sections 7.4, 7.5 and 7.6. Finally, it discusses findings about both groups in Sections 7.7 and 7.8. Section 7.9 is a chapter summary.

10.2.1 Discussion of findings from the experimental group

Figures 7.1.1, 7.1.2, 7.2.1 and 7.2.2 clearly indicate that participants with fewer misconceptions performed better in basic electronics content than those with more misconceptions.

The information in Table 7.1.1 shows that the average number of misconceptions held by participants in the experimental group before the treatment was 13 while the pre-test mean score was 17.1 percent. But the information in Table 7.2.2 indicates that after the treatment, the average number of misconceptions per participant in the experimental group reduced to 7.8 (from 13) while the post-test mean score of that group increased to 55.3 percent (from 17.1%). In addition, the information in frequency tables of Appendix F, revealed that both the post-test range and mode of test scores for experimental group were bigger than those of the pre-test scores. This clearly confirmed that participants in the experimental group performed better in the post-test than in the pre test. Therefore, the fewer the misconceptions held by participants in the experimental group the higher were the participants' performance in basic electronics content and vice- versa.

Fig. 7.3.1 shows that participants in the experimental group had fewer misconceptions after the treatment than before the treatment. Fig. 7.3.2 shows that participants in the experimental group performed better in the post-test than in the pre-test. This further confirmed that there was a negative relationship between misconceptions held by participants and their performance in basic electronics content. Those with fewer misconceptions performed better than those with more misconceptions.

These findings were in line with the current theoretical framework, which claims that misconceptions impede learning, so that the more misconceptions a learner has the more difficult it is to learn (Hammer, 1996; Knight, 2004). Therefore, the findings pointed to a negative relationship between misconceptions held by student teachers of physics and their performance in basic electronics. This was so because the fewer misconceptions participants had, the better was their performance in basic electronics and vice versa. In other words, there was a negative correlation (An average of - 0.7, df = 28, p = 0.01, 2-tailed) between misconceptions held by participants in the experimental group and their performance in basic electronics content. Participants with fewer misconceptions performed better than those with more misconceptions.

The negative correlation could imply that although all participants received same instruction under same conditions, those with more misconceptions did not learn as much as those with fewer misconceptions, as the former resisted change, and so performed poorly in the tests. That was so, because as Sewell (2002) alludes to, quite often, students with misconceptions reject what they are taught and so find it difficult to learn. This view was shared by Kyle and Shymansky (1989) who said that misconceptions interfere with learning because students resist change. These experiences and feelings seem to contradict what students read in their textbooks and/or are taught by their teachers (Driver et al.; 1994). Unless, misconceptions are minimised or eradicated, learning could be quite difficult if not impossible.

10.2.2 Discussion of findings from the control group

Figures 7.4.1, 7.4.2, 7.5.1 and 7.5.2 also indicate that participants with fewer misconceptions perform better in basic electronics content than those with more misconceptions.

The information in Table 7.4.1 shows that the average number of misconceptions held by participants in the control group before the treatment was 14 while the pre-test mean score was 16.5 percent. But the information in Table 7.5.1 indicates that after the treatment, the average number of misconceptions per participant in the control group remained 14 while the post-test mean score increased to 17.6 percent (i.e by 1.1%). In addition, the information in frequency tables of Appendix F, revealed that both the post-test range and mode of test scores for experimental group were more or less the same as those of the pre-test scores. This clearly confirmed that performance of the control group did not change between pre- and post tests. Participants who had more misconceptions and performed poorly in the pre-test still had more misconceptions in the post-test and performed poorly in the post-test in the pre-test and vice-versa. Therefore, the fewer the misconceptions held by participants in the control group the higher were their performance in basic electronics content and vice- versa.

Fig. 7.6.1 shows that participants in the control group had more or less same misconceptions before and after the treatment. Fig. 7.6.2 shows that performance of participants in the control group was the same in the pre-test as in the post-test. This further confirmed that there was a negative relationship between misconceptions held by

participants and their performance in basic electronics content. Furthermore, it showed that the study had internal validity. Participants with fewer misconceptions always performed better than those with more misconceptions. In other words, there was a negative correlation (An average of - 0.7, df = 28, p = 0.01, 2-tailed) between participants' misconceptions and their performance in basic electronics content, the result that agreed with the theoretical framework of the study that misconceptions impede learning. This was an important finding which needed verification using a larger sample size. This is because going by this finding, if misconceptions on the remaining sections of ordinary level physics can be revealed or verified and later dislodged or minimised in the same way, physics which is considered the most difficult subject (Redish, 1994; Haambokoma, 2002; Ornek et al., 2014) could just be as friendly as other subjects.

10.2.3 Pearson's Product Moment Correlation for pre- and post-test scores

According to the information in Table 7.1.1, before the treatment, the value of Pearson's Product Moment Correlation for the experimental group was – 0.6. After the treatment, the information in Table 7.2.2 shows that the value of Pearson's Product Moment Correlation for the experimental group was - 0.8. Therefore, in both cases the value of Pearson's Product Moment Correlation was negative and above -0.5. This confirmed that participants with fewer misconceptions in the experimental group performed better in basic electronics than those with more misconceptions.

The information in Table 7.4.1 indicates that for the control group, the value of Pearson's Product Moment Correlation before the pre-test was -0.8, while after the treatment it was -0.6. This shows that even the control group experienced a negative correlation, so that participants with fewer misconceptions better than those with more misconceptions in basic electronics and vice versa.

The information in Table 7.7.1 shows that the Pearson's Product Moment correlation before the treatment for both groups (combined) was - 0.7, while after the treatment it was - 0.9 as shown in Table 7.8.1. Therefore, it was clear from all of the Pearson's Product Moment Correlation coefficients that regardless of : the type of group, size of group and type of test whether pre or post, the value of Pearson's Product Moment correlation was negative showing that as the number of misconceptions increased, participant's performance went down and vice versa. All the values were above -0.5 (significant at the 0.01 level, 2-tailed) and so the results obtained were significant, the

most significant being the results for all participants after the treatment, as the value of Pearson's Product Moment Correlation in that case was the largest (- 0.9; 2-tailed).

The average value of Pearson's Product Moment Correlation for both groups was – 0.8 (df = 58, p = 0.01, 2-tailed). According to Gay (1996) the value was good enough for the researcher to be certain that the coefficient represented a true relationship. Therefore, the researcher was very confident that the decision concerning the relationship was correct.

The following section discusses findings on the effect of misconceptions on the teaching of basic electronics by student teachers of physics..

10.3 Discussion of findings in Chapter 8 about physics student teachers' teaching skills in basic electronics.

Here the research question to be answered was, **"How do these misconceptions affect the teaching of electronics by student teachers in senior secondary physics**?" Before the treatment, participants in both groups did some peer-teaching. After that the treatment was given to the experimental group for four weeks. During that time the control group learnt a lot of work about conservation laws. Both groups were assured that after some time they would swap the topics to cover the content which the friends did. After the treatment, student teachers of physics from both groups did their second round of peer teaching and the work was evaluated by the researcher and assistant researchers accordingly.

An evaluation form from UNZA was used to evaluate the work during the peer-teaching sessions. The form was devised by the institution, in particular the School of Education, for evaluating student teachers during peer teaching sessions and school teaching experience. It had various elements, including: Lesson objectives, Lesson introduction, Lesson development, Use of resources, Use of questioning technique, Attention to individual needs, Summarizing the work done, Evaluation of the work done and giving of class notes. In this study the form was slightly modified so that it could suit what the study required. The findings of the study were discussed in two parts as follows.

10.3.1 Discussion of findings from peer teaching sessions for participants in the experimental and control groups before the treatment

Looking at Element **'A'** of Table 8.1.1, it was clear that before the treatment, 40 percent of the experimental group and 43 percent of the control group wrote attainable objectives on basic electronics. By then, all the participants were conversant with work on behavioural objectives. They knew an objective as a statement which specifies performance or behaviour a learner is expected to demonstrate after receiving instruction or after a learning experience (Haambokoma, 2002). They knew the three types of objectives as: cognitive, psychomotor and affective. **Cognitive objectives** being those which mainly involve the mental processes of perception (i.e. thinking), **Psychomotor objectives** as those which focus on acquisition of skills such as measurement, drawing, carrying out experiments, and handling apparatus correctly (motor skills) and **Affective objectives** as those that are concerned with aspects such as attitudes, interest in the subject, values and development of appreciation for a subject. Apart from this, they knew the components of objectives as: the **condition statement**, **performance term** and the **qualifying term**. The condition statement being that part of an objective which gives the condition under which the required performance (behaviour) is to be carried out, the **performance term** as a part of the objective which states what the learner must be able to do or perform after instruction/lesson and **qualifying term** as the part of an objective which states the acceptable level of attainment of the performance term. Furthermore, they were conversant with the role of objectives and their limitations. They also knew that in order for an objective to communicate the teacher's intent, it needed to be: Specific, Measurable, Attainable, Relevant and Time bound. However, many of them (about 60% from each group) could not write attainable and time bound objectives. This showed that they did not understand how involving the content they chose to present was. They only realized as they presented their work that the lesson objectives meant much more than they thought.

In Element 'B', a number of participants in the experimental group (77%) and control group (83%) introduced lessons which were relevant to basic electronics. However, only about half the number of participants per group (50% of experimental and 47 % of control) managed to introduce their lessons in a way that attracted learners' attention. This meant that only about half the number of participants per group understood what they presented and so found an interesting way to present that information.

In Element 'C', about half the number of participants (53% of experimental group and 57% of control group) managed to present the lessons logically. This was attributed to

lack of good content knowledge. Learners were rarely involved in non practical class activities (17%) and no participant (0%) involved the learners in an experiment. This created the impression that participants lacked enough content knowledge and so did not know what experiments to do in basic electronics. Learners were rarely allowed to work on their own (17%). Therefore, participants did not utilize learner centred methods of teaching. Those who did some activity used a demonstration (33% of experimental and 43% of control group) but the demonstration they used was not suitable for basic electronics (0%). It was appropriate for third year university physics and not senior secondary physics. Many participants (67% of experimental and 57% of control) used the lecture method (**only**) to present their lessons in basic electronics. They mostly referred to the notes and dictated notes to learners, showing that they lacked confidence in their presentations.

In Element 'D', about 33 percent of the experimental group and 43 percent of the control group used more than one teaching aid. Those were, the chalk board, text book and the equipment already mentioned on logic gates from the Department of Physics, in the School of Natural Sciences . The equipment was not suitable for basic electronics but for 3rd year students of physics at the University of Zambia. All the participants did the same activity using the equipment above. They neither utilized other activities nor improvised any materials that could help to simplify work in basic electronics. Therefore, participants did not know what practical activities to do in basic electronics, including many other resources available.

In Element 'E', the questioning technique was not used well. Those who tried to use it (33% of experimental and 27% of control group) asked questions and the class chanted answers but the teachers rarely commented on the answers given. This indicated that the teachers were not sure whether the learners were right or wrong because participants were not conversant with basic electronics. Very few participants (17%) asked questions and invited learners to discuss the answer, encouraged learners to put hands up to give answers, asked other learners to comment on the answers given and allowed learners to express their opinions before the teachers finally made right comments.

It was sad to note that many teachers (60% of experimental and 40% of control) did not take account of the fact that learners worked at different rates. Instead they expected everyone to work at same rate as shown in Element 'F'. Those who had difficulties were

left with difficulties till the end of lessons. That was attributed to the fact that participants were limited in knowledge of basic electronics, which made it difficult for them to think of what to do if they were asked to make clarifications on what they taught.

In Element 'G', very few subjects (about 20% of each group) explained the relevance of the work done to everyday life, that is, in controlling street lights, robots and computers. Many subjects (77% of experimental and 80% of control group) did not summarise their work due to lack of time. This was because their lesson objectives were not attainable and time bound.

A lot of subjects (60%) did not manage to evaluate their work due to time factor, arising from the same reasons above. Those who managed to do so avoided open ended questions but gave tasks that required a single right answer. Therefore, the depth of their content knowledge was questionable.

In Element 'I', many participants (60% of experimental and 53% of control) could not manage to give notes. The few who did, never asked the class to write their own notes based on the work that was presented. Instead, the class was asked to copy notes from the blackboard.

In summary, before the treatment, the overall performance of both groups in the following lesson Elements : [A] writing of lesson objectives, [B] lesson introduction, [C] lesson development, [D] use of resources, [E] use of questioning technique, [F] attention to individual needs, [G] summarizing of the work done, [H] evaluation of the work done and [I] giving of class notes was more or less the same and generally poor (19 % for experimental group and 20% for Control group).

The findings in Table 8.1.3 show that there was a good level of agreement in the way the two observers, A and B awarded scores to participants during peer teaching sessions (Cohen's Kappa = 0.8, $p < 0.005$, 95% CI).

The results in table 8.1.4 show that before the treatment, there was no significant difference in teaching basic electronics between the experimental and control groups ($t = - 0.85$, $df = 62$, $p = 0.933$, t-tailed). Therefore, before the treatment the two groups taught basic electronics in more or less the same way as shown in Fig. 8.1.1. The lowest performance was recorded in Elements F and G, showing that participants did not think about the learners, and the relevance of what they taught to the learners' everyday life.

Subsection 10.3.2 discusses the findings of both groups about their teaching after the treatment.

10.3.2 Discussion of findings from peer teaching sessions for participants in the experimental and control groups after the treatment

Elements 'A' to 'I' of Tables 8.2.1 and 8.2.2, and Fig. 8.2.1 give a different picture of how the two groups performed after the treatment. Element 'A' shows that more subjects in the experimental group (83%) wrote attainable and time bound objectives than those in the control group (40%). This meant that after the treatment the subjects were clearer about what to do than before. Their knowledge of basic electronics made more sense and this made it possible for them to estimate the time for their lessons correctly.

It was interesting to note that both groups ensured that lesson introduction was relevant to electronics. However, more subjects in the experimental group (80%) attracted learners' attention than those in the control group (57%). This indicated that the former were more conversant with basic electronics and could introduce the lessons in various ways which motivated the learners.

According to Element 'C', after the treatment, more subjects in the experimental group (97%) presented the lessons logically than those in the control group (53%). This was evident enough that due to the treatment, the experimental group understood basic electronics and could put themselves in the shoes of learners and present the work in a manner that would make it understandable. At times subjects from both groups divided the class into small groups and discussed some work. But it was more interesting after the treatment to note that some subjects from the experimental group (40%) did class experiments on the following : resistors, potentiometers, diodes, transistors, logic gates and computers compared to the control group which did none. More learners were allowed to work on their own and engaged on task by the experimental group (67%) than the control group (23%). Where it wasn't possible to do an experiment or any other class activity, participants in both groups used some demonstration. The only thing was that those in the experimental group utilized a variety of demonstrations which were suitable for the class while those in the control group used the same demonstration all the time which was unsuitable for the class. The above observations indicated that the treatment helped the participants in the experimental group to understand basic electronics more and they taught the content better both theoretically and practically.

After the treatment, no subjects in the experimental group used the lecture method only to present the lessons while many subjects in the control group (77%) still did so. This was mainly because after the treatment, those in the experimental group were more conversant in basic electronics than the latter.

According to Element 'D', nearly all the subjects in the experimental group (93%) used various teaching resources such as: resistors, potentiometers, thermistors, light dependent resistors, diodes, reed switches, transistors, logic gates, computers and lamps to present their work. Only about 23 percent of the subjects from the control group used more than one teaching resource. The rest either used the same unsuitable teaching aid or did not use any teaching aid at all.

Generally speaking, the experimental group used the questioning technique better than the control group. The former rarely encouraged the chanting of answers by the class (10%) while the control group (40%) still allowed the chanting of answers by the class without any comments about the answers which were given. The experimental group allowed more class discussions (43%) than the control group (27%). The experimental group encouraged learners to put hands up before giving an answer, asked other learners to comment on the answers given, allowed learners to express their opinions (90%) before finally giving the right answer (70%). The control group did very little in such areas.

It was sad to note that (again) both the experimental as well as the control group did not take account of the fact that learners worked at different rates. It was also noted that several participants (60% of experimental and 73% of control) expected learners to work at the same rate. This was attributed to the limited time of 30 minutes the presenters had per lesson. Although time was limited, many participants in the experimental group (83% compared to 33% in the control group) summarized the lessons and explained the relevance of the work done to everyday life. This clearly showed that those in the experimental group understood the content better than the control group to the extent that they could relate it to their everyday life.

According to Element 'H', in evaluating the work done, the experimental group utilized open-ended tasks more (40%) than the control group (10%) which relied on closed-ended tasks. Furthermore, while only 3% of the experimental group still failed to evaluate the work, due to lack of time, 43 percent of the control group failed to do so in the same time.

These findings showed that after the treatment the experimental group knew much more about basic electronics than the control group. Furthermore, since the former group was more knowledgeable than the control group, they managed to handle the lessons better than the latter in the same time.

Under Element 'I', in many cases, the experimental group (47%) asked the learners to take down short notes as they taught the work while 17 percent of the control group also did so. More subjects from the control group (57%) asked the class to copy notes from the board than the experimental group. Worse still, 27 percent of the participants in the control group did not give any notes due to time factor while 7 percent of the subjects in the experimental group also did not do so. These findings clearly indicated that those in the experimental group were more confident as they presented the work in basic electronics than their colleagues in the control group.

In summary, after the treatment the overall performance of the groups in the following Elements : [A] writing of lesson objectives, [B] lesson introduction, [C] lesson development, [D] use of resources, [E] use of questioning technique, [F] attention to individual needs, [G]summarizing of the work done, [H] evaluation of the work done and [I] giving of class notes, was almost the same as before, for the control group (22% from 20%) but much better for the experimental group (48% from 19%). Therefore, after the treatment the experimental group performed better than the control group in all elements of a lesson on basic electronics ($t = 2.627$, $df = 55$, sig .0.01, 2-tailed). This indicated that misconceptions lower performance of physics student teachers in teaching basic electronics.

10.3.3 Discussion of findings from the attitude (likert) scale.

Here, eighteen statements were given to respondents in the experimental group in form of an attitude scale. The subjects were asked to respond, by either agreeing or disagreeing with the statements given. A summary of the findings were as shown in Table 8.3.1 and Fig. 8.3.1.

The first statement read, "Before the lessons above, I had misconceptions in basic electronics." All the subjects (100%) agreed with the statement. This indicated that all the participants realized that some or all of the conceptions they had about basic electronics

before the treatment were incorrect. Therefore, all the participants were victims of one or more misconceptions in basic electronics content.

In the second statement, nearly all the subjects (93%) agreed that the misconceptions they had, negatively affected their performance in basic electronics content. This clearly showed that when they compared their content knowledge before and after the treatment, they were convinced that some (if not all) of the content they knew was erroneous and that was why they performed poorly in their pre test. The remaining participants (7%) who did not agree with the second statement after accepting the first one, did so because they still held on to their misconceptions. That was not surprising because as Kyle and Shymansky (1989) said, the worst part of misconceptions is that they interfere with learning because students resist change unless they are dissatisfied with their current explanations and can find sensible alternatives with supporting evidence. Those students resisted change probably because they were not dissatisfied with what they had in mind.

A good number of subjects (60%) admitted that the misconceptions they had before the treatment, negatively affected their performance in the teaching of basic electronics. This meant that before the treatment it was clear to the subjects that their teaching on basic electronics was not in line with what they had learnt in several ways, including: [A] writing of lesson objectives, [B] lesson introduction, [C] lesson development, [D]use of resources, [E] use of the questioning technique, [F] attention to individual needs, [G]summarizing of the work done, [H] evaluation of the work done and [I] writing of notes.

Some subjects (63%) agreed that "Due to misconceptions, there were very few topics in basic electronics that they could teach with confidence." The most popular topic was logic gates. Unfortunately, before the treatment, even this topic was not well presented. Those who managed to do a practical activity used the same activity from the 3rd year physics laboratory manual of UNZA. The activity was not suitable for basic electronics but participants could not think of alternatives. This explained why some of them (40%) confessed that "Because of misconceptions, they did little or no practical work when they taught basic electronics."

It was interesting to note that a number of participants (47%) were not comfortable when they were asked by the class to clarify some of the concepts they taught in basic

electronics. They said that “Due to misconceptions, they were not comfortable with questions in basic electronics from the class.” This meant that although they stood in front to teach, they were not sure if what they taught was true or false. No wonder why Lawrenz (1986), cited in Blosser (1987) concluded that some of the errors which student teachers make in teaching are due to lack of content knowledge while others are indicative of serious misconceptions. Therefore, he wondered how teachers who did not understand elementary physical science concepts, could teach their students.

Due to misconceptions many participants (60%) could not easily think of a variety of class activities in basic electronics lessons. Those who presented an activity used the same university equipment on logic gates, which was unsuitable and so not helpful. Worse more, they could not use a variety of teaching strategies but depended on the lecture method (53%). Therefore, in many cases, the lessons were not learner centred but teacher centred. Teaching aids were rarely used (50%).

But after the treatment, the picture was completely different. Nearly all participants (97%) found the discussions they had in basic electronics content, during MSE lectures, an exciting experience. Many of them (83%) agreed that the information they received on all the topics in basic electronics was clear.” The few who did not agree (13%) were probably holding on to their misconceptions. It was also interesting to learn from the participants (93%) that “The amount and quality of materials the subjects covered in basic electronics were right compared with what they knew before.” Once again, the few (7%) who did not agree were probably holding on to misconceptions. Many subjects (97%) admitted that the clarifications made in all topics increased their degree of interest in basic electronics and physics in general. Furthermore, all of them (100%) agreed that the clarifications made helped them to be more practical in basic electronics.

Therefore, there was no doubt that the treatment helped the participants to understand basic electronics in a more scientifically acceptable way and prepared them for practical work in electronics. This was later confirmed in their final teaching sessions where they delivered lessons on various topics in basic electronics and did a variety of practical activities in which the class was always involved. All the subjects (100%) gained confidence and said that the lessons they had (treatment) would help them to present basic electronics well to all learners in or outside Zambia.

Despite the remarks above, although a good number of subjects (80%) indicated that after the treatment they no longer had misconceptions in basic electronics, some subjects (20%) openly declared that they still had. Those subjects (20%) held on to their misconceptions because they had not found sensible alternatives yet with supporting evidence in order for them to discard their misconceptions. One way to help them could have been to isolate them from the group and take them slowly through the same work practically, but time could not allow, as they also needed to concentrate on their academic work.

All the participants (100%) suggested that every year, work in basic electronics should be clarified to student teachers of physics before they get into the field to teach. They (100%) further added that 'The University of Zambia should ensure that final year student teachers of physics are conversant with basic electronics content before they join teaching (as this cannot easily happen when they have left the institution.'

10.4 Discussion of findings in Chapter 9, about the effect of the 'BE' Education Resource on misconceptions and performance of physics student teachers in basic electronics

This section discusses the findings which answered the last research question of the study. This was as follows: 'What effect does the 'BE'' Education Resource and have on physics student teachers' misconceptions and performance in basic electronics?' In order to arrive at the answer, the study utilised the findings shown in Figures. 9.1.1, 9.2.1, 9.3.1 and 9.4.1.

Before the treatment, the experimental and control groups had more or less the same number of misconceptions (Fig.9.1.1). After the treatment, the experimental group had fewer misconceptions than the control group (Fig 9.2.1). This suggested that the treatment helped to reduce the number of misconceptions in the experimental group.

Secondly, before the treatment, the performance of both groups was more or less the same (Fig. 9.3.1). The values of the t-test were: t = .261, df = 58, p = 0.792, t- tailed, which indicated that there was no statistically significant difference in performance between the two groups. But after the treatment the performance of the Experimental group was far much better than that of the control group (Fig. 9.3.2). Using SPSS, the t-

value obtained for the two independent samples was 12.3 (df = 58, ρ = 0.01, 2-tailed). This confirmed that:

i. Physics student teachers' misconceptions were the cause of lower performance of the control group than the experimental group in basic electronics content

ii. When used as a supplement to the traditional educational resources in physics, the treatment, 'BE' Education Resource minimised physics student teachers' misconceptions and in turn enhanced students' performance in basic electronics.

Although previous studies did not focus on basic electronics, both the theoretical framework and the literature reviewed support the fact that misconceptions on the areas studied affect learners' performance negatively (Kelly, 1966; Blosser,1987; Glasersfeld, 1995; Yip et al. , 1998; Groves and Pugh, 1999; Papadimitriou ,2004). One way to minimise them is to ensure that learners are actively engaged in the lessons as was the case in the current study. Active engagement helps students to build their mental models rather than receive them from the instructor using: Interactive demonstrations, nearest neighbour discussion activities, collaborative group activities, microcomputer-based laboratories or other guided-discovery laboratories and take-home experiments (Knight, 2002).

10.5 Theoretical implications of the current study

The theoretical framework of the current study indicates that learners bring their personal experiences into the classroom which have a tremendous impact on students' views of how the world works. In other words, learners come to learning situations with a variety of knowledge, feelings, and skills.

According to Kyle and Shymansky (1989; p.1).

> *Every learner brings his or her own set of experiences and knowledge to new learning experiences. We have a world view and new knowledge must fit into our world view. If new knowledge does not fit into our pre-existing view, then we must adapt our mental structure of our world view before we can place the new knowledge into our knowledge structure.*

This knowledge exists within students and is developed as they interact with their peers, teachers, and the environment. Learners' construct understanding or meaning by making sense of their experiences and fitting their own ideas into reality. Stepans (1994, p.1) also supports this view by saying that,

> *Beliefs resulting from personal experience, intuition, and 'common sense' lead students to form their own ideas and models, often well before formal instruction. These experiences and feelings seem to contradict what students read in their textbooks and/or are taught by their teachers. Worse still, even with instruction, it is often difficult for students to give up these ideas, or they may revert to them later even though it appears they may have learned the correct ideas in class*.

The findings of the current study were consistent with the theoretical framework. This is because student teachers of physics gave several alternative conceptions to the first research question. As misconceptions increased performance of participants went down, which confirmed the theory that misconceptions impede learning. In addition, misconceptions lowered performance of participants in teaching basic electronics. This confirmed the theory that misconceptions impede teaching. Finally, use of the 'BE' minimised misconceptions. This confirmed the theory that use of teaching resources and strategies in which participants are actively engaged in a lesson clarifies work more and enhances academic performance of learners. Therefore, the theory of cognitive constructivism which was used in the study was right.

This means that the methods used to arrive at the findings and the way data were analysed were appropriate. However, at this point, it is important to mention that there was no single pre-modern theory that could guide the study particularly in terms of methodology and data analysis. Hence, the reason for combining two cognitive

constructivist theories of learning which are at the two extreme ends in the constructivist continuum, to come up with the theoretical framework. The current study, realised that the theory of Radical constructivism by Glasersfeld (1995) favours qualitative research in terms of ontological, epistemological and methodological issues. While the theory does not deny the existence of an external reality which is independent of the observer it makes a claim that it is not possible for observers to know that independent reality except through their constructions of it. As a result the theory cannot accept anything as right or wrong, implying that it cannot favour experimental research which aims at establishing the truth. While it is true that science is dynamic so that what is true today may not be true tomorrow, previous studies show that independent reality exists. This being the case, common sense indicates that there should be a *possibility to know that reality directly if you use a perfect method. This is why* researchers argue that some constructions are indeed better than others if they conform more adequately to the contours of external reality (Landfield,1980; Walker, 1992; Warren, 1992, Howard, 1997; Stevens, 1998; Warren; 1998). Therefore, unless Radical constructivism accepts and accommodates this aspect, it will not be helpful enough in quantitative research. Future research should consider this issue seriously.

10.6 Implications of the current study for policy and practice

The study implies that the School of Natural Sciences, Department of Physics and the School of Education, Department of Mathematics and Science Education at UNZA should pay attention to misconceptions in the course of teaching and learning of existing physics and physics education courses. Secondly, the CDC should to pay attention to misconceptions as they develop physics materials for teachers and pupils. The ECZ should also consider student misconceptions when preparing final examinations.

10.7 Chapter Summary

Results of this study revealed several misconceptions including: Thermionic emission is loss of heat by materials, Cathode rays are electromagnetic waves that travel at the speed of light; Conventional current is the same as convection current has no specific direction; Application of cathode rays are same as those of electromagnetic waves; The Cathode ray oscilloscope has one X and one Y- plate that form a pair; In a CRO the heater produces light which is deflected by X and Y plates; Intergrated circuits, Amplifiers, Logic gates and Transformers are some of the basic components in electronics; All band values must

be added to find resistance of band resistors; A potentiometer acts as an ammeter, detects resistance and measures resistivity of wire; Half Wave Rectification produces an output which is partly DC and partly AC; a Thermistor detects temperature; LDR depends on light to measure resistance; Capacitor discharges whenever it is not part of a complete circuit; A reed switch operates on the principle of induced current and regulates voltage; A reed relay uses temperature changes to control current; Bipolar transistor is made up of two transistors, when one is on, the other is off and so it acts as a switch;

Others were that a Bipolar transistor is made up of two transistors and this enables it to amplify; In all cases NAND outputs are opposite to NOR outputs; 0+0 = 1 and 1+0 = 0 for OR gate; Astable circuit has one stable state; and that Computer hardware are wares that are external while computer software are wares that are stored inside a computer.

The correlation between physics student teachers' misconceptions and performance in basic electronics was - 0.8. This indicated that the more misconceptions a physics student teacher had, the lower was one's performance in basic electronics content and vice-versa. It was also clear from the results obtained that the relationship above was causal, that is, misconceptions contributed to the low performance of participants.

Second, comparison of participants' pre and post-test performance in teaching revealed that the experimental group performed better than the control group in terms of: formulation of lesson objectives, lesson introduction, lesson development, use of resources, use of questioning technique and other teaching strategies, attention to individual needs, summarizing of the work done, evaluation of the work done and giving of class notes. This indicated that changing, dislodging or minimising student teachers' misconceptions improved their teaching skills.

Finally, all the participants who utilised the 'BE' Education resource as a treatment, performed better than those who didn't and recommended that every year, work in basic electronics should be clarified to student teachers of physics in that manner before they get into the field to teach. They further added that UNZA should always ensure that final year students of physics are conversant with basic electronics content before they join the teaching profession. According to them, this may not happen when they have left the institution. This indicated that the treatment had minimised participants' misconceptions and simultaneously enhanced their performance in basic electronics.

CHAPTER 11

CONCLUSIONS AND RECOMMENDATIONS

11.0 Introduction

This study investigated the conceptions and performance of student teachers of physics in basic electronics in senior secondary physics. It sought to answer four important questions, as follows:

(i) What misconceptions do student teachers of physics have about basic electronics, as they finish their training?

(ii) What is the correlation between such misconceptions and performance of physics student teachers in basic electronics content?

(iii) How do these misconceptions affect the teaching of basic electronics by student teachers in senior secondary physics?

(iv) What effect does the ‘‘BE’’ Education Resource and Teaching Approach have on physics student teachers’ misconceptions and performance in basic electronics?

Data related to question 1 were collected using a Questionnaire, while the data required to answer Questions 2 were collected using pre and post-tests. In order to answer Question 3, the study used data captured by the UNZA teacher evaluation form. This is a standard form used by supervisors to evaluate students on teaching experience and those who do peer teaching. Pre-and post-tests were used to capture data which helped to answer question four. An attitude scale provided data which were used to find out what feelings participants in the experimental group had about the treatment they were given, the lessons in basic electronics. Sections 11.1 to 11.3 indicate the conclusions, Section 11.4 shows the recommendations and the last Section, 11.5 suggests areas for further research.

11.1 Conclusions

The study revealed that student teachers of physics had several misconceptions in basic electronics, the most prevalent ones being that: Cathode rays are electromagnetic waves that travel at the speed of light, Half Wave Rectification produces an output which is partly DC and partly AC and that a Capacitor discharges completely when it is disconnected from a circuit.

With regard to the correlation between misconceptions and performance of students of physics in basic electronics, the conclusion made was that there was a negative correlation of – 0.8 (df = 58, significant at 0.01, 2-tailed) between the misconceptions held by student teachers of physics and their performance in basic electronics content. Therefore, the more misconceptions a student had the lower was one's performance and vice-versa.

In terms of teaching basic electronics, the study concluded that misconceptions lowered performance of participants in the following areas: formulation of lesson objectives, lesson introduction, lesson development, use of resources, use of questioning technique and other teaching strategies, attention to individual needs, summarizing of the work done, evaluation of the work done and giving of class notes.

Finally the study concluded that the 'BE' Education Resource with the Teaching Approach imbedded in it, minimised the misconceptions held by student teachers of physics and simultaneously enhanced their academic performance on basic electronics.

This is the new knowledge which the study contributed on physics student teachers' misconceptions about basic electronics.

11.2 Recommendations

Following the conclusions above, the following were the recommendations made:

i. The Department of physics at UNZA should identify physics student teachers' misconceptions in Electronics at every level and take appropriate measures to alter or dislodge them.

ii. Physics education courses at UNZA should not only focus on pedagogical strategies but also relevant physics content to enhance physics student teachers' understanding of fundamental physics concepts.

iii. Further research should be done to investigate the effect of the 'BE' Education resource on performance of physics student teachers in basic electronics.

11.3 Recommendations for further Research

The results of this study suggest that more research is needed in the following areas:

i. Nature of misconceptions held by physics student teachers about all sections

of ordinary level physics, in the Zambian context?

ii. Effective pedagogical strategies of reversing the negative correlation between misconceptions and student teachers' performance in physics.

iii. Effect of misconceptions on the choice of physics as a teaching subject by student teachers of science.

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APPENDICES

APPENDIX A

QUESTIONNAIRE ON BASIC ELECTRONICS

Participant ID……..

Programme……

Year of study……..……

Course code……...……...……

Instructions to participants:

The questionnaire has twenty (20) questions. Write your answers in each of the boxes of the third column labelled, **Participant's response**. Leave the other two columns blank.

S/NO.	Question	Participant's response	Nature of misconception(s)	X
1	Describe Thermionic emission			
2	State four properties of cathode rays.			

3	Is there any difference between the direction of flow of electrons and flow of conventional current? Explain.			
4	State four applications of electron beams.			
5	Describe the basic structure and action of the cathode ray oscilloscope			

6	List eight**(8)** basic electronic circuit components			
7	Describe how you determine resistor values using standard colour codes.			

8	Describe the action of a potentiometer			
9	Distinguish between half wave and full wave rectification			
10	Explain the action of a thermistor			

11	Explain the action of a light dependent resistor			
12	Describe the charging and discharging of capacitors			
13	Explain how a reed switch works			

14	Explain how a reed relay works			
15	Describe how a bipolar transistor works as a switch			
16	Describe how a bipolar transistor works as an amplifier			
17	Distinguish between the action of NAND and NOR gates			

18	Derive the truth tables for AND, OR, NAND, NOR and NOT gates.			
19	Describe the use of Bistable and Astable circuits			

20	Distinguish between computer hardware and software.			
Total				

N.B The letter **X** represents the number of misconceptions.

APPENDIX B

TEST ON BASIC ELECTRONICS

Participant ID :……...……

Programme :...……

Year of study:……...

Course code :……...……

Section A

Answer each question in section A by circling the letter of your choice.

1. Thermionic emission is
   A. the loss of heat by heated electrons
   B. the loss of electrons by radioactive isotopes
   C. the loss of electrons due to photoionisation
   D. the loss of electrons by heated metals
   E. the loss of metals due to loss of electrons

2. Which of the following is not a property of cathode rays?
   A. They travel at a speed of 3.0×10^8 m/s in air
   B. They do not make bends as they travel
   C. They carry a negative charge
   D. They are deflected by an electric field
   E. They are deflected by a magnetic field

3. If cathode rays flow from X to Y, it implies that
   A. electrons flow from X to Y
   B. electrons flow from Y to X
   C. conventional current flows from X to Y
   D. protons flow from X to Y
   E. metal Y has a negative charge

4. The time-base of cathode-ray oscilloscope is set to 100ms/cm.
   What is the frequency of a signal on the CRO screen, whose wavelength is 2cm?

   A. 0.1 Hz B. 0.2 Hz C. 0.5 Hz D. 5Hz E. 50Hz

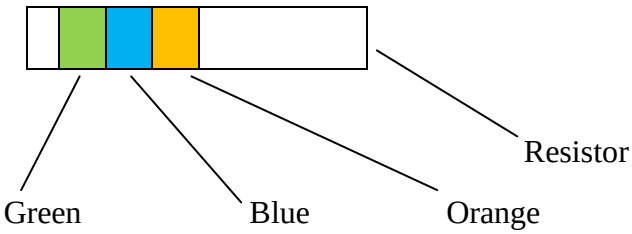
5. Which part of the cathode-ray oscilloscope regulates the number of electrons moving towards the screen?

A. cathode B. Anode C. Grid D. X-plates E. time-base circuit

6. Which of the following would result in recapturing of electrons by a cathode in the Cathode Ray Oscilloscope?

A. Decrease in potential difference between the heater and cathode
B. Decrease in potential difference between the cathode and grid
C. Decrease in potential difference between the cathode and anode
D. Decrease in potential difference between the anode and Y-plates
E. Decrease in potential difference between the X and Y plates.

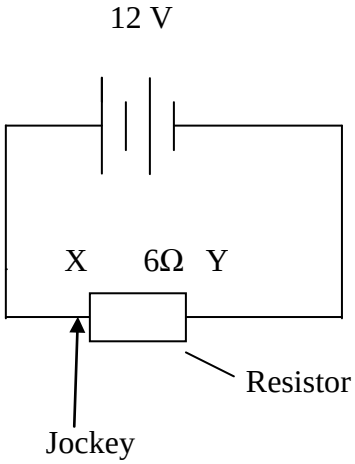
7. A resistor with a band of colours shown in the diagram has a resistance of 56000 Ω.



What numbers do the colours represent in the resistor colour code?

	green	blue	orange
A.	0	5	6
B.	0	6	5
C.	3	5	6
D.	5	6	0
E.	5	6	3

8. For the potential divider shown below, if the jockey touches point X in the circuit and the battery's EMF is 12V, what is the output voltage between terminal Y and the jockey? Assume the wire has negligible resistance.



A. 0 V B. 0.5 V C. 2.0 V D. 6.0 V E. 12.0 V

9. Which component can be used as a temperature sensor in an electric circuit?

A. Capacitor B. Thermistor C.Diode D. Light Dependent Resistor E. Relay

10. Which of the following is true?
    A. Capacitors allow direct current to pass through
    B. Capacitors allow alternating current to pass through
    C. In a capacitor, a dielectric has free electrons
    D. The time constant is the product of Capacitance and Voltage in seconds
    E. Decrease in plate distance enables capacitor to store more charge

11. A reed switch
    A. does not require any current to complete a circuit
    B. uses an alternating current to complete a circuit
    C. uses induced magnetism to complete a circuit
    D. has glass reeds which turn into magnets due to direct current
    E. only controls direct currents

12. For an NPN transistor, a small base current
    A. causes a larger collector–emitter current
    B. implies that the transistor is reverse biased
    C. causes the transistor base to be forward biased
    D. allows a small current to flow from emitter to collector
    E. creates holes that repel electrons from a power supply

13. What single gate is equivalent to an AND gate followed by a NOT gate?
    A. NOT B. OR C. NAND D. NOR

14. A NAND gate has its two inputs A and B connected together (in series) to form one input. What type of gate is now formed?
    A. NOT B. AND C. OR D. NOR

15. The table below shows a truth table of a logic gate.

Input A	Input B	Output C
0	0	1
0	1	1
1	0	1
1	1	0

The truth table is for

A. NOT gate B. NOR gate C. NAND gate D. OR gate

16. A Bistable circuit
    A. has one stable state
    B. latches on to the state of S(set)
    C. has no memory property
    D. has two cross coupled diodes
    E. is made up of two capacitors

17. An Astable circuit
    A. can serve as an a.c generator
    B. can generate voltage pulses
    C. has two stable states
    D. has a memory property
    E. latches on to the state of R(reset).

18. The CPU with the monitor, keyboard and mouse connected to it can be referred to as a

A. Computer B. Computer system C. Malware D. BIOS Chip E. Transiducer

19. Which component below stores the data and information as a computer is working?

A. ALU B. RAM C. CD-ROM D. BIOS E. CPU

20. Electronics has a lot of impact on the following, except

A. Robots

B. Calculators

C. Telephones

D. Television

E. Baryons

SECTION B

Answer all questions in section B. *Write your answers in the spaces provided.*

1.(a) Draw a labelled diagram to show the main features of a cathode ray oscilloscope.[4]

(b) Explain the working of each of the labelled features above.

...……

……..

…….

…….

…….

...……..

…….(6)

2. (a) Define the term Full Wave Rectification

……

……...…(2)

(b) Draw a labelled diagram to show a Full-Wave Rectifier circuit. Include the power supply. (4)

(c) Describe briefly how the circuit in 2(b) operates

……..

……..

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……..…(3)

(d) Explain why capacitors are often included in most rectifier circuits.

…..……

…….

…….(1)

3. (a) Draw a diagram of an electronic circuit, showing how a light dependent resistor may be used to control five lamps that are connected in parallel. Include any suitable components of your choice. (5)

(b) Briefly describe how the circuit in 3(a) works.

……..

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……..…(5)

4. (a) What are logic gates?

……

……...(1)

(b) Using logic gates, show how in a school the main safe can be opened only by two Accounts officers both using their keys in two locks, or by the Headteacher alone using his/her key in one special lock. Include a Truth table. (5)

(c) In a certain “Cold” room, the temperature and humidity (moisture) must not both be above a particular value, otherwise the window must be opened. Using a suitable logic gate or more, explain how this could be done. (4)

5. Using labelled diagrams describe

(a) the action of a Bistable circuit (5)

(b) how an Astable circuit manages to produce pulses of voltage.

APPENDIX C

OBSERVATION SCHEDULE

OBSERVATION OF TEACHING

Participant ID:…… Topic :…….....……

Programme :…… Date :.....

Year of Study:……

Course code :.....

ACTIVITY THAT TAKES PLACE DURING THE LESSON UNDER THE FOLLOWING CATEGORIES:	TALLY	
	Yes	**No**
(A) LESSON OBJECTIVES		
Student teacher ensures that the objectives of the lesson on basic electronics: (i) Are attainable in the time available		
(B) LESSON INTRODUCTION		
Student teacher ensures that the lesson introduction: (i) Is relevant to the topic		
(ii) Attracts pupils' attention		
(C) LESSON DEVELOPMENT		
Student teacher:		
(i) Presents the lesson logically		
(ii) Involves the class in a non practical activity		
(iii) Involves the class in an experiment		
(iv) Allows pupils to work on their own		
(v) Ensures that pupils are engaged and on- task		
(vi) Does a demonstration while pupils watch him/her		
(vii) Uses a demonstration which was used by others on the same topic		
(viii) Uses a demonstration which is suitable for the class		

(viii)Uses the lecture method and other teaching strategies to present the lesson		
(ix)Uses the lecture method (only) to present the whole lesson		
(D) USE OF RESOURCES		
Student teacher:		
(i) Uses various teaching aids during the lesson		
(ii) Uses a common teaching aid, already used by others on the same topic		
(E) USE OF QUESTIONING TECHNIQUE		
Student teacher:		
(i) Asks question to the whole class and they chant the answer		
(ii) Asks question and invites the pupils to discuss the answer with each other		
(iii)Encourages pupils to put their hands up and chooses one to give an answer		
(iv)Asks other pupils to comment on the answer given		
(v) Allows pupils to express their opinions		
(vi)Makes comments on the answers given by pupils		
(vii) Makes right comments all the time		
(F) ATTENTION TO INDIVIDUAL NEEDS		
Student teacher:		
(i) Takes account of the fact that pupils work at different rates		
(ii) Expects every pupil to work at same rate		
(G)SUMMARISING OF THE WORK DONE		
Student teacher:		
(i) Explains how the work covered is relevant to every day life		
(ii) Links current lesson to next lesson		
(H)EVALUATION OF THE WORK DONE		
Student teacher:		
(i) Gives open- ended tasks		

(ii) Gives tasks with a single right answer (closed)		
(I) **NOTES**		
Student teacher:		
(i) Asks pupils to write their own notes based on the work they have done in the lesson		
(ii) Asks pupils to copy notes from the chalkboard		

ELABORATION (Other relevant information on the teaching of basic electronics by student teachers of physics, clarifications etc)

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APPENDIX D

ATTITUDE SCALE

Participant ID:.....Programme of study:.....

Year of Study:.....Course code:.....

Age Last birth day:.....
Sex:.....

The statements listed in the table below are about your conceptions in basic electronics before and after the 'Treatment'. For each statement, indicate with a tick, ✓ whether you Strongly Agree, Agree, are Neutral, Disagree or Strongly Disagree with it.

S/NO.	STATEMENT	RESPONSES				
		Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1
1	Before the lessons above , I had misconceptions in basic electronics					
2	The misconceptions that I had, negatively affected my performance in basic electronics content					
3	The misconceptions that I had, negatively affected my performance in the teaching of basic electronics					
4	Due to misconceptions, there were very few topics in basic electronics that I could teach with confidence					
5	Because of misconceptions, I did little or no practical work when I taught basic electronics					

6	Due to misconceptions, I was not comfortable with questions in basic electronics from the class					
7	Due to misconceptions I could not easily think of a variety of class activities in basic electronics lessons					
8	Because of misconceptions, I did not use a variety of teaching strategies in basic electronics; I mainly relied on the lecture method					
9	Due to misconceptions it was difficult for me to think of teaching/learning Aids in basic electronics.					
10	Later, the discussions we had in basic electronics (content) during MSE lectures was an exciting experience					
11	The information on all the topics in basic electronics was clear					
12	The amount and quality of materials I covered in basic electronics were right compared with what I knew before.					
13	The clarifications made in all topics increased my degree of interest in basic electronics and physics in general					
14	The clarifications made helped me to be more practical in basic electronics					
15	The lessons we had will help me to present basic electronics well (to all learners) in or outside Zambia					
16	After our lessons above, I no longer had misconceptions in basic electronics					
17	I suggest that every year, work in basic electronics be clarified to student teachers of physics before they go to teach					

18	The University of Zambia should ensure that final year student teachers of physics are conversant with basic electronics content before they join teaching (as this cannot easily happen when they have left the institution).					

Thank you for the time and effort you put into completing this questionnaire.

APPENDIX E

RESULTS FOR EXPERIMENTAL AND CONTROL GROUPS

Table 7.1.1 Pre-test results for Experimental group

Participant ID	Number of pre-test misconceptions	Pre-test score(%)
E1	14	13
E2	15	13
E3	15	16
E4	13	16
E5	17	16
E6	10	19
E7	19	19
E8	8	40
E9	11	19
E10	19	14
E11	13	40
E12	18	9
E13	15	16
E14	16	3
E15	17	16
E16	10	13
E17	15	11

E18	8	20
E19	10	20
E20	16	8
E21	14	14
E22	8	27
E23	15	8
E24	16	5
E25	7	39
E26	9	17
E27	12	15
E28	10	17
E29	11	14
E30	11	16

Using SPSS, the results in Table. 7.1.1 produced the statistics shown in Table 7.1.2.

Table 7.1.2 Statistics based on the findings in Table 7.1.1

Statistics

		Pretest Scores (%)	Pretest Misconceptions
N	Valid	30	30
	Missing	0	0
Mean		17	13
Median		16	14
Mode		16	15
Std. Deviation		9	3
Variance		81	12
Skewness		1.4	-0.04
Std. Error of Skewness		0.4	0.4
Range		37	12
Minimum		3	7
Maximum		40	19

The same results above produced more information about pretest scores for the experimental group as shown in Table 7.1.3.

Table 7.1.3 More findings on pre-test scores of Table 7.1.1

Pre-test Scores

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
3	1	3.3	3.3	3.3
5	1	3.3	3.3	6.7
8	2	6.7	6.7	13.3
9	1	3.3	3.3	16.7
11	1	3.3	3.3	20.0
13	3	10.0	10.0	30.0
14	3	10.0	10.0	40.0
15	1	3.3	3.3	43.3
16	6	20.0	20.0	63.3
17	2	6.7	6.7	70.0
19	3	10.0	10.0	80.0
20	2	6.7	6.7	86.7
27	1	3.3	3.3	90.0
39	1	3.3	3.3	93.3
40	2	6.7	6.7	100.0
Total	**30**	**100.0**	**100.0**	

Furthermore, the findings in Table 7.1.1 revealed the information in Table 7.1.4, about pre-test misconceptions for experimental group.

Table 7.1.4 More findings on pre-test misconceptions of Table 7.1.1

Pre-test Misconceptions

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
7	1	3.3	3.3	3.3
8	3	10.0	10.0	13.3
9	1	3.3	3.3	16.7
10	4	13.3	13.3	30.0
11	3	10.0	10.0	40.0
12	1	3.3	3.3	43.3
13	2	6.7	6.7	50.0
14	2	6.7	6.7	56.7
15	5	16.7	16.7	73.3
16	3	10.0	10.0	83.3
17	2	6.7	6.7	90.0
18	1	3.3	3.3	93.3
19	2	6.7	6.7	100.0
Total	30	100.0	100.0	

After that a graph was plotted as shown in Fig. 7.1.1 to show the relationship between misconceptions and pre-test scores for the experimental group.

Table 7.2.1 Post-test results for Experimental group

Participant ID	Number of Post-test misconceptions	Post-test score(%)
E1	5	74
E2	4	59
E3	3	71
E4	8	49
E5	9	47
E6	4	67
E7	7	63
E8	8	69
E9	7	61
E10	16	47
E11	5	74
E12	10	39
E13	8	26
E14	10	33
E15	11	57
E16	4	70
E17	4	74
E18	3	73
E19	8	51

E20	14	27
E21	11	42
E22	7	56
E23	10	44
E24	11	44
E25	9	43
E26	5	73
E27	10	47
E28	7	62
E29	7	56
E30	10	60

The results in Table 7.2.1 produced the statistics in Table 7.2.2.

Table 7.2.2 Statistics based on the findings in Table 7.2.1

Statistics

		Post-test Scores (%)	Post-test Misconceptions
N	Valid	30	30
	Missing	0	0
Mean		55.3	7.8
Median		56.5	8.0
Mode		47[a]	7[a]
Std. Deviation		14.3	3.2
Variance		203.8	10.1
Skewness		-0.4	0.5
Std. Error of Skewness		0.4	0.4
Range		48	13
Minimum		26	3
Maximum		74	16

Multiple modes exist. The smallest value is shown.

The same results in Table 7.2.1 produced more information about post-test scores for the experimental group as shown in Table 7.2.3.

Table 7.2.3 More findings on post-test scores of Table 7.2.1

Post-test Scores

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	26	1	3.3	3.3	3.3
	27	1	3.3	3.3	6.7
	33	1	3.3	3.3	10.0
	39	1	3.3	3.3	13.3
	42	1	3.3	3.3	16.7
	43	1	3.3	3.3	20.0
	44	2	6.7	6.7	26.7
	47	3	10.0	10.0	36.7
	49	1	3.3	3.3	40.0
	51	1	3.3	3.3	43.3
	56	2	6.7	6.7	50.0
	57	1	3.3	3.3	53.3
	59	1	3.3	3.3	56.7
	60	1	3.3	3.3	60.0
	61	1	3.3	3.3	63.3
	62	1	3.3	3.3	66.7
	63	1	3.3	3.3	70.0
	67	1	3.3	3.3	73.3
	69	1	3.3	3.3	76.7
	70	1	3.3	3.3	80.0
	71	1	3.3	3.3	83.3
	73	2	6.7	6.7	90.0

74	3	10.0	10.0	100.0
Total	**30**	**100.0**	**100.0**	

In addition, the results in Table 7.2.1 produced more information about post-test misconceptions for the experimental group as presented in Table 7.2.4.

Table 7.2.4 More findings on post-test misconceptions of Table 7.2.1

Post-test Misconceptions

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
3	2	6.7	6.7	6.7
4	4	13.3	13.3	20.0
5	3	10.0	10.0	30.0
7	5	16.7	16.7	46.7
8	4	13.3	13.3	60.0
9	2	6.7	6.7	66.7
10	5	16.7	16.7	83.3
11	3	10.0	10.0	93.3
14	1	3.3	3.3	96.7
16	1	3.3	3.3	100.0
Total	**30**	**100.0**	**100.0**	

Therefore, after the treatment the number of misconceptions per participant in the experimental group reduced to an average of 7.8 (from 13.1) while the post-test mean score increased to 55.3% (from 17.1%). This indicated that the fewer the misconceptions

held by each participant in the experimental group the higher was the participant's performance and vice versa. The graph that follows compared the post-test results for the experimental group.

Table 7.3.1 Pre-test results for Control group N= 30

Participant ID	X = Number of pre-test misconceptions	Y = Pretest score(%)
C1	15	7
C2	17	16
C3	16	7
C4	15	11
C5	15	23
C6	8	44
C7	16	19
C8	12	17
C9	14	26
C10	11	17
C11	13	20
C12	8	35
C13	11	20
C14	16	9
C15	14	13
C16	17	10

C17	13	16
C18	12	15
C19	15	15
C20	12	17
C21	14	15
C22	9	28
C23	18	5
C24	11	13
C25	18	10
C26	20	8
C27	16	10
C28	12	17
C29	20	6
C30	11	26

The statistics for the findings in Table 7.3.1 are displayed in Table 7.3.2.

Table 7.3.2 Statistics based on the findings in Table 7.3.1

Statistics

		Pre-test score	Pre-test misconceptions
N	Valid	30	30
	Missing	36	36
Mean		16.5000	13.9667
Std. Error of Mean		1.59939	.58030
Median		15.5000	14.0000
Mode		17.00	11.00[a]
Std. Deviation		8.76022	3.17841
Variance		76.741	10.102
Skewness		1.331	-.023
Std. Error of Skewness		.427	.427
Kurtosis		2.323	-.454
Std. Error of Kurtosis		.833	.833
Range		39.00	12.00
Minimum		5.00	8.00
Maximum		44.00	20.00
Sum		495.00	419.00
Percentiles	25	10.0000	11.7500
	50	15.5000	14.0000
	75	20.0000	16.0000

a. Multiple modes exist. The smallest value is shown

The same results in Table 7.3.1 yielded the results in Tables 7.3.3 and 7.3.4.

Table 7.3.3 Pre-test Scores for Control group (%)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	1	1.5	3.3	3.3
	6	1	1.5	3.3	6.7
	7	2	3.0	6.7	13.3
	8	1	1.5	3.3	16.7
	9	1	1.5	3.3	20.0
	10	3	4.5	10.0	30.0
	11	1	1.5	3.3	33.3
	13	2	3.0	6.7	40.0
	15	3	4.5	10.0	50.0
	16	2	3.0	6.7	56.7
	17	4	6.1	13.3	70.0
	19	1	1.5	3.3	73.3
	20	2	3.0	6.7	80.0
	23	1	1.5	3.3	83.3
	26	2	3.0	6.7	90.0
	28	1	1.5	3.3	93.3
	35	1	1.5	3.3	96.7
	44	1	1.5	3.3	100.0
	Total	30	45.5	100.0	
Missing	System	36	54.5		
Total		66	100.0		

Table 7.3.4 Pretest Misconceptions for Control group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	8	2	3.0	6.7	6.7
	9	1	1.5	3.3	10.0
	11	4	6.1	13.3	23.3
	12	4	6.1	13.3	36.7
	13	2	3.0	6.7	43.3
	14	3	4.5	10.0	53.3
	15	4	6.1	13.3	66.7
	16	4	6.1	13.3	80.0
	17	2	3.0	6.7	86.7
	18	2	3.0	6.7	93.3
	20	2	3.0	6.7	100.0
	Total	30	45.5	100.0	
Missing	System	36	54.5		
Total		66	100.0		

The average number of misconceptions held by participants in the control group before the treatment was 14 while the pre-test mean score was 16.5%. The information in the table was presented graphically as shown in Fig. 7.3.1.

Table 7.4.1 Post-test results for Control group N= 30

Participant ID	X = Number of post-test misconceptions	Y = Post-test score(%)
C1	16	19
C2	11	24
C3	14	7

C4	15	11
C5	15	13
C6	10	50
C7	14	21
C8	11	13
C9	13	33
C10	18	24
C11	18	7
C12	10	22
C13	12	19
C14	15	11
C15	16	13
C16	15	10
C17	13	17
C18	11	20
C19	13	19
C20	15	12
C21	14	20
C22	11	23
C23	15	14
C24	16	11

C25	14	14
C26	18	6
C27	14	17
C28	17	10
C29	9	26
C30	13	23

The findings in the Table 6.4.1 produced the statistics in Table 7.4.2

Table 7.4.2 Statistics based on the findings in Table 7.4.1

Statistics

		Post-test Scores for Control group (%)	Post-test Misconceptions for Control group
N	Valid	30	30
	Missing	0	0
Mean		17.6	13.9
Median		17.0	14.0
Mode		11[a]	15
Std. Deviation		8.9	2.5
Variance		78.4	6.1
Skewness		1.8	-0.1
Std. Error of Skewness		0.427	0.427
Range		44	9
Minimum		6	9
Maximum		50	18

a. Multiple modes exist. The smallest value is shown

Other results emanating from those in Table 7.4.1 were as shown in Table 7.4.3.

Table 7.4.3 More findings on post-test scores of Table 7.4.1

Post-test Scores for Control group (%)

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
6	1	3.3	3.3	3.3
7	2	6.7	6.7	10.0
10	2	6.7	6.7	16.7
11	3	10.0	10.0	26.7
12	1	3.3	3.3	30.0
13	3	10.0	10.0	40.0
14	2	6.7	6.7	46.7
17	2	6.7	6.7	53.3
19	3	10.0	10.0	63.3
20	2	6.7	6.7	70.0
21	1	3.3	3.3	73.3
22	1	3.3	3.3	76.7
23	2	6.7	6.7	83.3
24	2	6.7	6.7	90.0
26	1	3.3	3.3	93.3
33	1	3.3	3.3	96.7
50	1	3.3	3.3	100.0
Total	**30**	**100.0**	**100.0**	

The data in Table 7.4.1 also resulted in additional information on post-test misconceptions as shown in Table 7.4.4.

Table 7.4.4 More findings on post-test misconceptions of Table 7.4.1

Post-test Misconceptions for Control group

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	9	1	3.3	3.3	3.3
	10	2	6.7	6.7	10.0
	11	4	13.3	13.3	23.3
	12	1	3.3	3.3	26.7
	13	4	13.3	13.3	40.0
	14	5	16.7	16.7	56.7
	15	6	20.0	20.0	76.7
	16	3	10.0	10.0	86.7
	17	1	3.3	3.3	90.0
	18	3	10.0	10.0	100.0
	Total	**30**	**100.0**	**100.0**	

It can be seen that, after the treatment, the average number of misconceptions for participants in the control group reduced slightly to 13.9 (i.e. by about 0.7%) while the post-test mean score of the same group increased slightly to 17.6% (i.e. by 1%). Therefore, within limits of experimental error, the number of pre and post test misconceptions and scores for the control group remained the same. The graph in Fig. 7.4.3 was used to confirm this finding.

Table 7.5.1 Pre-test results for both groups

Participant ID	Number of pre-test misconceptions	Pre-test score(%)
E1	14	13
E2	15	13
E3	15	16
E4	13	16
E5	17	16
E6	10	19
E7	19	19
E8	8	40
E9	11	19
E10	19	14
E11	13	40
E12	18	9
E13	15	16
E14	16	3
E15	17	16
E16	10	13
E17	15	11
E18	8	20
E19	10	20

E20	16	8
E21	14	14
E22	8	27
E23	15	8
E24	16	5
E25	7	39
E26	9	17
E27	12	15
E28	10	17
E29	11	14
E30	11	16
C1	15	7
C2	17	16
C3	16	7
C4	15	11
C5	15	23
C6	8	44
C7	16	19
C8	12	17
C9	14	26
C10	11	17

C11	13	20
C12	8	35
C13	11	20
C14	16	9
C15	14	13
C16	17	10
C17	13	16
C18	12	15
C19	15	15
C20	12	17
C21	14	15
C22	9	28
C23	18	5
C24	11	13
C25	18	10
C26	20	8
C27	16	10
C28	12	17
C29	20	6
C30	11	26

Using SPSS, various statistics were determined as in Table 7.5.2.

Table 7.5.2 Statistics based on the findings in Table 7.5.1

Statistics

		Pre-test Scores for both groups	Pre-test Misconceptions for both groups
N	Valid	60	60
	Missing	0	0
Mean		16.8	13.5
Median		16.0	14.0
Mode		16	15
Std. Deviation		8.8	3.3
Variance		77.8	11.2
Skewness		1.3	-0.1
Std. Error of Skewness		0.309	0.3
Range		41	13
Minimum		3	7
Maximum		44	20

More information was revealed on pre-test scores for both groups as in Table 7.5.3.

Table 7.5.3 More findings on pre-test scores of Table 7.5.1

Pre-test Scores for both groups

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	1.7	1.7	1.7
	5	2	3.3	3.3	5.0
	6	1	1.7	1.7	6.7
	7	2	3.3	3.3	10.0
	8	3	5.0	5.0	15.0
	9	2	3.3	3.3	18.3
	10	3	5.0	5.0	23.3
	11	2	3.3	3.3	26.7
	13	5	8.3	8.3	35.0
	14	3	5.0	5.0	40.0
	15	4	6.7	6.7	46.7
	16	8	13.3	13.3	60.0
	17	6	10.0	10.0	70.0
	19	4	6.7	6.7	76.7
	20	4	6.7	6.7	83.3
	23	1	1.7	1.7	85.0
	26	2	3.3	3.3	88.3
	27	1	1.7	1.7	90.0
	28	1	1.7	1.7	91.7
	35	1	1.7	1.7	93.3
	39	1	1.7	1.7	95.0

40	2	3.3	3.3	98.3
44	1	1.7	1.7	100.0
Total	60	100.0	100.0	

Frequency results on pre-test misconceptions for both groups were produced as in Table 7.5.4.

Table 6.5.4 More findings on pre-test misconceptions of Table 7.5.1

Pre-test Misconceptions for both groups

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
7	1	1.7	1.7	1.7
8	5	8.3	8.3	10.0
9	2	3.3	3.3	13.3
10	4	6.7	6.7	20.0
11	7	11.7	11.7	31.7
12	5	8.3	8.3	40.0
13	4	6.7	6.7	46.7
14	5	8.3	8.3	55.0
15	9	15.0	15.0	70.0
16	7	11.7	11.7	81.7
17	4	6.7	6.7	88.3
18	3	5.0	5.0	93.3
19	2	3.3	3.3	96.7
20	2	3.3	3.3	100.0
Total	**60**	**100.0**	**100.0**	

After that the pre-test results for both groups were correlated as shown in Fig. 7.5.1.

Table 7.6.1 Post-test results for both groups

Participant ID	Number of Post-test misconceptions	Post-test score(%)
E1	5	74
E2	4	59
E3	3	71
E4	8	49
E5	9	47
E6	4	67
E7	7	63
E8	8	69
E9	7	61
E10	16	47
E11	5	74
E12	10	39
E13	8	26
E14	10	33
E15	11	57
E16	4	70
E17	4	74
E18	3	73

E19	8	51
E20	14	27
E21	11	42
E22	7	56
E23	10	44
E24	11	44
E25	9	43
E26	5	73
E27	10	47
E28	7	62
E29	7	56
E30	10	60
C1	16	19
C2	11	24
C3	14	7
C4	15	11
C5	15	13
C6	10	50
C7	14	21
C8	11	13

C9	13	33
C10	18	24
C11	18	7
C12	10	22
C13	12	19
C14	15	11
C15	16	13
C16	15	10
C17	13	17
C18	11	20
C19	13	19
C20	15	12
C21	14	20
C22	11	23
C23	15	14
C24	16	11
C25	14	14
C26	18	6
C27	14	17
C28	17	10

C29	9	26
C30	13	23

The results in Table 7.6.1 produced the statistics in Table 7.6.2.

Table 7.6.2 Statistics based on the findings in Table 7.6.1

Statistics

		Posttest Scores for both groups	Posttest Misconceptions for both groups
N	Valid	60	60
	Missing	0	0
Mean		36.5	10.9
Median		30.0	11.0
Mode		11[a]	10[a]
Std. Deviation		22.3	4.1
Variance		498.8	17.2
Skewness		0.329	-0.177
Std. Error of Skewness		0.309	0.309
Range		68	15
Minimum		6	3
Maximum		74	18

a. Multiple modes exist. The smallest value is shown

The results in Table 7.6.1 also produced more information about the post-test scores as shown in Table 7.6.3

Table 7.6.3 More findings on post-test scores of Table 7.6.1

Post-test Scores for both groups

Valid	Frequency	Percent	Valid Percent	Cumulative Percent
6	1	1.7	1.7	1.7
7	2	3.3	3.3	5.0
10	2	3.3	3.3	8.3
11	3	5.0	5.0	13.3
12	1	1.7	1.7	15.0
13	3	5.0	5.0	20.0
14	2	3.3	3.3	23.3
17	2	3.3	3.3	26.7
19	3	5.0	5.0	31.7
20	2	3.3	3.3	35.0
21	1	1.7	1.7	36.7
22	1	1.7	1.7	38.3
23	2	3.3	3.3	41.7
24	2	3.3	3.3	45.0
26	2	3.3	3.3	48.3
27	1	1.7	1.7	50.0
33	2	3.3	3.3	53.3
39	1	1.7	1.7	55.0
42	1	1.7	1.7	56.7

43	1	1.7	1.7	58.3
44	2	3.3	3.3	61.7
47	3	5.0	5.0	66.7
49	1	1.7	1.7	68.3
50	1	1.7	1.7	70.0
51	1	1.7	1.7	71.7
56	2	3.3	3.3	75.0
57	1	1.7	1.7	76.7
59	1	1.7	1.7	78.3
60	1	1.7	1.7	80.0
61	1	1.7	1.7	81.7
62	1	1.7	1.7	83.3
63	1	1.7	1.7	85.0
67	1	1.7	1.7	86.7
69	1	1.7	1.7	88.3
70	1	1.7	1.7	90.0
71	1	1.7	1.7	91.7
73	2	3.3	3.3	95.0
74	3	5.0	5.0	100.0
Total	60	100.0	100.0	

In addition, the results in Table 7.6.1 produced several frequency information on post-test misconceptions for both groups as shown in Table 7.6.4.

Table 7.6.4 More findings on post-test misconceptions of Table 7.6.1

Post-test Misconceptions for both groups

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	2	3.3	3.3	3.3
	4	4	6.7	6.7	10.0
	5	3	5.0	5.0	15.0
	7	5	8.3	8.3	23.3
	8	4	6.7	6.7	30.0
	9	3	5.0	5.0	35.0
	10	7	11.7	11.7	46.7
	11	7	11.7	11.7	58.3
	12	1	1.7	1.7	60.0
	13	4	6.7	6.7	66.7
	14	6	10.0	10.0	76.7
	15	6	10.0	10.0	86.7
	16	4	6.7	6.7	93.3
	17	1	1.7	1.7	95.0
	18	3	5.0	5.0	100.0
	Total	**60**	**100.0**	**100.0**	

The results in Table 7.6.1 were correlated and they produced the graph in Fig. 7.6.1.

Table 9.1.1 Pre-test Misconceptions for both groups

Participant ID	Number of pre-test misconceptions
E1	14
E2	15
E3	15
E4	13
E5	17
E6	10
E7	19
E8	8
E9	11
E10	19
E11	13
E12	18
E13	15
E14	16
E15	17
E16	10
E17	15
E18	8
E19	10

E20	16
E21	14
E22	8
E23	15
E24	16
E25	7
E26	9
E27	12
E28	10
E29	11
E30	11
C1	15
C2	17
C3	16
C4	15
C5	15
C6	8
C7	16
C8	12
C9	14
C10	11

C11	13
C12	8
C13	11
C14	16
C15	14
C16	17
C17	13
C18	12
C19	15
C20	12
C21	14
C22	9
C23	18
C24	11
C25	18
C26	20
C27	16
C28	12
C29	20
C30	11

The findings in Table 9.1.1 were used to plot the graph in Fig. 9.1.1. This was done so that the data obtained could be understood better.

Table 9.2.1 Post-test Misconceptions for both groups

Participant ID	Number of Post-test misconceptions
E1	5
E2	4
E3	3
E4	8
E5	9
E6	4
E7	7
E8	8
E9	7
E10	16
E11	5
E12	10
E13	8
E14	10
E15	11
E16	4

E17	4
E18	3
E19	8
E20	14
E21	11
E22	7
E23	10
E24	11
E25	9
E26	5
E27	10
E28	7
E29	7
E30	10
C1	16
C2	11
C3	14
C4	15
C5	15
C6	10

C7	14
C8	11
C9	13
C10	18
C11	18
C12	10
C13	12
C14	15
C15	16
C16	15
C17	13
C18	11
C19	13
C20	15
C21	14
C22	11
C23	15
C24	16
C25	14
C26	18

C27	14
C28	17
C29	9
C30	13

The fingings in Table 9.2.1 were used to plot the graph in Fig. 9.2.1.

The findings in Table 9.3.1 show the pre-test scores for both groups.

Table 9.3.1 Pre-test scores for both groups

Participant ID	Pre-test score(%)
E1	13
E2	13
E3	16
E4	16
E5	16
E6	19
E7	19
E8	40
E9	19
E10	14

E11	40
E12	9
E13	16
E14	3
E15	16
E16	13
E17	11
E18	20
E19	20
E20	8
E21	14
E22	27
E23	8
E24	5
E25	39
E26	17
E27	15
E28	17
E29	14
E30	16

C1	7
C2	16
C3	7
C4	11
C5	23
C6	44
C7	19
C8	17
C9	26
C10	17
C11	20
C12	35
C13	20
C14	9
C15	13
C16	10
C17	16
C18	15
C19	15
C20	17
C21	15
C22	28

C23	5
C24	13
C25	10
C26	8
C27	10
C28	17
C29	6
C30	26

Table 9.4.1 Post-test scores for both groups

Participant ID	**Post-test score(%)**
E1	74
E2	59
E3	71
E4	49
E5	47
E6	67
E7	63
E8	69

E9	61
E10	47
E11	74
E12	39
E13	26
E14	33
E15	57
E16	70
E17	74
E18	73
E19	51
E20	27
E21	42
E22	56
E23	44
E24	44
E25	43
E26	73
E27	47
E28	62

E29	56
E30	60
C1	19
C2	24
C3	7
C4	11
C5	13
C6	50
C7	21
C8	13
C9	33
C10	24
C11	7
C12	22
C13	19
C14	11
C15	13
C16	10
C17	17
C18	20
C19	19
C20	12

C21	20
C22	23
C23	14
C24	11
C25	14
C26	6
C27	17
C28	10
C29	26
C30	23

APPENDIX F

CONSENT FORM

Researcher: Goodwell Kaulu, Doctoral Student, University of Zambia

Research Title: *Physics student teachers' misconceptions and performance in basic electronics at the University of Zambia.*

I **(participant)**..... agree to participate in this study conducted by Mr. Goodwell Kaulu, a Doctoral Student of the University of Zambia, School of Education, Department of Mathematics and Science Education.

I have been informed that the purpose of the study is to investigate the correlation between physics student teachers' misconceptions and their performance in basic electronics in senior secondary physics in the Zambian context.

It is clear to me that my participation in the study is voluntary and I can withdraw at any time should I be uncomfortable with anything.

It is also clear that in this study I will be expected to answer a questionnaire, write a test on basic electronics, participate in peer teaching and finally express my feelings about how the study will go.

I have been assured that I will be fully protected in the study and whatever grades I get shall only be revealed to me and no other person.

If I happen to have any questions about the study, they shall be directed to Mr. Goodwell Kaulu (Cell No: 0979486484 and e-mail: gkaulu@unza.zm) or Dr. Silvester Haatwambo (Cell No: 0977117931).

All the questions I had about the study have been answered to my satisfaction. Therefore, I'm willing to do the following:

i. Answer the questionnaire
ii. Write the test on basic electronics
iii. Participate in peer teaching
iv. Respond to statements on the Likert scale

I'm really interested in participating in this study and the following are my details:

Name:……..……..……

Year of study:…….…….……...…….

Cell:……..…….

Email address:……...

Signature:……..

Date:……..

APPENDIX G

PERMISSION TO CONDUCT RESEARCH IN THE SCHOOL OF EDUCATION, DEPARTMENT OF MSE.