AN EXPLORATION OF THE UTILISATION OF MATHEMATICS SKILLS BY TECHNOLOGY EDUCATION PRE-SERVICE TEACHERS TO ENHANCE CONCEPTUAL UNDERSTANDING OF ELECTRONIC SYSTEMS

BY

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DECLARATION

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I declare that '**An exploration of utilisation of Mathematics skills by Technology Education pre-service teachers to enhance conceptual understanding of Electronic Systems'** is not a duplication of any previous work but my own work. All quotations have been indicated and acknowledged by means of complete referencing.

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Date

I, Dr. D. Brijlall confirm that '**An exploration of utilisation of Mathematics skills by Technology Education pre-service teachers to enhance conceptual understanding of Electronic Systems'** is not a duplication of any previous work but the work of Mr B. M. Thabethe (Student Number 206525561). All quotations have been indicated and acknowledged by means of complete referencing.

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Dr. D. Brijlall

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ABSTRACT

The study focused on an exploration of utilisation of Mathematics skills by Technology Education pre-service teachers to enhance conceptual understanding of Electronic Systems during the design and construction of artefacts. This study attempted to discover Mathematics concepts that pre-service teachers utilised in the completion of their artefacts and it encapsulated design and making of a model of a house and an electronics circuit.

Data were collected through qualitative participant observation, semi-structured interviews and the submission of working artefacts. A sample considered for this study was the whole cohort in the EDTE 210 Electronic Systems course at the University of KwaZulu-Natal. Data were collected through observation of construction of a model house and design of a circuit for Electronic Systems in different phases. In each phase of design, observations and notes were supplemented by semi-structured interview questions as design and construction unfolded. Observation looked for the geometry involved in design of a model house and algebra involved in the design of electronic circuits. Data from interviews with the pre-service teachers indicated mathematical connotations in both the modelling of the house and electronics circuits. It was imperative to know how and why certain measurements, angles and shapes were used for their model houses. Furthermore, it was essential to understand the motives behind particular manipulation of different formulas, conversions and fraction implications by pre-service teachers in their design of effective circuit diagrams.

Pre-service teachers at a university level have arithmetic experience which can be used in Technology and may be extended to mainstream Mathematics. It was observed that design and making of this project exposed concepts of Mathematics that made Electronic Systems manageable and comprehensible. Use of projects was discovered to have a positive impact on enhancing understanding of abstract concepts in Mathematics that are essential for Electronic Systems. It is believed that these skills of integrating different areas of learning through interdisciplinarity are paramount for pre-service teachers, as they will soon assume autonomous professional positions for curriculum design in Technology. This provides a diverse approach to conceptual understanding of Electronic Systems through participative learning. Findings and recommendations for effective teaching of Electronic Systems through mathematical skills/concepts are outlined.

TABLE OF CONTENTS

CHAPTER 3: THEORETICAL FRAMEWORK

CHAPTER 4: METHODOLOGY

CHAPTER 5: DISCUSSION OF DATA: CIRCUITS AND MEASURING INSTRUMENTS

CHAPTER 6: DISCUSSION OF DATA: SIMULATION AND DESIGN OF ARTEFACTS

CHAPTER 7: DISCUSSION OF DATA: MODEL AND CIRCUIT DIAGRAM INTERPTRETATION

CHAPTER 8: FINDINGS AND RECOMMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

PARTICIPANT RESPONSES

CHAPTER 1

INTRODUCTION

1.1 Overview and background to the study

This chapter provides an overview of and the background to this study. A major concern to all stakeholders in education is education transformation and priorities of learning areas/subjects. The approach of this study is projected from the perspective of interdisciplinarity and integration of learning fields. This study attempts to explore a comprehensive application of Mathematics into the design of artifacts in Technology. Ultimately the study seeks to explore the way in which pre-service Technology Teachers relate their Mathematics skills to their conceptualisation of electronic systems in design and construction of artifacts, to enhance their understanding and application in Technology Education.

This study was conducted at the University of KwaZulu-Natal among second-year pre-service electronic systems students. These students were capacitated to teach in the Technology learning area in the General Education and Training (GET) band, which includes electronic systems. This group was multiracial and included both male and female students, and was expected to be capable of teaching electronic systems to learners of school-going age.

This group was tasked to design and construct a burglar alarm system for a model of a house with at least one door and one window in a single room. The alarm should be activated if either the door or the window is opened, and should continue to sound even if the door or the window is closed again. Two different tasks involving the design and construction of artifacts were developed for the purpose of this study. The tasks involved objects that the pre-service students were familiar with, and a single-story house from the previous module on Material and Structures. The students were asked to design the house first on paper, using drawings showing the floor plan and, if possible, some views of the room/house, materials used in a circuit diagram for an alarm system, and then to construct the model of the house.

In the light of the above task and the research we had in mind, we intended to address the research topic “An exploration of utilisation of Mathematics skills by Technology Education pre-service teachers to enhance conceptual understanding of electronic systems”. We asked the following critical questions:

1. What is meant by calculation?
2. What is the significance of calculation in Electrical Technology?
3. Why is it important to manipulate the subject of a formula?
4. How does a substitution of electrical values affect the logic in the calculation?
5. Why is it important to arrive at the correct answer?
6. How can a correct answer in electricity affect the safety of a person?

1.2 Pre-knowledge

This project was undertaken with students having basic prior knowledge of constructing and wiring electrical circuits (simple circuits). Students were taught about resistance, current, voltage, conductors, insulator and semi-conductors, switches and switching and series and parallel circuits during theory lessons. Further, these concepts were reinforced, where students had to draw various electrical circuits and wire them accordingly. They had to test for quantities such as resistance, voltage and current, and observe their behavior in series and parallel circuits.

All activities involved in different phases of the design process of the project (development of the model house and design of a circuit) revealed mathematical principles that were embedded in the proper design of artifacts in the electronic systems. Relevant application of the findings to education transformation is discussed as part of the interviews with participants.

1.3 Researcher’s experience and interests

I was privileged to begin my teaching career in the final stages of the apartheid system. With all my enthusiasm, I taught Mathematics from Standard 6 to Standard 10 in the deep rural areas of Maphumulo in KwaZulu-Natal for two years (1994 - 1995) after I graduated from a college of education. After that period I taught electrical-related subjects and Physical Science in a township school from Grade 10 to Grade 12. This was followed by my teaching Technology in Grades 8 and 9 with the elimination of Physical Science from my duty load.

In the teaching of Technology, I discovered that there was a lot of applied mathematics that was involved, for example: (a) add, subtract, multiply and divide whole numbers and decimals, (b) manipulate positive and negative numbers, (c) manipulate powers of ten, (d) understand symbols for subunits of electrical quantities and be able to convert from one subunit to another (e.g. k = kilo = 1000, μ = micro = 10^{-6}), (e) solve equations given a formula such as Ohm's law, and (f) understand what direct and inverse relationships are.

These principles are essential for the entire conceptualisation of technological concepts. A further observation by the researcher during his coordination of a Technology workshop for senior phase was that an electrical system was not fully emphasised as being based on beliefs and fears of practitioners in Grades 8 and 9 Technology classrooms. However, Technology Education is one of those highly prioritised areas of learning that the Government regards as an essential element for economic growth and development through capable learners as a human resource of the country. Hence Technology has been made a compulsory subject together with Science and Mathematics at school.

A stereotypical attitude even among the community is that Technology is good for candidates of lower academic ability. It is regarded as a subject that trains people to acquire abilities for elementary living without intellectual engagement. This ideology is still dominant among a number of people in institutions of higher learning. In choosing their specialisations, Technology is mostly taken as an elective module, which confirms it as a vocational subject, and it has evidently been identified that students' performance in learning areas such as electricity is poor (Gayadeen & Brijlall, 2011). Design in Technology is a predetermined outcome-based activity that requires mathematical manipulation as a basic requirement for education transformation through curriculum development. While I was teaching Electrical Technology in the further education and training (FET) band, I encountered a challenge in the hypothetical approach to Technology in the community and educational expectations about Technology. A stereotypical attitude among the community is that Technology is good for candidates of lower academic ability. Parents insisted that low achievers in the GET band be enrolled in the Technology stream in the FET band for skills acquisition for living. It is regarded as a subject that trains people to acquire abilities for elementary living without intellectual engagement. I interrogated a Technology module in an institution of higher learning. Design in Technology is a predetermined outcome-based activity that requires mathematical manipulation as essential in electrical application. I then developed an interest in exploring utilisation of Mathematics skills by Technology Education pre-service students to enhance conceptual understanding of electronic systems, echoing a requirement of educational transformation.

1.4 Educational transformation

Educational transformation is an endeavour to change completely the nature of education that portrayed the legacy of apartheid practices, so that it can be improved for a purposeful projection. This study was conducted within an outcomes-based education (OBE) paradigm with the intention of exploring interdisciplinary as it is emphasised in the (DoE, 2001) and National Curriculum Statement (NCS) of 2003 (DoE, 2003b).

According to Lattuca (2003), interdisciplinarity is a field of study that crosses traditional boundaries between academic disciplines or schools of thought as new needs and professions emerge. Interdisciplinarity serves as integration across the learning fields. A new approach in education encourages integration of common sections in different learning areas, which is encapsulated in the philosophy of OBE. Technology and Mathematics are no exceptions to this approach. In these two learning areas (Mathematics and Technology) an OBE philosophy and practice is used as an underlying educational philosophy which emphasises effective delivery for local and national existence (DoE, 2003c). The underpinning principles for these curriculums are solely based on social justice, health, environment and inclusivity, as entrenched in the Constitution of the Republic of South Africa (Act 108 of 1996).

A common fundamental of curriculums in these learning areas places the child at the centre of education as a potential citizen, assisting a child to achieve to his/her utmost abilities. The foreground is in learner-centeredness and an activity-based approach in education. Both critical and developmental outcomes for learners envisaged in these policies highlight cooperative teamwork, critical thinking, problem solving and environmental sensitivity in exploring strategies for effective learning in a global society across a range of social contexts (Dryer, 1999).

Advancement of technology is taking the world by storm, particularly in the younger generation, making electricity of essence in our modern society, as a commodity that regulates businesses, health care services, communication, traffic control and security.

Electricity needs to be respected by all, since it has the potential to kill. Scholars categorise electricity as high-voltage or low-voltage electricity. High-voltage electricity is electrical power generated in big plants and transmitted over long distances for high-voltage technology as well for use in the home. On the other hand low-voltage electricity refers to a reduced power that cannot be extremely harmful to the human body, in the range of 120 volts to 220 volts/50Hz.

Most of those who are killed, as well as a few who are injured, are victims of electrical shock in the process of current flow. Unfortunately we cannot predict the existence of electrical power in either a conductor or an appliance; it can only be quantified through measurement or calculations. These calculations are dependent on Technology and Mathematics for their prediction, design and safety.

1.5 Definition of key concepts

1.5.1 Technology

Technology is a purposeful application of scientific knowledge that meets human needs and wants without compromising environment (Wright, 1992). According to Brijlall, Maharaj and Jojo (2006), Technology is compulsory and works alongside Mathematics to promote purposive activity in design and presentation of projects, in fulfilling purposeful requirements for a particular project. Technology emphasises design, construction and evaluation of a project, affording learners opportunities for extra informal use of Mathematics related to their real-world experience as creative and intelligent candidates. Through a well-developed curriculum Technology education programmes are able to reinforce academic content, enhance higher-order thinking skills, and promote active involvement with Technology (Wright, 1992).

This development provides an intellectual process as a primary goal of education for a productive citizen as a meaningful human resource of a country. According to the RNCS (DoE, 2003b) document for Technology in the GET band, learners are pursued as potential candidates who need to contribute meaningfully in the economic development of South Africa by applying knowledge and skills in a purposeful manner.

1.5.2 Mathematics

According to the RNCS, the Department of Education (DoE, 2002b) defines Mathematics as a human activity that involves observing, representing and investigating patterns and quantitative relationships in physical and social phenomena and between mathematical objects themselves. Through this process, new mathematical ideas and insights are developed. Mathematics uses its own specialised language that involves symbols and notations for describing numerical, geometric and graphical relationships. Mathematical ideas and concepts build on one another to create a coherent structure. Mathematics is a product of investigation by different cultures – a purposeful activity in the context of social, political and economic goals and constraints (DoE, 2002b) (DoE Annual Report). Mathematics proficiency is of paramount importance to enable students to realise their full potential pertaining to issues of patterns and relationships in a language that describes mathematical terms and symbols. Students' beliefs about Mathematics are coincidentally influenced by existing educational practices, teachers' own opinions about Mathematics and parents' own perspectives thereof (De Corte, 2000).

1.5.3 Design

Design is regarded as the core problem-solving process of technical development. The design process is defined as a systematic problem-solving strategy, with criteria and constraints used to develop many possible solutions to solve a problem and satisfy human needs and wants, to winnow down the possible solution into one final result (Williams, 2000). In Technology design adopts a principle of intuition science that serves as an alternative to step-by-step logic. It is, however, important to acknowledge the importance of imparting knowledge and skills to learners to empower their young minds with intuition and understanding, because it broadens the range of their experience. This makes them better able to envisage other needs and incorporate general social and environmental considerations into their technical achievements (Williams, 2000).

According to McCade (2006), design encompasses engineering design that uses Mathematics and Science to serve the foundational purpose of development and industrial design, where creativity and aesthetics are the foundation of development.

1.5.4 Safety

In relation to the above concepts, safety means a provision of sound knowledge of algorithmic procedure and operations of electrical-related technologies. Safety becomes a domain in the syntheses of Technology and Mathematics as relevant features of design (Cowan, 1991). Purposefulness of Technology requires origin and understanding of Mathematics that suggests an optimisation of mathematics application in the wide range of electronics systems, including design of projects.

1.6 Outline of chapters to follow

In chapter two related literature is reviewed in the light of curriculum transformation in a democratic education system. Attention is paid to curriculum design that 'de-schools' academic content into a purposeful meeting of human needs and wants. Relevant concepts of electrical technology are addressed, e.g. energy in technology (generator and cells). Human body function is addressed in light of electrical generation and operation. The dangers of precocious operation of electricity in general are highlighted to avoid electrocution for safety purposes.

Chapter three provides a theoretical framework in line with the education policy as an endeavour to integrate learning areas and areas of knowledge. Constructivism and number theory are used to guide this study. In this chapter intuitive involvement is underlined, in accordance with Mathematical experience gained with positive real numbers and personal experience gained via social relationships.

Chapter four provides a detailed explanation of the method of data collection in the qualitative paradigm. The research methodology is demonstrated in this chapter through triangulating participant observation, submission of a working project, and interviews with participants.

Chapter five will deal with data analysis. It provides thick, qualitative analyses of findings from participant observation in the theoretical part of the circuit calculations. Chapter six analyses the data obtained when participants were interrogating simulations and project design. No quantitative data are provided since the behaviour of the participants could not be quantified. Data are analysed throughout the module and conclusively with interviews after all submissions.

Chapter six will deal with the analyses of data in the simulation and design of artifacts while chapter seven will discuss the interpretation of data collected during a design of a model and circuit diagram.

Chapter 8 will serve as a concluding chapter in demonstrating findings to the research questions and provide recommendations to technology education lecturers.

CHAPTER 2

REVIEW OF RELEVANT LITERATURE AND CONCEPTS

2.1 Introduction

This chapter examines issues influencing curriculum transformation in approaching electrical factors. It looks closely at the importance of critical thinking and effective design in the classroom as a centre for training young minds as potential citizens. It also underlines crucial areas of knowledge pertaining to electrical energies required for design in electronics systems.

2.2 Curriculum transformation in a democratic education system

Before the adoption of the Government of National Unity in 1994, the South African Education Department was split into 18 racially segregated education departments. Separate education departments governed by specific legislation were fragmented along racial lines, reinforcing divisions in the education system. Each education department had their own policies regarding communal needs. The education system in South Africa was clouded by segregation and marginalisation of some population groups from disadvantaged communities that could have benefitted through education before the first democratic election in 1994. Black population groups were deprived of meaningful education that included mathematics and scientific knowledge essential for economic development and sustainability of the country. Evidently less than 20% of black learners matriculated with Mathematics in the 1990s, while 61% of white learners matriculated with Mathematics. About 44% of white learners also had Physical Science that is regarded as a subject crucial for producing effective candidates for economic development and sustainability (Moleke, 2003).

The need for education transformation became inevitable after the Soweto uprising in 1976, which was an indicator of dissatisfaction in the black population. The Human Sciences Research Council (HSRC) was tasked to investigate this, and recommended a paradigm shift from a formal-based education grounded in the traditional academic art-science curriculum to an appropriate skills-based curriculum tailor-made for some racial groups as vocational education and training (Stevens, 2004). *Vocational education and training* is education that prepares learners for jobs or careers at various levels from a trade/craft or a position of employment in engineering, etc. (Williams, 1985). Craft vocations are usually based on manual or practical activities, traditionally termed handwork. Non-academic-related activities were encouraged for a specific trade, but learners were trained single-mindedly for a specific task, creating marketable products as mass products that yielded to a demand-supply process for active consumers.

This is sometimes referred to as *technical education,* since the trainee directly develops expertise in a particular group of techniques. According to Stevenson (2005), vocational education was tailor-made to teach procedural knowledge, which was contrasted with declarative knowledge as projected in education in a usually broader scientific field, foregrounded on theory and abstract conceptual knowledge and characteristic of tertiary education.

Vocational education was offered at secondary, post-secondary (high school) and the further education levels, where it was closely linked with the apprenticeship system. Vocational education was also related to the age-old apprenticeship system of learning, where apprenticeships were designed for many levels of work from manual trades to high knowledge work.

Curriculum transformation was paramount to depict identities founded on democratic principles by critically interrogating the elementary relationship between knowledge, academic practices, social consequences and community responsibilities. Technology and Mathematics is vital for individual and national development thus moving away from factual knowledge but closer to high-order thinking. Knowledge and skills expected in Technology demanded recurriculation in the technical-related subjects. Hence curriculum design was essential for the way forward in Technology.

2.3 Curriculum design

Curriculum design is a purposeful decision aimed at arranging the content of subjects that need to be included in the case of study and application that needs to be taught in school or in the institution of higher learning for the enhancement of a better life for all. Zuga (1989) considers curriculum design as a way in which subject matter is conceptualised and the arrangement of major concepts for the sake of focusing curriculum development based on knowledge and skills.

During the elementary stages of vocational education and industrial arts, Technology education provided educational goals that were similar in nature. Furthermore, vocational education provided a continual influence on technical education and identification with a historical relationship in different spheres of life for technology and designs. It was realised that prescriptive curriculum theory on both vocational education and technology education relied solely upon technical curriculum design. Persuasively, Zuga (1989) identified five major categories of curriculum projection as essential for technology: (a) academic, (b) technical, (c) intellectual process, (d) social and (e) personal.

2.3.1 Academic design for technology

This is an arrangement of subject matter into groups that form logical categories of knowledge and append value to those categories, thus advocating the learner envisaged in the RNCS document for Technology. The central focus of an academic design is on the body of knowledge that is grouped into discipline, subject matter, and in broader fields. The purpose of academic design is to provide direction to the curriculum through disciplinary organisation of the content of the subject matter. It provides logic in knowledge and assists in identifying subject matter appropriate for the transmission of cultural heritage through literature, history, science and other fundamental disciplines (Zuga, 1989).

2.3.2 Technical design for technology

This is the analysis of behaviour and performance that is aimed at preparing people for functioning in a specific job. According to Zuga (1989), in technical design efficiency is desired. This requires that the curriculum provide the most efficient means of delivering the performance objective. The objectives become the essential organising element of the curriculum. One focus of technical design is on analyses of performance and process sequencing. The main purpose is to provide detailed tasks for a job and to organise curriculum and instruction with a specific performance objective in mind, and to employ technical teaching devices that provide programmed lessons (Zuga, 1989). Furthermore, technical design is to provide comprehensive instruction that will always enhance an appropriate performance.

2.3.3 Intellectual process design

Intellectual process design is the development of the cognitive process required in the design. It serves as the exercise of mind that provides a person with abstract thinking far above the situation in existence. The focus is on critical thinking, problem solving, human process and traits for creativity and self-confidence (Zuga, 1989). The purpose of this category of design is to increase efficiency in learning and to transfer problem-solving abilities to all areas of curriculum and one's entire life. It takes into account the importance of the context within which the content of the learning situation should be used.

2.3.4 Social design for technology

Social design is an educational approach that deals with social reconstruction and social adaptation. This design is directed towards imparting knowledge to people through education and to allow learners to work on community projects for the sake of impacting on their environment. The main focus of social design is on the application of knowledge to a real-life situation which demands that learners be put at the centre of education for appropriate provision of solutions in the community (Zuga, 1989). Purposes of this design are multifaceted: social reconstruction aimed at changing the future of the society. This is done through the educational activities of the current generation, to engage learners in societal projects with the intention of influencing their environment. Also, this is expected to ensure that education is geared to provide such an opportunity to learners and to prepare learners to be able to adapt to an ever-changing society. This is with an understanding that they need to realise that they are raw materials of a society and need to conform to the existing needs of the societal values (Zuga, 1989).

2.3.5 Personal design for technology

Personal design is a learner-centred design that acknowledges personal involvement of a child in education. Zuga insisted that this type of design encourages educational planning that promotes contributions of learners in expressing their interests and investigating those interests, while the teacher serves the purpose of being a diagnostician and facilitator of the process. The ultimate focus is on the personal experience and a willingness to de-school society, because of the endeavour to redress rigidity of the school to fit into personal design (Zuga, 1989). The purpose of personal design is to allow learners to take a lead in controlling and choosing the curriculum instead of allowing specialists to facilitate development, and to allow them to incorporate the information they have chosen.

Detection of these categories (academic, technical, intellectual process, social and personal) identifies with Technology and its effectiveness, not only emanating from the basis of technical and vocational education but projecting to the interdisciplinarity of Technology with other subjects, like Mathematics and Science, for design purposes. In redesigning the system of education, institutions were categorised into FET colleges and universities of technology, and universities were merged into clusters. The intention was to address confusion about the different needs offered by the curriculum in Technology as a subject, the institution where Technology will be offered, and who will offer various subjects within the interdisciplinarity of Technology.

The development of Technology placed emphasis on the importance of creativity, flexibility in thinking, integration of concepts and procedural knowledge, and the practical application of such knowledge in real-life situations. Hence the NCS advocated the integration of Technology with Mathematics including the Arts, Design, and Engineering fields that had few professional teachers to facilitate. According to Stevens (2004), recirculation inspires the development coherent to tertiary interdisciplinarity courses that assists in alleviating scarcity of qualified teachers relevant to Technology.

2.4 Energy in Technology

Technology is concerned with energy-changing in favour of a human need and want. As stated earlier, technology puts scientific findings into practice. Design of an artifact in an electronic system deals solely with chemical energy changing into electrical energy and produced into sound energy. Technology lays emphasis on design, construction and evaluation of a project, affording learners information on mathematical calculation essential in their real-world experience as creative and intelligent candidates. Perhaps a power source is harnessed in an equivalent way, so as to serve a purpose and not damage electrical components.

2.5 Power generation

Electrical power is an autonomous section, serving as an aspect of Technology. It requires interdisciplinarity with other learning areas such as Mathematics and Science. Electrical power is a necessary resource that regulates daily living. Daily activities in industries, households and business sectors function under the influence of electrical power supply. Energy must be available to drive charges around a circuit. Any type of energy can be used e.g. a battery of cells, a generator and/or human body and electrolytes. A battery uses chemical energy while a generator uses mechanical energy to induce electrical energy as a source of supply (Hughes, 1960). The source of supply produces voltage to motivate electrons around the circuit. There are two major sources of supply that I wish to depict in this study: (a) cells and (b) generators.

2.5.1 Cells

A battery of cells is an alternative source of electricity used in domestic electricity supply when a generated electricity supply is inconvenient. However, the type of cell and its voltage is determined by the material used to make the electrolyte and the electrodes; hence we have a primary and a secondary cell (Hewitt, 1989). According to Hughes (1960) a primary cell cannot be recharged. The chemical reaction in a primary cell is irreversible, making it better for low current, as the voltage decreases in the process of current flow increase. A secondary cell can be recharged by passing the current through it in the opposite direction. Comparatively speaking, secondary cells have a lower energy density than the primary cell, making a secondary cell able to deliver a higher current with longer durability (Boylestad & Nashelsky, 1987).

2.5.2 Generators and induction of power

According to Hughes (1960), a generator is used to induce an electromotive force as an alternating current supply. Two permanent magnets are placed between loops that are fixed into an external circuit. When a loop is rotated at a constant speed, cutting through the magnetic field between the poles of a permanent magnet, an alternating voltage is generated between the ends of the loop. The voltage depends on the velocity at which the loops cuts through the magnetic field, the strength of the magnetic field and the length of the wire loop (Gupta, 2008). One revolution generates one side of an alternating voltage. An alternating voltage produces an alternating current. Logically, the flow of electrons starts at zero in proportion to an initial move of a loop, increases to a maximum then decreases to zero. The flow is then reversed, increases to a maximum in the opposite direction, and again returns to zero. This cycle is repeated until the flow is stopped.

The time between two identical values on a cycle is called a period, denoted by T, while the number of cycles per second is called frequency, denoted by f but measured in hertz (Hz) (Edward, 1960; Hewitt, 1989). For mathematical logic all current and voltage measurements are made from a baseline known as zero axes, and time measurements are usually made from the point when the curve crosses the baseline. Electrical power is paramount in circuit designs, and is the rate at which energy is produced and transformed, denoted by P and measured in watts (Fewson, 1998; Hewitt, 1989). As indicated in Hettema (1984) and Cowan (1991), when electrons flow through a conductor some collide with fixed atoms, thus generating heat. The greater the collision in a conductor, the hotter it becomes. This process is evident in electric heaters, grills and hot plates when they glow red hot, and lamps filaments when they glow yellow to white hot.

2.6 The human body and its electrolytes

The human body is complex, abstract and has detailed chemical reactions for daily functions. In its vast operation I wish to focus on the entities that make the human body a good electrode. The human body contains blood, water, salt and acids that are chemically related and regulated by the heart under the function of the brain (Waugh & Grant, 1963).

2.6.1 Liquids in the body

Blood plasma makes up an average of 55% of the volume of the body, while the remaining 45% is the corpuscles. Ninety per cent is water and 10% dissolved substances, e.g. digested foods, salts, gases, excretory waste, plasma protein, hormones, enzymes and antibodies (Smeltzer & Bare, 2003).

2.6.2 Acids in the body

According to Smeltzer and Bare (2003) there are not many acids in the body as most fluids maintain a pH of seven and greater. However, acid is present in the cells where it is found in genetic material, namely deoxyribonucleic acid, commonly known as DNA, and ribonucleic acid (RNA). These acids are found in the chromosomes of cells. Other acids found in cells are known as amino acids and are responsible for the manufacturing of proteins, which are essential for growth and the repair of damaged tissue such as skin and muscles torn during exercise. Acid is also found in the stomach, where it is responsible for the digestion of food, this is a mixture of many acids including hydrochloric acid (HCl) and carbonic acid (H_2CO_3). Finally, lactic acid is found in humans due to the consumption of sour dairy products, fermented fruits and vegetables and sausages (Waugh & Grant, 1963; Smeltzer & Bare, 2003).

2.6.3 Salts in the body

There are not many organic salts in the body. However, the sodium component of salt is vital for controlling the amount of water in the body, maintaining the normal pH of blood, transmitting nerve signals and helping muscular contraction. Salt is present in all foods in varying degrees, and almost all processed foods contain added salt, mainly sodium chloride (NaCl).

2.7 Conductors

From the atomic structure, the attractive energy of an electron (in their permissive orbits) to a nucleus will be differentiated by the position of an orbit of an atom. The further the orbit from the nucleus the less the stability of an electron in that orbit. As a result the weaker force of attraction to a nucleus arises. An orbit with a deficiency in electrons is known to be a valance orbit, and conductivity of an atom depends on this deficiency of that atom.

Material	**Chemical formula**	**Micro-Ohm Metre (µ.Ω.m)**
Silver	Ag	$1{,}62\times10^{-8}$
Copper	Cu	$1{,}72\times10^{-8}$
Gold	Au	$2{,}45\times10^{-8}$
Aluminium	Al	$2{,}83\times10^{-8}$
Tungsten	W	$3{,}50\times10^{-8}$
Nickel	Ni	$7{,}80\times10^{-8}$

Table 1: The conductivity of common materials

Conductivity of an atom depends on the number of electrons in the valence orbit, which is essential to determine whether a material is a conductor or an insulator. The conductivity of various materials is shown in Table 1. If an atom has less than four (4) valence electrons, it is considered a conductor. An atom with four valence electrons is classified as a semi-conductor, and an atom with eight valence electrons is purely an insulator.

2.8 Semi-conductors

Semi-conductors are manufactured for specific purposes, e.g. rectification, amplification, acting as a switch, etc. A semi-conductor material has four valence electrons in a valance orbit. These materials are typically silicon (Si), germanium (Ge), cadmium (Cd) sulphide (SO_2), or arsenide (AsO_2). Their conductivity lies between the extremes of conduction and insulation (Rubin, Newman, Chan, Fu & Ross, 2009). Table 2 shows the location of some of these materials.

Material	Group	Valence
Silicon (Si),	4	4
Germanium (Ge),	4	4
Cadmium (Cd)	Transition metal	4
Sulphide (SO_2)	Compound	4
Arsenide (AsO_2)	Compound	4

Table 2: Composition of proper semi-conductors

In a valence orbit that accommodates eight electrons, electrons combine in the form of a covalent bond, leaving no free electron in that orbit and thus making the process intrinsic. The process of adding an impurity atom in a silicon atom is termed 'doping' and is referred to as extrinsic (Hewitt, 1989). When components are manufactured for electronic purposes, they are categorised into N-type and P-type materials. When an N-type material is formulated, an impurity atom with five valence electrons (pentavalent) (e.g. phosphorous (P), arsenic (As), or antimony (Sb)) is doped into a silicon atom which contains four valence electrons (Hewitt, 1989; Rubin et al., 2009). Table 3 provides an analysis of pentavalent materials.

Material	Group	Valence
Phosphorous (P),	5	5
Arsenic (As),	5	5
Antimony (Sb)	5	5

Table 3: Location of pentavalent on the periodic table

The four electrons from the impurity atoms will form a covalent bond with four valence electrons, leaving the fifth electron to break away from the stable state of the four silicon electrons, and the four electrons from the impurity atom take part in the conduction. Opposition will be less because of this free electron since, as mentioned earlier (Hewitt, 1989; Look, Litton, Jones, Eason & Cantwell, 2002), a conductor material has less than four valence electrons in the valence orbit. The formulation of the P-type material is by adding an impurity atom with three valence electrons in the valence orbit (e.g. boron (B), gallium (Ga), or indium (In)) to a silicon atom to form a tetra valence bond. Table 4 indicates the group and number of valence electrons of the impurity atom.

Material	Group	Valence
Boron (B)	3	3
Gallium (Ga)	3	3
Indium (In)	3	3

Table 4: Impurity atoms

Three electrons from the impurity and three electrons from the silicon atom assume a stable state, leaving an electron from silicon unbalanced with a majority carries being, the absence of the electron (hole) from the impurity atom.

2.9 The significance of safety

The importance of safety is to provide a comprehensive understanding and the application of all basic principles in electrical and electronic systems, that justify effectiveness and efficiency in interaction at all levels (from low current rating to high current rating). According to Lunt (1999) electricity is silent and dangerous but an effective tool for improving human lives in a man-made environment. If a person accidentally comes into contact with a current flow, he/she becomes a victim of an electrical shock. This process will affect a muscle of the heart leading to the interruption of the blood circulation, resulting in brain damage that may require quick attention before mortality occurs.

2.10 Possibility of electrocution

The human body contains many entities that are essential building blocks responsible for effective body functioning. However, all of the functions are chemically related in order to perform perfectly on a daily basis. Hence Kenneth, Ray and Jones (2003) regard the human body as an electrical system, based on the chemical functioning of the blood formulation and circulation mechanism, removal of waste material from the body and tissue repair after certain activities. Keller (2010) defines electricity as an imbalance of movement in electrons and protons of an atom. Naturally, in a human body an electrical current is chemically generated in the brain and transmitted to a specific muscle as an electrical current through a system of conduction in the form of a movement. Thus the movement of the lungs will provide a messaging effect to the heart, encouraging correct pulsation in the entire body. In the case of direct contact of a human body with electricity, direct or indirect danger is likely to take place. Lunt (1999) identifies a direct danger as associated with a spark or electrostatic discharge, while indirect danger is associated with burns and cardiac effects. This section concentrates on the direct danger that results in cardiac effects evident in the electrocution of a person.

A human body is a complex, complicated and natural machine that operates as a complete, perfect system fully influenced by internal chemical reaction. If a human body comes into direct contact with a source of electrical power due to a current leakage, the amount of current that flows is proportional to the voltage and inversely proportional to the resistance of that body, based on the nature of the dryness of the outer skin. A difference between the resistance of the outer skin and the inner body with its all electrolytes will provide a limitation to the current flow in relation to the dry cells at an average current of less than 20 mA (Lunt, 1999). In serious electrocution incidents, electrons flow abnormally through the body, depolarising movement and thus imitating the electrical rhythm in the heart and brain (Cadick, Capelli-Schellpfeffer, & Neitzel, 2000). This process takes place when the current exceeds 20 mA. According to Adams (1994), this condition leads to deoxygenation of the blood and unconsciousness. If electricity leaks from the external source of energy to a human body, it will develop continuity with body persuading the heart pump that is responsible for the circulation of the blood to change from an average of 1,2 times per second to 50 times per second. The pulse may be irregular, weak or non-existent. Movement of the lungs will provide a messaging effect to the heart, encouraging it to fail. The chemical formation of a human body tends to make the blood a very good conductor of electricity. Serious electrocution damages both the heart and the brain if the current rating is above 50 mA. This process is dangerous, especially in the case of an alternating current (AC) supply, resulting in mortality of the person being electrocuted (Lunt, 1999). Table 5 illustrates a current rating, minimum time lapsed, and the effects on the human body.

Current rating	**Time elapsed**	**Effects on human body**
1 mA	1 second	Threshold of perception
5 mA	1 second	Acceptance; harmless current intensity
10 – 20 mA	1 second	A victim can survive muscular contraction without a problem

50 mA	1 second	Pain and a strong muscular contraction resulting in exhaustion and possible fainting, but heart and respiratory functions continue
100 – 300 mA	1 second	Ventricular fibrillation can start, respiratory function continues
6 A	1 second	Temporary cardiac and respiratory disturbance
More than 20 A	1 second	Severe physical dismemberment

Table 5: Effects of current rating on the human body

Most electrical incidents can be prevented by training, awareness, rules and instructions when a person is doing a job, because these incidents are perpetually the result of human error. When preparing to do any electrical job, personal safety and the safety of others are of paramount importance, with avoidance of accidental contact with live circuits (Fewson, 1998). In the case of electrical operation, proper harnessing of a current is pivotal to ensure that a current leaves a source and returns to the source without electrical shocks (Cowan, 1991). However, negligence means that often people compromise safety when they work with tattered cords, cracked insulation, joined flexible cords, exposed live wires, missing covers, loose connections, temporary connections, and damaged switches.

Electrical specifications on electronics components are important to describe the large numbers of identities and behaviours and the application of a particular component in the designed project. Specifications set an efficient standard of quality that a designer requires in operation in relation to value for money.

It is important to learn graphic symbols when interrogating project design to evoke confidence in reading drawings of projects, and drawings should be mastered at least from structural drawings from the print to the basic structural systems design (Cowan, 1991). The end product of the design process in sketching provides a calculated idea of cost, operation and maintenance of the project in the form of a plan before it is made, and making it fulfils the actual design of the project with proper specifications.

2.11 Mathematics and Electronics

2.11.1 The nature of Mathematics

Mathematics is known as evidence of conjectures and proofs that play an integral role in design, trading, communication and sustainable development (Moodley, Njisone, & Presmeg, 1992). Mathematics develops the ability of precise record- keeping and capacity to measure even complex distances through its integral role. According to van Sertima (1999), this integral role was evident in astronomical science, navigation, architecture, engineering, agricultural science and trading in Africa long before colonisation, making an application of numbers the basis of development. In describing the essence of Mathematics, the South African educational policy says:

> Mathematics enables creative and logic reasoning about problems in the physical and social world and in the context of Mathematics itself. It is a distinctly human activity practiced by all cultures. Knowledge in the mathematical science is contracted through the establishment of descriptive numerical and symbolic relationships. Mathematics is based on observing patterns, with rigorous logic thinking and this leads to theories of abstract relations. Mathematical problem solving enables us to understand the world and make use of that understanding in our daily lives. Mathematics is contested over time through both language and symbols, by social interaction and is thus open to change. (DoE, 2003b, p. 9).

Moodley et al. (1992) and Brijlall et al. (2006) highlight the relevance of Mathematics, insisting that the academic content of this subject becomes valuable to a learner if it provides a valuable context for thinking about and using a particular aspect of Mathematics outside the school environment or in the world of work. Hence, Ernest (1998) indicated that mathematical education at school ought to make students aware of themselves in relation to other people. Mathematics should make students perceive themselves as citizens of a country with certain obligations. These obligations carry with them certain responsibilities and require an attitude of understanding and patriotism. For that reason, Turner, Gatienez and Sutton (2011) suggest that linking mathematical ideas and procedures in a context that students' value motivates and develops their critical consciousness, thus linking Mathematics ideas to the depth of understanding and range of contexts in which they apply the Mathematics lens.

2.11.2 The nature of Technology

As indicated in Hewitt (1989), Technology concerns itself with using tools, techniques and procedures in putting scientific findings into practice in relation to human measures and factors. Its main purpose is to provide a service to people in general by advancing their lives without harming the environment. Electronics is no exception in the use of tools, techniques and procedures to put scientific findings into practice in relation to human measures and factors. Electronics is rooted on electrical principle based on parallel, and series connections and the combination of both.

Connecting electronics components will always challenge the understanding of series and parallel combinations of loads which emanates from the development and interpretation of circuit diagrams. However, the following factors inform design of any circuit construction: a) the voltage applied in a series circuit divides among electrical devices, allowing the sum of the voltage drop across the resistor of each individual device to be equal to the voltage supply, b) electrical current has a single pathway to go through, which means a common current flow through each device in succession, c) in a parallel-connected circuit the voltage is the same at all the branches, thus providing the same voltage across each device, d) the total current divides among the parallel branches of the circuit, and the overall resistance in the circuit is less than a single resistance of the same circuit and e) the total current in the circuit divides and the voltage remains the same in all branches.

2.12 Design

We adopted the following notion of change: design is regarded as the core problem-solving process of technical development. The design process is defined as a systematic problem-solving strategy with criteria and constraints used to develop many possible solutions to solve a problem and satisfy human needs and wants. It examines the possible solutions before coming to one final choice (Williams, 2000). In Technology, design adopts a principle of intuition science that serves as an alternative to step-by-step logic. It is, however, important to acknowledge the importance of imparting knowledge and skills to learners to empower their young minds with intuition and understanding; this broadens the range of their experience and makes them able to better envisage other needs and incorporate general social and environmental considerations into their technical achievements.

According to McCade (2006), design encompasses engineering design that uses mathematics and science to serve the foundational purpose of development and industrial design, where creativity and aesthetics are the foundation of development and forms: (a) in choosing material, (b) the type of power required, and (c) quantities.

2.13 Knowledge required for design in Electronic Systems

Design is a purposeful problem solving process that requires both procedural and conceptual knowledge for the effective implementation of scientific findings in the Electronic Systems. Such knowledge eradicates misconceptions about numerical involvement that quantifies energies in electronics and contracts new concepts commensurate with daily experiences (McDermott, 1992).

2.14 Participants' mathematical perspective on daily living

Some participants had a negative attitude, believing that Mathematics is difficult and dull (Geldenhuys, 2000). Mathematics is abstract, tricky and may not be applicable to other areas of knowledge. Because of the use of symbols and numbers in Mathematics, it decontextualises the subject and makes it too abstract for human use in daily activities. A failure to understand the language of Mathematics and its symbols, the fragmentation of mathematical topics into disconnected subtopics, the failure to construct mathematical concepts and discover mathematical relations for personal use suggest that Mathematics is framing academic context as valuable knowledge and provide misconceptions that promote resistance to teaching, as highlighted by Moodley et al. (1992).

2.15 Conclusion

This chapter demonstrated a literature orientation of Technology and Mathematics. It underlined a close relationship between electrical and electronics fundamentals, e.g. current, voltage, conduction and insulation. We provided a quantifying approach to the operation of electronics that employs mathematical concepts and understanding. Chapter three provides the theoretical framework adopted for this research.

CHAPTER 3

THEORETICAL FRAMEWORK

3.1 Introduction

This chapter provides the theoretical framework that guided this study. The main focus was based on the way in which policies were developed in addressing a need for transformation in a democratic society. It emphasised the essence of creativity by highlighting theories that advocated creative thinking and participation in learning. It is in this light that I adopted constructivism and a number theory as a theoretical framework.

3.2 Education policy

In all phases of governance (colony and apartheid) education was used to project the economy of the country based on political insinuation (Dryer, 1999). Likewise, democratic governance education is highly prioritised, with Technology, Science and Mathematics used as instruments for economic development and sustainability. Legitimate adoption of democracy in South Africa in 1994 demanded an enormous change in the education system as an endeavour to redress the legacy of apartheid, and underlined the need for South Africa to adhere to a common global context and the demands of international organisations as well as translational labour (Young, 2005). According to Dyer (1999) education policies that were applied before 1994 perpetuated further division in favour of mono-cultural activity in the name of apartheid. Hence Apple (1990) highlighted that many people considered the curriculum at that time to be irrelevant and mono-cultural since it served to strengthen the citizenship of one race over others, with Afrikaans as the medium of instruction in most schools. The latter practice brought about the Soweto uprising of 1976 in the fight against apartheid education.

Among many policies that were adopted after 1994 (South African Schools Act (SASA) of 1996, South African Qualification Authority (SAQA) Act 1995, National Qualification Framework (NQF) and Curriculum 2005 (C2005)) for providing the framework for education transformation, this study will pay attention to Curriculum 2005 that emphasised equality and social justice as entrenched in the Constitution of the country, Act 108 of 1996. Curriculum 2005 was updated into the RNCS as an endeavour to address pedagogic and curricular issues which were identified as educational goals. This major policy is foregrounded on the philosophy of OBE (Muller, 2005), which was employed to spearhead a system of a life-long learning, eradicating the racist apartheid rote-learning model of learning and teaching to liberate nation building and learner-centred OBE (DoE, 2001). Wright (1992) depicted that education in South Africa experienced a switch from concrete (hands-on) tasks to abstract (minds-on) tasks which required cognitive skills in the form of the symbolic and abstract thinking essential for professional change, with a terminology change from industrial arts to Technology education.

3.3 Theory of education

The theory of education integrates a set of ideas that forms the basis of why knowledge is transmitted from one person to another. It informs a process of teaching, training and learning in a particular environment, to improve knowledge and develop skills (Ernest, 1998). The theory of education is interested in identifying gaps between the actual developmental level that is induced by independent problem solving and the level of potential development produced through problem solving under mentoring (Vygotsky, 1978). Constructivism is an element of educational theory, and has contributed effectively to educational policies that brought about transformation for democracy in South Africa.

3.4 Original perspective of constructivism

Constructivism emanates from an argument against the behaviourist theory of learning that children can only develop knowledge through personal experience. Basically constructivism is a philosophy of knowledge and learning that articulates mechanisms by which knowledge is conceptualised by learners. Constructivism claims that knowledge is linked to other sources and can be acquired through an experience from the social environment (Jaworski, 1994). Constructivism emphasises involving learners in learning dialogue, arguments, and conversations and consideration of their cognitive level as essential for achieving certain aims appropriate for their conceptual systematic planning. Constructivism is foregrounded on learner-centeredness and an activity-based approach to education which advocates cooperation, networking, critical thinking, and problem solving. According to Cunningham

(1992) learners do not transfer knowledge from the external world to their memory, but interpret the world on the basis of past experience and their exposure to real-life situations.

3.5 Framework for operation and number theory

This study is guided by constructivism as a framework for operation and number theory. The choice of this theoretical framework for this study is informed by the nature of design required for electronic systems. Operation of the project will yield to the positive asymptote which involves a square-free number in the form of natural numbers (Gyory & Halasz, 1990). Electrical energy is generally used to power equipment and components used in the project design. A comprehensive understanding of the safety and properties of components is paramount on the basis of a calculated selection of voltage and application of that voltage to certain components. For the design to be effective to the end user a counting number is essential in the form of natural numbers (Bostock, 2009).

3.5.1 Constructivism

Constructivism is a philosophy of knowledge, teaching and learning von Glaserfeld, (1984). It is a method of reflecting on students' own experiences while developing a deeper understanding of their environment (Thompson, 2004). This learning theory assumes that truth can be judged in relation to multiple social realities, recognising the mutual creation of knowledge by the viewers and viewed, and aims towards an interpretation of subject meaning (Denzin & Lincoln, 2003). Constructivists base their theory on the principle of active knowledge and adaptive cognitive function (Bradford, 2008). Davis (1996) described constructivism as a theory of limits of human knowledge, through which all that we can know is necessarily an outcome of our own cognition. Constructivism has an insertion of personal experience and social relationships with social urgencies like peers, elders and the entire society, within which knowledge is constructed through active participation in the learning process affected by prior learning experiences (van Niekerk, 2002). Constructivism bases its emphasis on the importance of Jean Piaget's levels of cognitive development, insisting that knowledge is constructed and learning occurs when children create artifacts. Piaget (1999) highlighted the importance of four levels of cognitive development in adaptation to cognitive structure: (a) the sensory-motor stage (0-2 years) where intelligence takes the form of sensory-motor action; (b) the pre-operational stage (3-7 years), where important activities are language, playing and fantasy (c) the operational stage (8-11years), where logic is expected and development of representational thought is marked by symbolic language as a systematic manipulation of symbols and (d) the formal operation stage (12-15 years) which represents abstract thinking and involves deductive reasoning and hypothesis. As an adolescent and adult an individual uses symbols related to abstract concepts.

Chronology of these stages will always ensure appropriate implementation and application of knowledge through participation in learning (Von Glasersfeld, 1984; Confrey, 1990 & Steffe, 1992). These levels of cognitive development of intellectual abilities contribute to the nature of Mathematics that endorses the essence of its practical application by different cultures, thus informing the perspective of Government projections of its role in economic development and sustainability. Von Glaserfeld (1984) insists on reflective ability at all levels of Mathematics as a major source of knowledge. this requires undergraduate students to share their thoughts about a project and confirm their consensus to their lecture as the facilitator in ensuring student-centeredness in their leaning.

3.5.2 Number theory

Number theory is the branch of pure mathematics committed to the study of positive real numbers, and the properties made out of whole numbers as solutions to equations (Hirst, 1995). Number theory is the science of numbers concerned with the relationship between numbers themselves (Cooper, 1975). According to Burton (2011) and Conway and Guy (1996) number theory considers the effective understanding of all matters as a positive real number rudiment to algebraic numbers resulting in the solution of equations. The design of a project comes as a result of a system of thoughts emanating from the foundation of mathematics. Hence Bostock (2009) and Gyory and Halasz (1990) emphasise the positive asymptote that will always result in natural numbers as the expected output of the design of the artifacts.

As this study seeks to understand the impact of utilisation of mathematics skills by Technology Education pre-service students to enhance conceptual understanding of electronic systems, it is situated within an interpretive paradigm.

In consolidating this theoretical framework I developed a model called the C&N (constructivism and number) model.

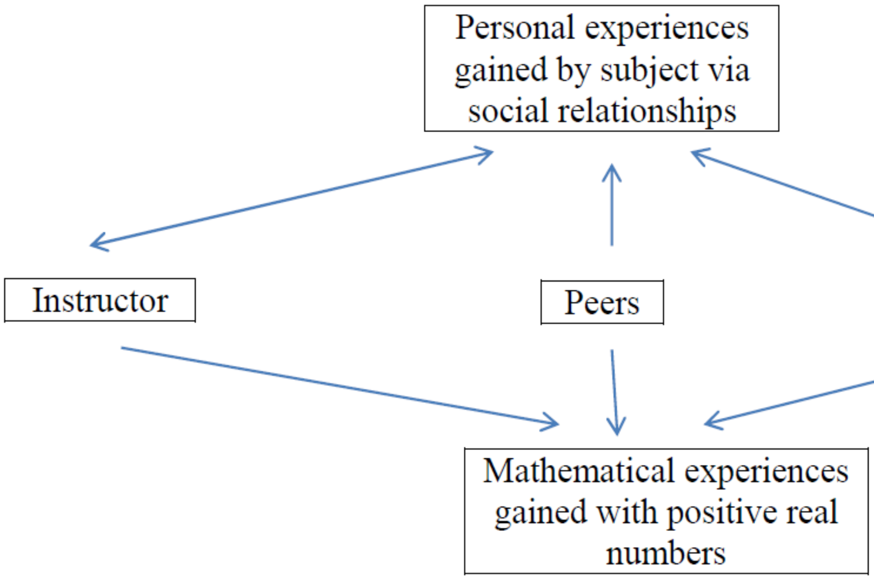


Figure 1: A simplified version of the C&N model.

This model will identify the potential of a student in totality, while providing an authentic application of mathematical skills by Technology Education pre-service students in enhancing conceptual understanding of electronic systems. A new trend, particularly in the European Mathematics Education Committee, is used to integrate different aspects from various theories in a meaningful way (Bradford, 2008). In coordinating theories different aspects are chosen and integrated to investigate a particular research problem. In this case, utilisation of mathematics skills by Technology Education pre-service students in enhancing conceptual understanding of electronic systems is the issue of research in this study.

3.6 Conclusion

This chapter highlighted the theories that underpinned the intuitive thinking though the use of numbers and observations. Constructivism and number theory were used to guide this research. Chapter 4 is dealing with the methodology chosen for this study.

CHAPTER 4

METHODOLOGY

4.1 Introduction

This chapter provides a discussion of the qualitative paradigm, and focuses on the background of the participants. Different methods of data collection are discussed and the data collection processes are described.

4.2 Qualitative approach

The qualitative approach is concerned with development of a detailed explanation of a social phenomenon, aimed at understanding the world people live in and why things are the way they are around them (Neuman, 2011). Cohen, Manion and Morrison (2005) argue that qualitative research is concerned with opinion, experiences and feeling of individuals who advocate subjective data collection and analysis. This approach does not attempt to manipulate subjects under study but rather describes social phenomena as they occur. Subjectivity employs an interpretive paradigm where reality is socially constructed and behaviour of an individual is guided by rules.

The purpose of this study was to explore the way in which Technology Education pre-service students utilise their Mathematics skills to enhance their conceptual understanding of Electronic Systems. The activities involved in Electronic Systems were linked with constructivism and number theory. Constructivism insists on active knowledge, participative experience and the inherent nature of Mathematics, as it underlines the issue of creative and logical reasoning about problems in the physical and social world as a product of active enquiry. Davis and Maher (1997) believe that learning incorporates investigation, discovery, discussion, play, cooperative work and exploration, which require language and symbolic interaction. For that, this study was placed within an interpretive paradigm. An interpretive paradigm is concerned with understanding and interpreting the world in terms of actions which participants engage with (Creswell, 2003).

This study was conducted at the University of KwaZulu-Natal among electronics systems pre-service teachers. These students were set to teach in the Technology learning area in the

General Education and Training (GET) band, which includes electronics systems. This group was multiracial and of both genders (male and female), and capable of teaching electronic systems to learners of school-going age.

To provide comprehensive responses of participants in a natural setting, purposive sampling was used. In purposive sampling the researcher hand-picks cases to be included in the sample on the basis of his judgement of typicality, by building up a sample that is reasonable for the researcher's needs (Cohen et al. 2005). Data were drawn from the Electronic Systems class EDTE 210 module (which formed the whole cohort), with students selected on the basis of their registration for module EDTE 210. Participants were chosen through convenience on the basis of their availability to be part of the study, particularly the interview process, and the fact that they are enrolled on the same campus and registered for the same module (EDTE 210, Electronic systems).

For interview purposes five pre-service teachers from each of the following achievement bands: 50-59%, 60-69%, 70-74% and 75-100%, were selected as elements of purposive sampling. Their final marks in Technology Education EDT 121 (a first module) were used. This setting simulates that of a case study, as defined by Cohen et al. (2005). De Vos, Strydom and Delport (2005) define a case study as "the examination of an instance in action, which tries to describe and analyze some entity in qualitative, complex and comprehensive terms not infrequently as it unfolds over a period of time". The context of this inquiry is dynamic, and provides a unique example of real undergraduate students engaged in electrical systems for design and construction in a real learning situation (Cohen et al., 2005). More specifically, Bennett and George (1997) refer to the type of case study the researcher intended to use as a "method of structured, focused enquiry".

The method of doing is 'structured' in that the same general questions were asked of each case in order to guide the data collection, thereby making possible systematic comparison and compilation of findings. The method was 'focused' in that it dealt only with certain aspects of the cases; that is, a selective theoretical focus guides analysis of the cases. The theoretical focus that guides this case study was to explore the way in which Technology Education pre-service students utilised their Mathematics skills in their conceptual understanding of Electronic Systems.

This was done with a view to contribute towards maximising participation of the diverse population of learners in a scarce subject in the education fraternity. This included searching for new variables, hypotheses and causal mechanisms that might have limited effective cognitive development in abstract, complex and invisible but hazardous learning areas such as electrical technology. Bennett and George (1997) proposed that the structure and focus of such studies are more easily attained when a single investigator plans and carries out all of the case study, which is what I did.

4.3 Background of participants

The whole cohort was used to constitute both the population and the sample for this study to ensure similarity and consistency in education provision. This study snowballed over different phases during participant observation. No age restriction was instituted and all racial groups and both genders were represented in this class. Not all participants were doing the second year but some took this module as an elective to complete their full qualification. Nevertheless, a minimum requirement for a pass was 50% (also for an elective). There was no evidence of participants engaging with Mathematics at university level, and whoever did Mathematics interrogated it as an autonomous module without intersection with Electronic Systems. I taught Electronic Systems and Mathematics in the FET band and also taught Technology at senior phase in the GET band. I am thus acquainted with aspects of Technology and Mathematics in project design in Electronic Systems.

4.4 Research site

This project was conducted in an institution of higher learning (university) in KwaZulu-Natal. This institution is continually developing teachers for their professional duties in all phases (Foundation, Intermediate, Senior and FET). Participants were provided with technology kits after they had registered for Technology. Participants were acquainted with most electrical appliances, e.g. electrical kettles stoves, heaters, lights, digital video displays (DVD), television sets, computers, cellular phones, hair dryers, hair cutters, tongs, etc. They were admitted at the university with a certain level of Mathematics as a prerequisite for tuition in all faculties. The School of Technology provided electrical equipment (soldering irons, glue guns, multi-meters, etc.) and components (e.g. variable resistors, carbon resistors, light-dependent resistors, thermistors, diodes, light-emitting diodes, transistors, relays and capacitors) pertinent to Electronic Systems.

The institution was expected to buy tools for Technology from the students' tuition fees as they are admitted in a Technology discipline. A workshop was provided for Technology activities as well as specialist storerooms for different areas offered in Technology as a curriculum prescription. The timetable catered for practical lessons as they were emphasised for theoretical enunciation. A Friday was allocated for further questions and individual practical engagements as a consultation time without appointment. There was a need for this study to run only for the specified duration (one semester) of the module (EDTE 210).

4.5 Research instruments

Three methods of data collection were employed: participant observation, submission of a working artifact and interviews.

4.5.1 Participant observation

Qualitative participant observation is a means to collect data and doesn't provide any significance of statistics (Cohen et al., 2005). We used a structured participant observation schedule in observing an application of Mathematics skills by Technology Education pre-service students in enhancing conceptual understanding of Electronic Systems in design. The qualitative approach provides an enhanced understanding of the real situation in the integration of Mathematics and Electronic Systems in Technology design and construction. In this project students were expected to design an alarm system by drawing a circuit diagram, and to experiment as to the functionality of the circuit using a breadboard and selected components before it was transferred into the model of the house. Experiments were done in the laboratory/classroom.

While different experiments were taking place, a participant observation data collection instrument was used, and structured participant observations and photographs were captured. This process intended to provide a comprehensive understanding of the application of Mathematics skills by pre-service students in enhancing conceptual understanding of

Electronic Systems. This group (pre-service teachers for EDTE 210 Electronic Systems) included those who took this module as an elective and wanted to complete their undergraduate degree in the same year. Since this research took place during tuition time I was able to carefully observe the development of different levels of their understanding and application of acquired skills, thus witnessing effectiveness of integration of Mathematics skills and Electronic Systems as well as Technology application.

Observation of participants took place during four phases: (a) a theoretical introduction, (b) measuring instruments and orientation, (c) simulation, and (d) design of a model that aimed at an ultimate working artifact. These phases served to introduce participants with aptitude to an authentic development of artifacts. However, it was discovered that participants had different objectives in registering for this module, which had significance in categorising their aptitudes pertinent to electricity. Participants with aptitude included students with a basic, average or advanced knowledge of electricity.

4.5.1.1 Brief explanation of the aptitude categories of participants

(a) Basic knowledge of electricity

At this level a person is able to operate electrical appliances as instructed by a manufacturer. Mostly these persons throw away anything that does not function according to the prescripts. They would prefer to go without that particular appliance instead of attempting to fix it.

(b) Average knowledge of electricity

At this level a person goes beyond basic operation of appliances and can check a cut-off from the main switch to switch it on if there has been an overload.

(c) Advanced knowledge of electricity

This level goes beyond both operation and fault spotting. A person is able to connect appliances properly using the relevant colour codes, and knows the colour relationship: red and brown for live wire, black and blue for neutral wire and yellow and green for earth wire.

(d) Phases of participants' observation schedule

These phases ensured observation of procedural knowledge as they (phases) are elementary requirements for knowledge, skills, techniques and processes essential for design of artifacts. Mogari (2004) argues that capacity, ability and knowledge are paramount for relating skills and procedures. These phases were used to lay a foundation for a complete and working project.

Phase 1

A theoretical introduction: A theoretical aspect of participant observation in phase 1 was fore-grounded on a relationship between current, voltage and resistance entranced in Ohm's law. All components used in circuits were considered loads as they consume electrical power for energy changing. Dynamics of increasing loads in either parallel or series was a major concern in the ultimate design of artifacts. With a range of components proposed to design and complete artifacts, participants were expected to bequeath unique behaviours of individual components (load) when accumulated in series or in parallel. Knowledge of components was inculcated into a principle of an Ohm's law for each individual case, resulting in an informed choice of appropriateness of the position and the function of actual components. Each component's behaviour was investigated in isolation in a broad complex and enormous circuits.

Dynamics of activities inculcate all essential basics of electricity, which is paramount for a circuit design in the electronic system. The highlight was the movement of electrons in the circuit through various electrical devices, to persuade the process to do something for us in the form of heat, light emission, etc., and considering it as a load that can be increased or decreased in the circuit from a single source. Emphasis was on the layout of the breadboard and the use of a digital multimeter to justify a theoretical approach of series and parallel connection of loads in the circuit. The whole population was taught theory, including Ohm's law as it applies on more than a single load either in series or in parallel. Connecting electrical devices poses a challenge of understanding in series and parallel combinations of loads. However, the following factors inform design of any circuit construction, as stated by Hewitt (1989).

Study of a series and a parallel circuit

(i) Series combination

- The voltage applied in a series circuit divides among electrical devices, allowing the sum of the voltage to drop across the resistor of each individual device, to be equal to the voltage supply, ignoring internal resistances.
- Electrical current has a single pathway to go through, which means a common current flow through each device in succession.

A typical exercise was given to participants to emphasise principles of Ohm's Law in an increased load in both series and parallel for a theoretical aspect.

Question 1

In a series circuit, certain general rules may be stated with regard to quantities of voltages, current and resistance. Express these rules using your own words with regard to behaviour of the quantities.

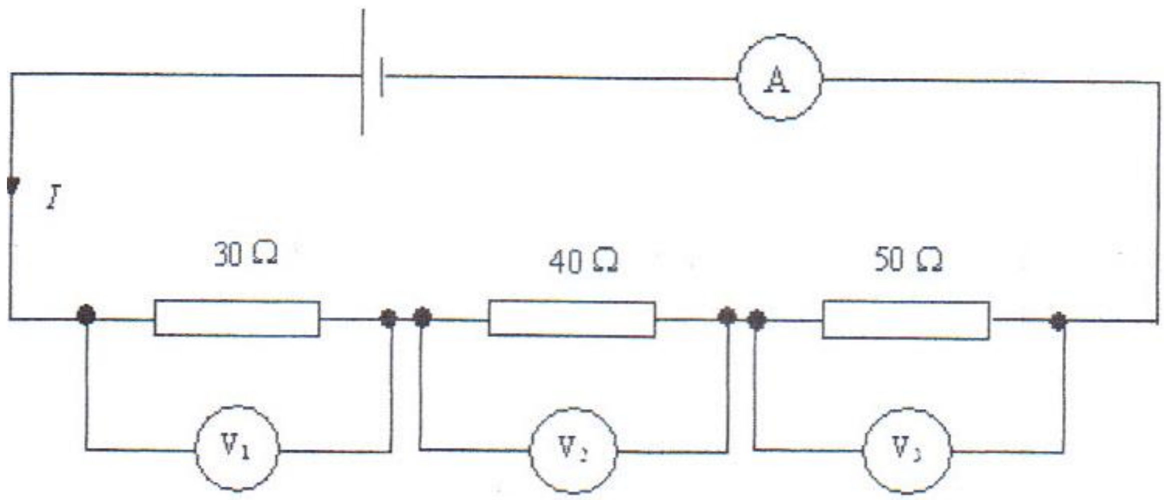
a. In a series circuit, voltage ________________________

b. In a series circuit, current ________________________

c. In a series circuit, resistance ________________________

Question 2

The following questions refer to the diagram below assuming no internal resistance. The ammeter reading is 100 mA.



a. What is 100 mA in Amperes?

____

b. What is the current in each resistor?

$I_{30\Omega}$ __________________________________

$I_{40\Omega}$ __________________________________

$I_{50\Omega}$ __________________________________

c. What is the voltage across each resistor?

$V_{30\Omega}$ __________________________________

$V_{40\Omega}$ __________________________________

$V_{50\Omega}$ __________________________________

d. What is the total resistance in the circuit?

____

e. What is the battery voltage in the circuit?

____

Question 3

A typical exercise was given to participants to emphasise principles of Ohm's Law in an increased load in both series and parallel for a theoretical aspect.

In a parallel circuit, a general rule may be stated with regard to the quantities of voltages, currents and resistance. Express these rules using your own words with regard to behaviour of the quantities.

(ii) Parallel combination

- The total current divides among the parallel branches of the circuit and the overall resistance in the circuit is less than a single resistance of the same circuit.
- An electrical current in the circuit does not have a single pathway. For that matter the total current in the circuit divides and the voltage remains the same in all branches.
- In a parallel-connected circuit the voltage is the same at all the branches, thus providing the same voltage across each device.

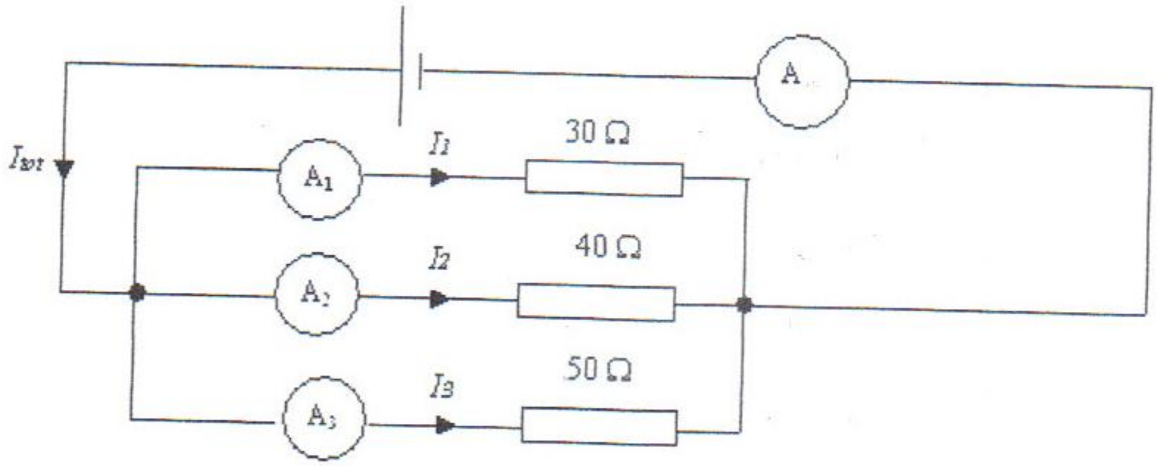
f. In a parallel circuit, voltage ___________________

g. In a parallel circuit, current ______________________

h. In a parallel circuit, resistance ___________________

Question 4

The following questions refer to a diagram below, ignoring the internal resistance. The reading on the ammeter is 100 mA.



a. What is the current in each resistor?

$I_{30\Omega}$ ____________________________________

$I_{40\Omega}$ ____________________________________

$I_{50\Omega}$ ____________________________________

b. What is the voltage across each resistor?

$V_{30\Omega}$ ____________________________________

$V_{40\Omega}$ ____________________________________

$V_{50\Omega}$ ____________________________________

c. What is the total resistance in the circuit?

____

d. What is the battery voltage in the circuit?

____

The exhaustion of phase 1 cued us to phase 2, where use of a measuring instrument was introduced to participants.

Phase 2

Measuring instruments and orientation:

Execution of this project design included practical use of a multimeter, measuring units, scales and quantities of measurement. Concurrently, a table of SI units was introduced to the cohort to showcase appropriate scaling and authentic calculation for appropriate, valid outcomes and quantities of measurement. A table with its SI units is provided. These SI prefixes were formulated by an international conference on weight and measures.

PREFIX	**SYMBOLS**	**FACTORS**	**ORIGIN**
Tera	T	$x10^{12}$	Greek: Teras meaning monster
Giga	G	$x10^{9}$	Greek: Gigas meaning giant
Mega	M	$x10^{6}$	Greek: Meagas meaning large
kilo	k	$x10^{3}$	Greek: Chilioi meaning thousand

Hecto	H	$x10^{2}$	Greek: Hekatom meaning hundred
Deca	Da	x10	Greek: Deka meaning ten
Deci	D	$x10^{-1}$	Latin: Decem meaning ten
Centi	C	$x10^{-2}$	Latin: Centum meaning hundred
Milli	M	$x10^{-3}$	Latin: Mille meaning thousand
Micro	µ	$x10^{-6}$	Greek: Mikros meaning small
Nano	n	$x10^{-9}$	Greek: Nanos meaning dwarf
Pico	P	$x10^{-12}$	Greek: Pekhys meaning cubit, a measure
Femto	F	$x10^{-15}$	Danish: Femten meaning fifteen
atto	A	$x10^{-18}$	Danish: Atten meaning eighteen

Table 6: The SI units used for electrical quantities

It was essential to capacitate the cohort in the appropriate position for connection prior to a measurement of a current or a voltage in both series and parallel connections of any circuit using appropriate scales.

Habituation of practical implementation: In accommodating a scope of electronic connection, the population was introduced to breadboards and Vero boards to enhance their skills of connecting designed circuits either in series or in parallel. A breadboard was used to house the simulation and Vero board to prepare them for soldering components in practical implementation of design.

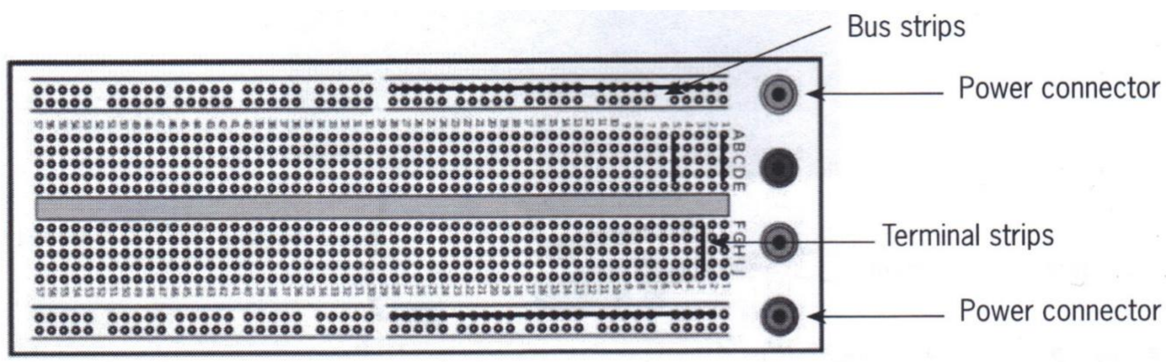


Figure 2: Illustration of a breadboard

A breadboard is a special gadget used for experiments in project designs. It is particularly used where soldering of components is not essential, in project simulations (McGowan, 2012). A construction of a breadboard has a special arrangement of bus strips and terminal strips that separate leads of individual components as well as unnecessary connections in the design of the same project. Those connections (different bus strips and terminal strips) are covered by a white plastic material, allowing components to be planted in it (breadboard) to make contact with the bus strips through holes. Holes on the breadboard assist in guiding leads of components and provide a typicality of the internal arrangement of bus strips. Figure 2 shows a typical example of a breadboard providing a layout in terms of bus strips and terminal strips.

Bus strips are situated in one or both sides of a breadboard, depending on the manufacturer. Bus strips are symbolised by two columns identified by a red and a blue colour (McGowan, 2012). These denotations make it easier for a flow of current and the appropriate use of a multimeter when following a design in the circuit diagram. They show a direction from the source of supply and a ground as a return pathway back to the source. Continuity runs from left to right on the individual coloured strip, with no continuity to the next horizontal strip, as designated in Figure 2.

Terminal strips are arranged in the form of rows of five holes. Continuity is only limited in those five holes separating individual groups. Internal strips make up a bigger part of a breadboard; these strips are connected and arranged in alphabetical order from A – J to indicate individuality of rows. A – E is an individual group that provides a row with continuity in all five holes and F – J provides another group with its own continuity not linked either to a bus strip or the A – E group.

It is always paramount to plant components in the correct hole (either bus strip or terminal strip) to avoid damage to both the breadboard and components. For safety purposes, emphasis should be placed on insulation since electrical power cannot be under-estimated in terms of human resistance. All components should be planted properly into the breadboard and open as well as lose wires should be avoided as a precaution whether supply voltage is less than 220 V or not. Components like variable resistors (potentiometers) need to have insulation knobs to avoid electrocution during operation.

Figure 3 is a typical example of the internal agangement of bus strips and terminal strips in the same breadboard.

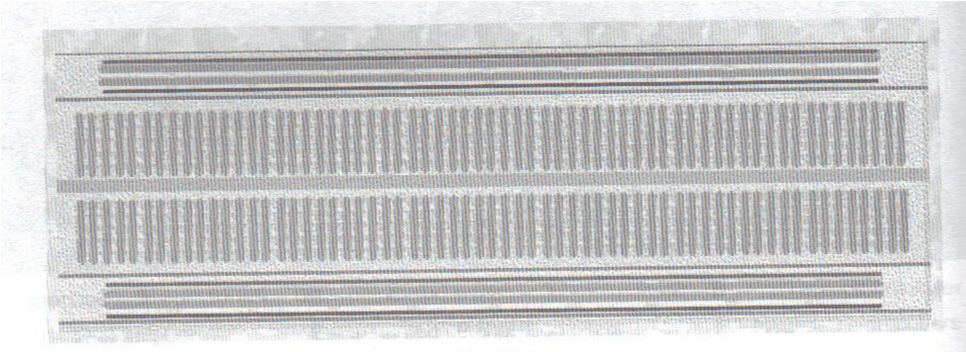


Figure 3: Internal arrangement of strips

It was highlighted that a supply voltage should be terminated from the breadboard after an experiment is completed. In the process of planting or removing components, all wires and components should be carefully removed from the breadboard to avoid damage of the breadboard and internal connections that may lead to leakage of current to other strips due to corrosion. Wires and component leads must be prevented from breaking off in the breadboard.

Vero board is a special type of board made for electronics purposes. A Vero board is tinted with a copper layer on one side, with a grid of copper strips that are running parallel in one direction of the board. As a circuit board, as shown in Figure 4, a Vero board is a prototype of a breadboard. It requires soldering when one needs to plant components.

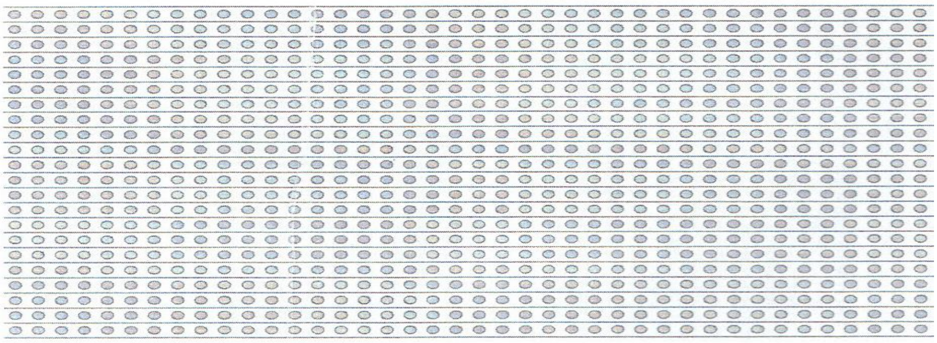


Figure 4: Connection on a Vero board

It has permanent holes drilled on the copper strips with an average spacing of 2.54 cm. When building a designed circuit, components are planted on the plain (alternative side) of the Vero board with leads protruding into the tinted side through permanent holes. During this process components are not connected to form a circuit but planted into the board. Leads should be soldered to copper strips vividly placed on one side of the Vero board. Vero boards do not provide bus strips and terminal strips but layout holes in column form that needs to be separated by a designer. In the case of excessive heating during soldering, copper strips may be damaged, but an external connection can be used by soldering wires to the boards through holes (Hiscocks, 2001).

At this stage of phase 2 participants were divided into groups of four members for purposes of cooperation, sharing of ideas and collegiality. A limited range of components was introduced to the cohort to control for a variation of design in the electronic systems before they could formulate an artifact out of a circuit diagram using these components. At some stage participants were requested to provide characteristics behaviour of each component for assessment, but we did not use assessment scores for this study. A researcher focused on participants' approach to the understanding of each component and their mathematical manipulation. The following list was provided:

> The components are: (a) variable resistor, (b) carbon resistor, (c) light dependent resistor, (d) thermistor, (e) diode, (f) light-emitting diode (LED), (g) transistor, (h) relay and (i) capacitor.

This information was not exposed to a particular group (sample) that needed a particular experiment as a unique privilege, but to the whole cohort since participant observation took place during tuition time in both theoretical and practical epochs, as mentioned before. This project did not intend to explore past experiences in electrical-related subjects, but in the utilisation of Mathematics skills by Technology Education pre-service students to enhance conceptual understanding of Electronic Systems. However, individual elements of the cohort had isolated familiarities in relation to electricity, Mathematics and design pertaining to design of artifacts in Electronic Systems.

Phase 3

Simulation is a situation in which a set of conditions is created to experience a factor which could exist in reality. It is an operation of a real-world project that has been developed as a model to represent the key characteristics of the selected abstract system, emphasising the operation of a system when it is interpreted in a model. Simulation was initiated as an endeavour to integrate circuit modelling and evaluation that emanated from the process of circuit design and testing of operation before translating this into a working artifact.

A breadboard was used to interpret a circuit diagram. During development of the circuit diagram components were placed and planted in the breadboard on the basis of calculated selection, as an open-loop system. Simulation was used to show a calculated real effect of alternative conditions. Simulation was apparent because a real alarm system engaged different components with different characters. At this phase participants (groups) were able to try numerous alternatives of circuit design but using effects of current and voltage in series/parallel calculation.

Phase 4

Artifact specification:

A group was expected to design and construct a burglar alarm system for a model of a house with at least one door and one window for a single room. The alarm should be activated if either the door or the window is opened. The alarm should continue to sound even if the door or the window is closed again. This data collection strategy was divided into two stages: written submissions of designs of artifacts and submission of complete working artifacts.

4.5.2 Submission of complete working artifacts

4.5.2.1 Written submission of designs of artifacts

Groups were expected to provide a design brief that would guide specifications essential for the logical development of the final product, which should ensure that it meets the needs of people as the main purpose of technology. The following guiding points were provided as rubrics to guide both their project development and assessment:

1. It should contain details of the functional and design features of the finished product,
2. Information on cost and profit margin
3. Specification for an electronic product should include electronic factors such as component details, maximum working voltages, maximum currents, and temperature or frequency ranges. A design brief and specifications were used to continually test and evaluate the product in ensuring that it met the needs of the customers.

4.5.2.2 Submission of working artifacts

Here groups supplied a report for their final project that provided a chronological development emanating from the original problem. The format of the presentation could be as follows:

- **Introduction**

  How did the problem originally present itself to you and how did it evolve over the course of the project? Give a detailed summary of the problem.

- **The solution**

  Describe your solution in detail.

- **The implementation process/results**

  Describe the process you went through to complete the project and compare what actually happened with the goals you were trying to achieve. Highlight any major variations from your original plans. Discuss the behaviour of the finished project, and show some of its functionality.

- **Conclusion**

  What has been accomplished and what are the major things that you learned from this project? What work still needs to be done on the system and how can it be improved and/or enhanced? Do you have any future plans for this package?

4.5.3 Interviews

A semi-structured interview was conducted with participants included in the sample (Technology Education pre-service students). I employed interview methods in order to corroborate the findings from the final working projects and participant observation that provides a quality inference justified in the qualitative approach yielding to the interpretive paradigm as stipulated by Cohen et al. (2005). The purpose of using a semi-structured interview was to gain in-depth data from participants and to find out what lay behind their understanding of electronic systems as they applied calculations, by following up their ideas and probing responses from them (Cresswell, 2003).

4.6 Trustworthiness

Ecological validity was used to provide authenticity and trustworthiness in this study. The main purpose was to provide evidence that the natural setting of this study was not disturbed and events occurred without my interference (Neuman, 2011). Qualitative participant observation on progressive stages of a final working project, assessment of an artifact and interviews after submission of a project were data collection instruments used to triangulate the researcher's findings through description and responses from participants. We used qualitative participant observation as the project progressed in stages, and thereafter conducted interviews as elements of credibility in relation to application of mathematics skills in the conceptual understanding of electronics systems.

An integration of these three research instruments provided an element of transferability to the application of mathematics skills in the entire electrical system in improving understanding and applications. The three forms of data collection confirmed the findings and led to application of these findings in a similar situation, as highlighted by de Vos et al. (2005) and Cohen et al. (2005).

4.7 Ethical issues

Participants were assured that their participation was purely voluntary and no one was obliged to be part of this study. The nature of this study was highlighted as well as that willingness to be part of it had no impact on their opportunities for promotion. In approaching participants the following steps were followed (Gay & Airasian, 2003):

- The purpose and an outline of the study were provided to participants and they were assured of confidentiality and anonymity.
- Participants were promised full confidentiality and anonymity of their involvement in events that took place during the study, but were further asked to give full release of the video/images and data for use in public domains such as actual learning in the classroom.
- It was emphasised that their participation was entirely voluntary, and guided by the School of Technology as a discipline in consultation with the faculty head.

We also followed ethical guidelines laid down by the research office of the university. Ethical certificate number HSS/0831/012M (see Annexure 3) was issued to us and ensured that all ethical aspects were abided by this study.

CHAPTER 5

DISCUSSION OF DATA: CIRCUITS AND MEASURING INSTRUMENTS

5.1 Introduction

This chapter provides a description of the classroom situation where most of the teaching and learning for the whole module EDTE 210 Electronic Systems took place. It provides a portrait of a class layout of pre-service teachers engaging into a two-fold activity, theory and practical, for a common conceptualisation of subject matter. Key areas that form the core of this chapter cover classroom dynamics for the module EDTE Electronic Systems, circuit calculation and measuring instruments, and recommendations. Tables, graphs and pictures have been provided as data accumulated and discussions out of these emanate.

5.2. Classroom dynamics

This section gives a brief description of the classroom set-up within which tuition was taking place.

5.2.1 Classroom layout

Figure 5 shows the overall plan of the laboratory environment. There was no permanent seating arrangement or single purpose of the classroom; it was designed for multi-purpose activities, i.e. theoretical teaching and practical tasks. Projection facilities (digital and overhead) were assigned to the front, at a similar position to the chalkboard. Alongside were the electrical socket outlets. In one front corner of the classroom was a hand basin with both cold and hot water, and to the back and front of the class were two storerooms. At the entrance were sliding doors big enough for use as emergency exits, as illustrated below.

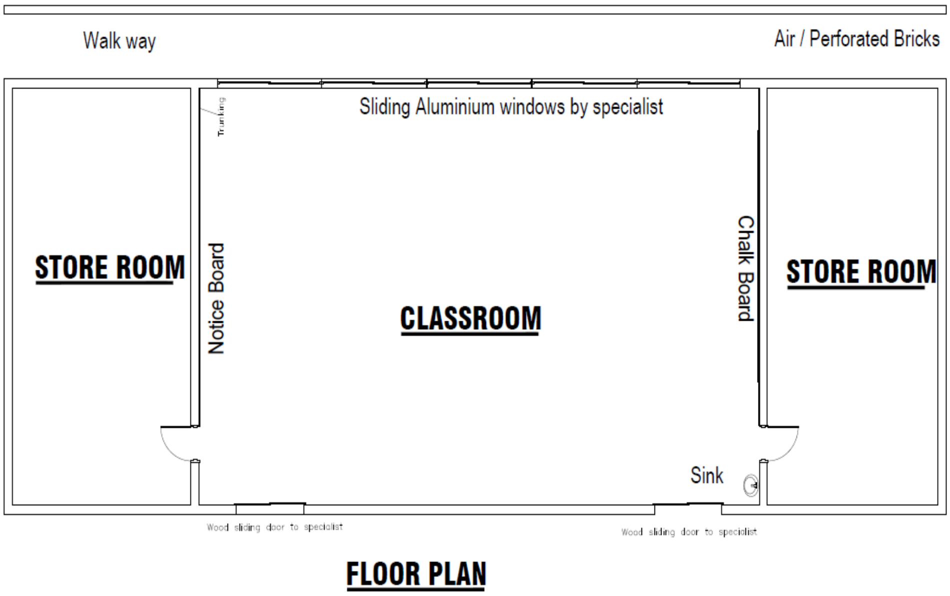


Figure 5: Floor plan of the laboratory

There was nothing remarkable about the walkways behind the classroom, except that they provided shade for effective projection and protection against vandalism. The classroom was well ventilated and properly maintained.

5.2.2 Nature of participants

All participants were doing their second year or above, within an undergraduate degree. All racial groups were included in this group and both genders (male and female). Their being in an institution of higher learning suggested that participants had capable potential in elementary Mathematics and had access to quality education through an adequately resourced institution. Their socio-economic status took no precedence over their learning opportunities, hence removing major barriers to their maximum achievements.

Theory and practicals were given equivalent time in the total time scheduled for Technology. Participants were provided with basic technology kits, and the institution provided consumables as well as major expensive electronics equipment. A module period was too short to allow for effective engagement in the tight schedule for Technology classes. A maximum use of time was expected from all parties involved in the teaching and learning process, administratively and educationally. All due dates and details of examinations (written exam and submission of a project) were issued in the first lesson. Maximum use of each period was paramount since it was leading to the next task. Participants were achievement conscious and would demand being engrossed in achievable tasks. This section provides analyses of the dual scrutiny that served as a foundation of design, and focuses mainly on the circuits and measuring instruments.

5.3 Circuit diagrams

Analysis of circuit diagrams was based on procedural mathematical calculations determined by the arrangement of components in circuits. It is, however, essential that we expose the mathematical calculation essential for theoretical comprehension of the entire operation.

5.3.1 Mathematics

Everybody experiences mathematical concepts incidentally in their daily practices. However, these concepts had to be explicitly taught to participants in conjunction with electronics requirements, as stated in section 1.3. A theoretical introduction provided procedural knowledge required for a proper application of Mathematics as a solid foundation for design in Electronic Systems, which involved specific language relating to symbols for subunits of electrical quantities, manipulation of powers of ten, solving equations when given a formula, understanding direct and inverse relationships, addition, subtraction, multiplication, and division of whole numbers and decimals as well as adequate use of a calculator. Participants experienced a challenge in articulating appropriate knowledge for a problem-solving exercise. All current-consuming components were categorised under a loads terminology, irrespective of their actual names and their behaviour, and were considered as resistors measured in ohms.

Arithmetic was however conceptualised better at points where manipulation of Ohm's law was executed. As the dynamics of increasing loads was getting tougher, participants tuned into solving problems quicker omitting the elementary approach to Mathematics language, linguistics and sequencing.

As far as participants' grasp of mathematical cognitive concepts relating to specific language and symbols for subunits of electrical quantities, manipulation of powers of ten, solving equations in given formulas, understanding direct and inverse relationships, addition, subtraction, multiplication, and division of whole numbers and decimals is concerned, the input provided by the literature (when students have misconceptions in Mathematics, they develop resistance to teaching of it) advocates obtaining participants' opinion around viewing Mathematics as an abstract area of knowledge good for a particular intellectual population. Participants had to respond after their achievements on an exercise based on the relationship between voltage, current and resistance and theoretical circuit analyses pertinent to calculations.

Most participants viewed circuit analyses and calculations as the most disadvantaging exercise and enunciated that they did not come for Mathematics in this module. They were made to respond anonymously in black and white in the light of this challenge. The following comments were made by some participants when asked to write down all concerns they had.

- For some of us that have not done mathematics, the explanat are insufficient and on a level that is difficult to understan This needs to be taken into account so as to accomodate all students.

Text 1: Written response of participant S2

Participant S2 thought that the module EDTE 210 required students' knowledge of Mathematics in the lower grades at school level, and that such exercises involved application of the prior knowledge accumulated.

I do not agree with the above concerns, I think there are students who didn't do Tech 120 module, so that is why they struggle because do not have the background of this module. The Lectu is doing his work well although some students want the Lecture on their own way or view. Th function of the Lecturer is to teach not to spoon-feed students.

Text 2: Written response of participant S6

S6 indicated that Mathematics skills required for Technology EDTE 210 should be involved in Technology EDTE 120, i.e. that the required Mathematics skills should be covered in the Technology Education modules. This seems to create a conflict, since the numbers required in Technology could not be traced back to previous modules or to basic Mathematics skills in all pre-service teachers. However, some believed that the required Mathematics skills were covered in school and in the foundational Mathematics modules (which are compulsory for all pre-service teachers). Pre-service teacher S6 obviously thought otherwise, and that such skills could be included in previous Technology modules.

When studying the other concerns of the pre-service teachers it was evident that participants had individual experiences and different perception about Mathematics. Some participants experienced a problem in relating Mathematics theory to electrical concepts and could not cope adequately with performance of basic mathematical computations.

5.3.2 Problem solving

Circuit theory was presented in the form of a problem-solving exercise. Participants were piloted through basic symbols for electricity (resistance, current and voltage) drawn in the form of a circuit (e.g. 4.5.1.1.(d) Phases of participants' observation schedule). All these electrical concepts (resistance, current and voltage) were calculated with their cumulative proportional relationships as a way to model to the participants the interaction with given information. This exercise reinforced procedural knowledge through subsequent steps in a relatively independent manner. The most challenging aspect was when loads were increasing either in series or in parallel, with a ripple effect that loads had a direct connotation to both current and voltage in their relative circuits.

This exercise was moving through the stages along the pathway from teacher-centred to learner-centered practice. It focused on building students' understanding of advanced stages for problem solving adopted in instructions in line with reformed movement, with a notion that learners can construct deep and interconnected mathematical understanding. The origin of the tension nested between the opposing thought that existed in the class in that this was not a Mathematics class and that participants intentionally did not register for a Mathematics module but Electronic Systems. A greater task lay in identifying common areas for Mathematics language and preciseness of Technology particularly Electronic Systems. Without denying the explicit importance of learning and development, it was paramount not to oversimplify the relationship between an appropriate language for Mathematics theory used in Electronic Systems and cognitive development for design. Nevertheless, a relationship may not necessarily be representative of a straightforward, direct type of association but more probably one that is under the surface with undiscovered sub factors, e.g. (a) procedural and conceptual knowledge and (b) academic confidence.

5.3.2.1 Procedural and conceptual knowledge

Participants portrayed limited conceptual knowledge in algebra, and it was further discovered that their conceptual knowledge did not correlate with their procedural knowledge. Hence they depended upon their calculators. Conceptual knowledge is considered as knowledge that is rich in relationships between variables and that embraces the ability to convert between various forms of presenting functions, e.g. from table format into graph format, etc. (Hiebert & Lefevre, 1986).

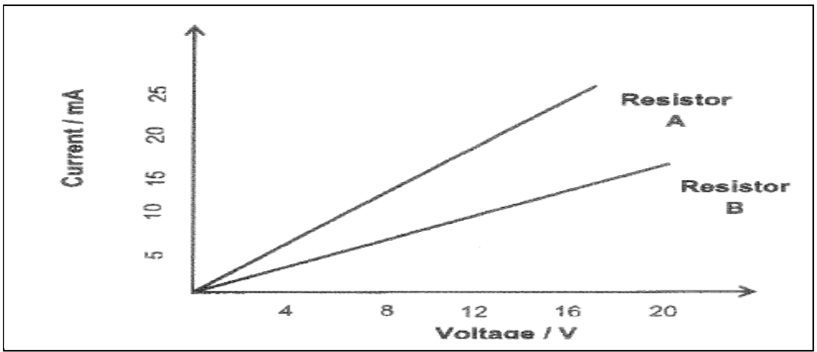


Figure 6: Scan of linear graph for Ohm's law

Figure 6 was given to participants to conclude a graphical relationship in Ohm's law. They were expected to compare resistance values from two or more resistances. The subtext was based on the gradients as mathematical differences in sloppy development of their approach to positive infinities. This yields more on gradient analyses:

$$\frac{y_2 - y_1}{x_2 - x_1}$$

When two resistances (R_A and R_B) were compared, their point of comparison was gradient-based, thus suggesting conductivities of those two resistors in terms of currents and voltages. Such conductivity $\frac{\Delta I}{\Delta V}$ suggested an inverse proportion to resistance, i.e. $\frac{1}{R}$. Therefore the whole analysis of both graphs on the same system of axes in Figure 6 clearly indicates that $R_B > R_A$ based on the shape and values of their gradients.

In exercises for representing graphical linear relationships for Ohm's law, participants did not have a clue as to the layout of axes, and hence did not know what to allocate to the x- or y-axes between current and voltage. There was a pounding need for developing activities that reinforce numerical relationships as an interpretation of a problem-solving exercise. There was a need for laying a firm foundation for interpretation, calculation and the manipulation of formulas as the essence of ultimate project design. The development of such skills resonated an effective use of mathematical skills and the appropriateness of the BODMAS (brackets off, divide, multiply, add and subtract) rule in enhancing procedural and conceptual knowledge, as advocated by Troutman and Lichtenberg (1995).

5.3.2.2 Academic confidence

Academic confidence is understood as a facilitating variable between the individual's inherent abilities, their learning styles and the opportunities afforded by the academic environment of higher education (Sander, 2004). Participants struggled to link fragmented knowledge related to their intuitive backgrounds with academic requirements when they were interrogating application of Mathematics to electrical concepts, as highlighted in the concepts (resistance, current and voltage) and the calculation approach appeared new to participants, and it was instantly concluded that they were not going to cope well with the demands of Electronic Systems if they yielded to Mathematics challenges.

As participants were requested to respond during the process of phase 1, they had different opinions on expectations of the demands in Electronic Systems as it (phase 1) formed a firm foundation for design nested in Mathematics. Participants were motivated by the fact that their ultimate goal was to pass the module (EDTE 201). Many consultative visits were experienced during consultation times on Fridays, which had a positive impact on their conceptualisation as a predictor of academic performance in overall achievement on the module. During their visits I discovered that arithmetic aptitude demonstrated in answering was inadequate. Although there was no statistical categorisation of participants' struggles, common challenges that overwhelmed participants were (a) handling fractions in all operations (addition, subtraction, multiplication and division) and (b) handling operation of exponential numbers.

5.3.2.2.1 Handling fractions in all operations (addition, subtraction, multiplication and division)

Accumulating loads in parallel was too demanding for participants (4.5.1.1, Question 4). Participants could not figure out a direct connotation theory between an increasing load in a parallel connection and a decrease in resultant resistance values, as it was cumbersome to handle a procedural operation of fractional calculation. Participants could not attempt Question 4, perhaps because of the denominator that needed to be formulated as part of the solution for consolidating resistors in parallel.

There was a need for a remedial intervention in forming the necessary understanding for a proper procedural approach to handling fractions. In relation to common current and division of voltage in a series circuit, participants were able to capture this very well but were challenged by a common voltage and division of current in a parallel circuit. It was noticeable that participants attempted to avoid a procedural approach to fractional calculations in Question 4 for a total resistance. They indicated that they may not know the correct algorithm in problem solving and could not embark on a mental calculation on the problem, but they could use their calculators to get the answers. Surprisingly, participants could only convert proper fractions into decimal fractions and add, which contradicts a procedural approach of writing a reciprocal of an answer for parallel calculation.

Understanding of fractions for series and parallel combinations'

Typical question on a series-parallel combination was given to participants as an exercise for assessment S_2 as shown in Figure 7.

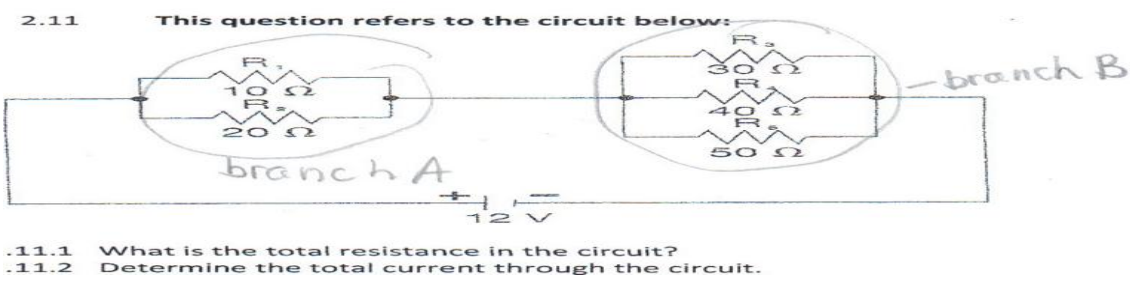
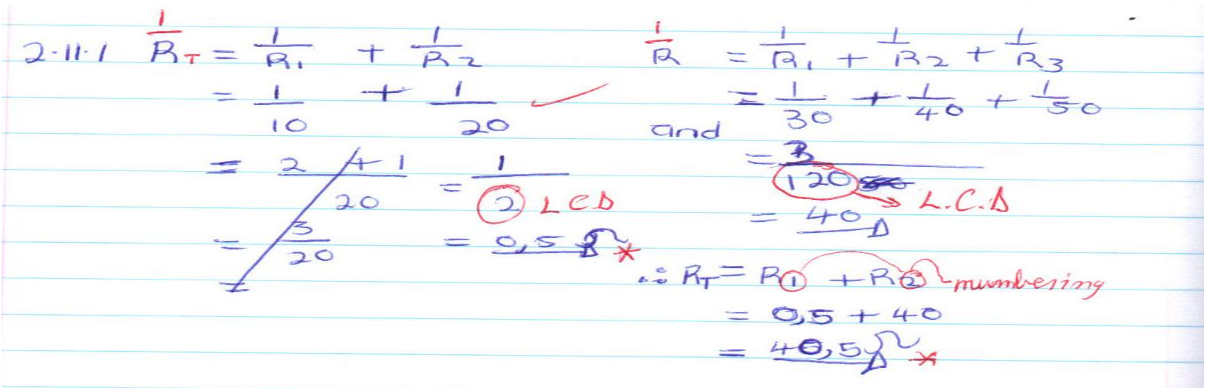


Figure 7: Series-parallel combination

This question was perceived by pre-service teachers as a very simple and easy task before they interrogated the task, while full comprehension and application of fractions was essential. After they submitted the task, I took responses purposively and strategically, and clustered them according to common areas of discrepancy that I observed. I selected two different categorical and grouped those clusters, A and B. Cluster A was a group of pre-service teachers that added all numerators together and denominators together and gave one subtotal while cluster B was a group of pre-service teachers that attempted to follow a procedure of working with fractions.

Cluster A



Text 3: Written response of S8 to illustrate cluster A

We observed that cluster A's written responses to this question calculated each branch separately. The response showed that no relevant notation was used to differentiate each calculation. The use of $\frac{1}{RT}$ could have been denoted by $\frac{1}{RA}$ and $\frac{1}{RB}$ instead of R and $1/R_B$ for branch A and branch B. For the calculation of branch A the correct computation was annulled and replaced by $\frac{1}{2}$. For branch B, the pre-service teacher wrote $\frac{3}{120}$ as a result of $\frac{1}{30}+\frac{1}{40}+\frac{1}{50}$ equals 40. Identification of different resistors as a result of their combinations through numbering was cumbersome in cluster A. Generally, participants experienced difficulty in relating a normal spontaneous sharing that is exercised on a daily basis with the understanding of fractions and performing computations. Indisputably this combination was emphasising all aspects of series and parallel connections in dynamic ways. Although branch A and branch B portray parallel connections, a logical and conceptual understanding of the procedural approach was to deal with them using appropriate operations and sharing. Computation of formulas and their numbering indicated a hazy understanding of reckoning approach, hence failing to expose participants' knowledge demanded in such non-routine arithmetic problem-solving in algebraic fractions.

In providing correct answers, participants were struggling to apply cognitive flexibility to fractions, as they were not providing adequate arithmetic principles on accumulation fractions with different denominators, as highlighted by Bulgar, Schorr and Warner (2004). Cluster A responses indicated that both denominators and numerators were added according to their branches. Particularly in branch B, 3 was given as an answer for the 3 numerators and 120Ω was provided as a sum for the denominators (30Ω, 40Ω and 50Ω). The participants' knowledge application was contrary to the prescript of the RNCS 2005 document in emphasising adequate use of correct operations and sharing in fractions (as indicated in section 4.1.11 of the RNCS 2003). This situational demand created a dilemma in participants' conceptualisation of logic and conceptual understanding of the procedures, because they had difficulty in concretely visualising the meaning of a fraction in resistors sharing electrical energy for parallel connections (Sadi, 2007).

I observed an inconsistency in procedure required for calculation of such a combination (series and parallel). This response prompted me to question the approach of this cluster, and hence I nominated S8 for interviews. The following interview serves to clarify what this pre-service teacher wrote.

Interview with S8

Researcher: Explain why you provided two calculations.

S8: *I wanted to calculate the resistance of the circuit as a whole. These are two parallels found in this circuit.*

Researcher: You have used $1/R_T = \frac{1}{R1} + \frac{1}{R2}$ and $1/R = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$ in the two calculation, why?

S8: *I was trying to get a correct answer.*

S8 had an idea of how to calculate total resistance when resistors are connected in parallel. However, calculating a reciprocal of total resistance in each branch did not display a proper meaning. It appeared that S8 was confident with the approach to these calculations even though there was a state of uncertainty about reciprocals before the final answer is arrived at.

Researcher: You start off the part in calculation, explain this.

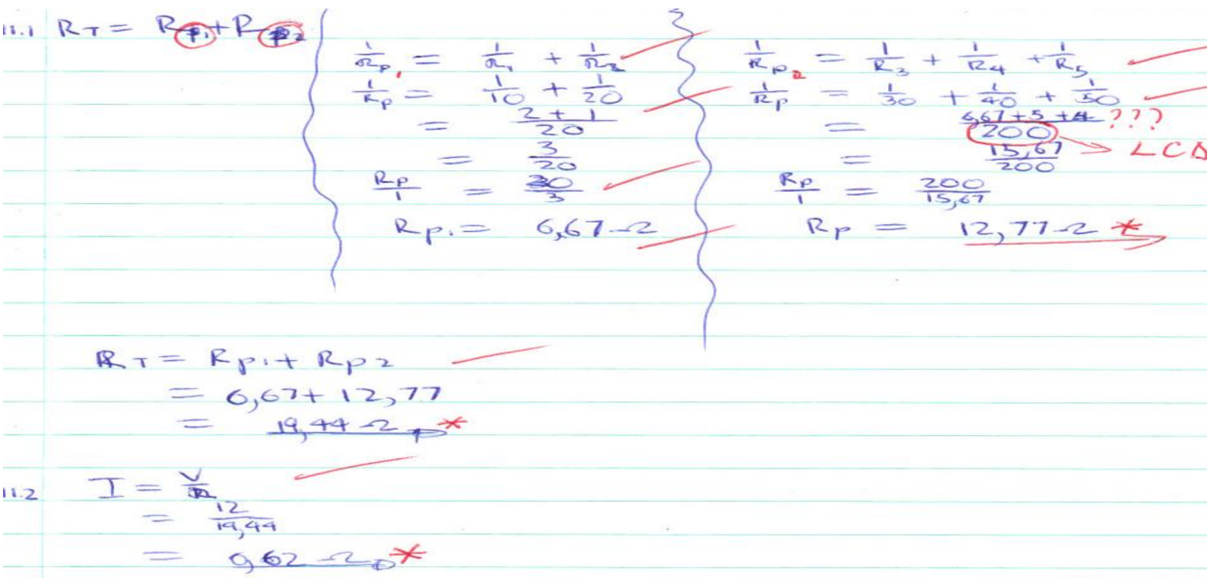
S8: *I have made a mistake on calculation number 1. I mentally cancelled 10 and 20 by the small number which is 10.* $\frac{1}{20}$ *Resulted in* $\frac{1}{2}$.

Researcher: You wrote $\frac{3}{120}$ = 40, is this correct? Explain.

S8: *It is correct when a person is reducing numbers into workable quantities. When you divide 120 by 3 you get 40*

I observed a deficiency of knowledge of fractions, and the authentic approach to calculation as well as computation of given data was cumbersome. This cluster had evidence of a similar trend, indicating a shabby foundation in fractions. S8 showed that he was confused about which number was the divisor and which the dividend.

Cluster B



Text 4: Written response of S13 to illustrate cluster B

We observed that cluster B's written responses to this question had a similar approach in separating calculations for each branch. This shows uncertainty; S13 scratched out numbering and no relevant notation was used to differentiate each calculation.

There seemed to be confusion in working with accumulating resistors in cluster B. There is no evidence of the logic and conceptual understanding of the procedures in finding a common denominator for branch A and branch B. This response depicted the inconsistency in a mathematical problems approach that participants encountered during problem-solving in accumulating loads. A 200 value of denominator for branch 2 in cluster B has no foundation as a common denominator in this situation. Participants were lacking strategic conceptual adaptive reasoning, as they were struggling to interpret such combinations of load typology into arithmetic cognitive flexibility demands (Kilparick, Swaford & Findell, 2001).

Interview with S13

Researcher: Explain why you provided two calculations.

S13: *I provided two calculations because I had two parallel branches and I couldn't calculate the total resistances in only one resistor.*

Researcher: You scratched out $R_T = R_1 + R_2$, why?

S13: *I did this because I had made a mistake. I wrote R_{S1} and R_{S2} which I thought will confuse at the end, and then I opted to use R_P denoting parallel.*

Researcher: You provided 200 as an LCD for = $\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$, how did you arrive at this?

S13: *This is the first number to come as a result of the two bigger denominators when they are multiplied.*

Researcher: How do you link a calculation of R_T at the beginning with an actual substitution of values in $R_T = R_{P1} + R_{P2}$?

S13: **S***ince I had two parallel branches I knew that I had to first calculate them separately and add them thereafter to get the total resistance. Identifying branches as P_1 and P_2 had not much significance as the logical approach was done in calculating branches individually.*

In cluster B the pre-service teachers had an element of certainty about fractions. When conducting an interview with pre-service teacher S13, I could see some confidence and reasoning behind each approach. Nevertheless, the nitty-gritty of differentiating Lowest Common Multiple and Highest Common Factor was still a challenge, especially with big numbers and growing fractions. As I interviewed pre-service teachers from time to time, the response showed that no relevant notation was used to differentiate each calculation. It appeared that responses provided by pre-service teachers did not show the understanding of mathematical concepts required for electrical behaviour. Nonetheless, they knew that the approach for series and parallel calculations was not the same.

Proper use of formulas and effective use of calculators: Participants were supposed to identify the given information from the circuit diagram and arrange those data in an orderly manner. A less than average cohort was able to follow that sequence. However, an observation was that their computation of formulas was adequate although there were a number of formulas involved in calculating the quantities of different aspects (voltage, current and resistance). Participants depended on calculators more than mental arithmetic. Calculators were able to handle whatever data were processed after computation of given information, and gave other values to those which were procedurally calculated using procedural and conceptual knowledge.

As a result of academic competency, those who were able to identify relevant information were able to manipulate formulas effectively and their utilisation of calculators did not have a negative effect on correct answers. Those who mastered a manual calculation could not draw inference of proper fractions to decimal fractions, hence experiencing challenges on quantifying outcomes (e.g. 600/47 for the total resistance in branch B) for further calculations.

5.3.2.2.2 Handling operations of exponential numbers

An understanding of Table 6 was the key to exponential numbers**.** The application of quantitative values of prefixes and the interpretation of factors into symbols was paramount in conceptualising SI symbols for number operations in Electronic Systems. However, questions 2 and 4 in 4.5.1.1 provided a current in 100 mA, which demanded an understanding of the value in terms of 10^{-3}. There were challenged as to how to simplify the value of a current for calculation purposes. They attempted the algebraic rules for exponential numbers but could not apply them any further than 10^{-3}. Instead they omitted a negative exponent, and others confused it with a positive exponent (10^{3}). There was no prohibition of calculators in the exercises, but observation indicated that manipulation of numbers on calculators could not provide a proper procedure in respect of algebraic rules for exponential numbers, resulting in participants giving incorrect answers in questions 2 and 4 related to current.

5.3.3 Measuring instruments

I found it interesting to note that introduction of measuring instruments and orientation captured the interest of most participants. Although metrics, the SI unit system and the habituation of practical implementation sections possessed elements of theory and rote learning, participants had a feeling of involvement when they experienced the interrogation with breadboard and multimeter.

Participants were organised into groups of four members at the initial stage of phase 2. This was purposely done to initiate co-operation, sharing of ideas and collegiality. A level of the Mathematics language of participants underpinned concern surrounding the linguistics of conceptual approaches to Electronic Systems. Practicals and active participation supported the corollary that mastery of the basic conceptual approach was needed by participants. Academic and social development of participants in their groups introduced them to a rich instructional experience that incorporated Mathematics with Electronic Systems in the broader sense based on the premise that learners develop an improved Mathematics language through using it in line with tangible objects (McDermott, 1992).

5.3.3.1 Group work

Participants were compelled to work in groups although there was no prescribed format for sitting. Initially very few members worked on the tasks spontaneously, but assumed the traditional class role where learning was led by the teacher not group members. Participants were used to these groupings only in forums that were generally engaging them for social talks and debates, and were thus influenced by the rigidity to pursue action learning for practical involvement. They had some difficulties in adjusting to personalities while they were working on problem-solving tasks, even after tuition. It was insisted that choosing a person to work with, irrespective of gender and nationality, was a voluntary exercise that needed to incorporate maximum common time. The intention was to avoid the ‘I don’t want to work with this person/I can’t work with this person’ syndrome. This seating arrangement was purposely done to allow all individuals to acquire meaningful knowledge pertaining to the subject, and as an effective approach for better understanding. Making groups of four members had potential to produce desirable results, since all individuals in the groups could be awarded equivalent opportunities (Nkuna, 2007). This gave participants enough knowledge in actions required for Electronic Systems (McDermott, 1992).

5.3.3.2 Multimeter

A digital multimeter (Figure 8) was selected for its multifuntionality. This device was able to measure voltage, current, resistance, capacitor, frequency, semi-conductors and temperature. A compelling challenge was regarding the sophistication of various types of multimeter. It was essential that procedures and principles of operation were made vividly clear to participants as an elementary design requirement as indicated by Scholz and Prede (2002). All participants were made aware of the importance of manual ranging within a selected function (volt, current, Ohm scale) before embarking on the particular measurement. A researcher went through different parts of the meter to reveal its essential functioning. To mention a few of these:

- Digital display – depicts a reading of whatever measurement is taken on the project.
- Selector switch – is used to select the correct function for the task in a project. This requires a correct setting before any measurement is taken.
- Measuring leads connector socket – serve as inputs for the measuring leads. Emphasis is placed on colours, where a red lead should be placed into a socket marked V/mA and the black lead into a socket marked Com. Imperatively, a red lead should only be placed into a socket marked 10 A/DC if a very high current is measured (Table 5).
- Transistor tester – this socket is used for measuring the gain of a transistor.

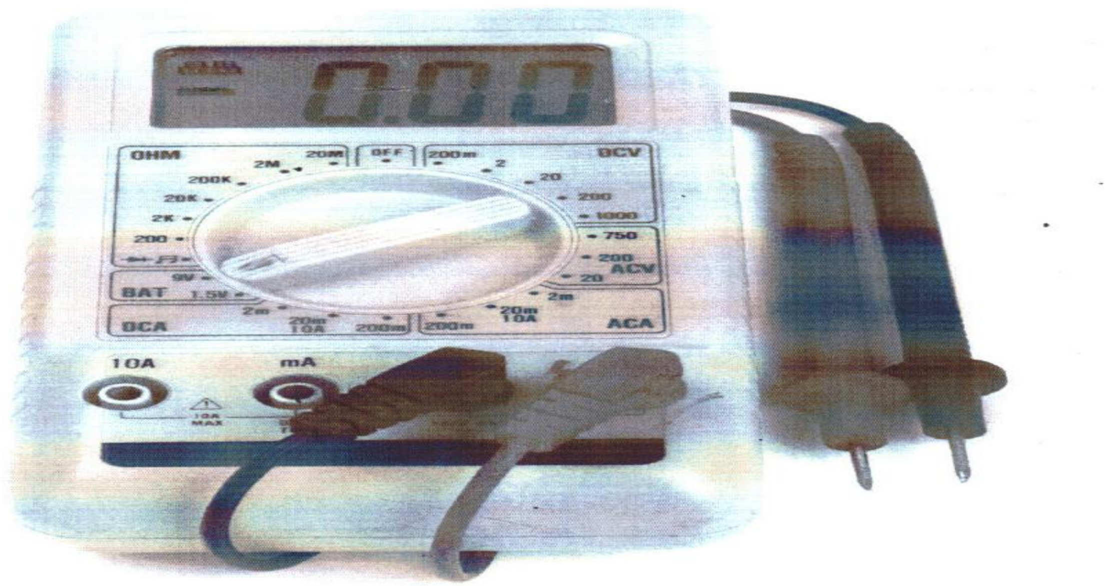


Figure 8: The multimeter

5.3.3.2.1 Principles of operation

Participants developed an interest in knowing more about the multimeter. Although there were tasks to research about a few details of the multimeter, it was important to indicate some highlights that make distinction between an analogue and digital meters. Multimeters use a liquid crystal digital display (LCD) to show the information measured (Scholz & Prede, 2002), where the unknown analogue signal is measured and converted to a digital signal (termed A/D) when measuring voltage.

Terminologies were now applicable in a practical way, as indicated in the theoretical application. However, for voltage measurement in a circuit or across a component it was emphasised that probes should be connected in parallel with the load, with the red lead connected to the positive side of the circuit and the black lead connected to the negative side. For current measurement, it was made clear that the probes were to be connected in series still maintaining the red and black leads appropriately with their colors. For unbiased resistance measurement, resistance was supposed to be removed from the circuit completely, and it should be measured when the resistor is autonomous to the operation and the probes connected in parallel with the resistor.

Both the theoretical and mechanical approach to Electronic Systems yielded to Mathematics connotations, since they required specifications and adherence to safety of persons and equipment (see 2.8 and Table 5). It was paramount to make use of a correct scaling in all quantities to be measured e.g. a DC and AC current (McGowan, 2012).

5.4 Recommendations

Mathematical connotation in the circuit analyses is crucial for the theoretical understanding of internal operations. Since the internal operations require accommodative proportionalities, it is paramount that number operations are handled procedurally in their essence, particularly regarding the basic principles of operations, e.g. fractions, exponents, decimals, etc. and the invisibility of internal operation.

5.5 Conclusion

This chapter provided an analysis of the foundation of design in the Electronic System. It highlighted the area of calculations and of understanding the measuring instruments in the light of their usage. Chapter 6 provides an analysis of participants' behavior as they engaged with components in the simulation and the design process.

CHAPTER 6

DISCUSSION OF DATA: SIMULATION AND DESIGN OF ARTIFACTS

6.1 Introduction

This chapter provides analysis of the researcher's observation during group simulation. It highlights the major areas of considerations pertaining to the design of this project in Electronic Systems.

6.2 Component analysis

Groups were tasked to provide a presentation of components and their behavior based on the list of components covered in the EDTE 210 module. There was a need for participants to interrogate component characteristics and their behavior. A task was given to the pre-service teachers, who were to investigate behavior of each component and to provide a scholarly explanation for each. The components were: (a) variable resistor, (b) carbon resistor, (c) light-dependent resistor (LDR), (d) thermistor, (e) diode, (f) light-emitting diode (LED), (g) transistor, (h) relay, and (i) capacitor. Components were strategically arranged as conductors and semi-conductors. In the submission of their tasks no group indicated a graphical representation of any component. However, their verbal response indicated that they could not comprehensively interpret the relationship found on axes of graphs, and that their graphical understanding was limited to linear representation.

6.3 Observations during presentation

Groups provided a detailed verbal description of components. They (groups) could not locate commonalities that could allow them to cluster components into families, e.g. family of resistors, family of switches, family of energy storages, etc. Nevertheless they could spot identical fixtures in colour codes used for both capacitors and resistors.

6.4 Ambiguous areas in components

6.4.1 Colour codes

It was cumbersome to pre-service teachers in that colour codes were the same for capacitors and resistors, yet capacitors support current flow and resistors oppose current flow. Some pre-service teachers challenged the fact that the capacitors and resistors were not using colour codes but still belonged to the respective categories. Some groups provided knowledge that they received during their research with a minimal connotation to design. Groups tasked individual members to prepare equivalent portions of components for presentation instead of a representative member to present all components on behalf of related groups. A remarkable presentation was made by group 9 in their illustration of the relationship between resistors and capacitors. Figure 9 is used to illustrate this relationship.

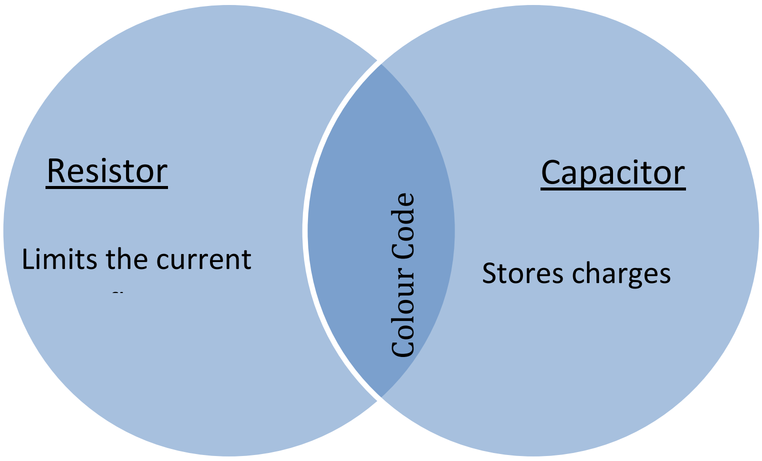


Figure 9: Illustration of similarities and differences between resistors and capacitors

After S16 completed his presentation on relationships, I observed that a lot of theory was used to highlight these relationships. I ask questions that would identify other dimensions about the two components during the interview.

> **Researcher:** If these components were to be connected in a circuit, what significance will they provide?
>
> **S16:** *A resistor will always oppose a current that will be flowing in a particular circuit, while a capacitor would be storing charges when the circuit is operating.*
>
> **Researcher:** Why would you want to oppose a current instead of reducing your supply voltage?
>
> **S16:** *Not all parts of the circuit will need a limited current but certain parts will.*

Researcher: Can you mention a specific part of the circuit that will require a minimised current?

S16: *I think will it depend on a designer, we cannot speculate it offhand unless we in a process of design.*

This was an abstract description with a non-transferrable understanding, but revolving around understanding of behavior of individual components.

6.4.2 LDRs and thermistors

Although groups demonstrated a well-researched explanation of LDRs and thermistors, their dilemma was on factors influencing LDRs and thermistors. Groups underlined that both LDRs and thermistors were able to complete or isolate circuits, but their operations depended on either light or temperature.

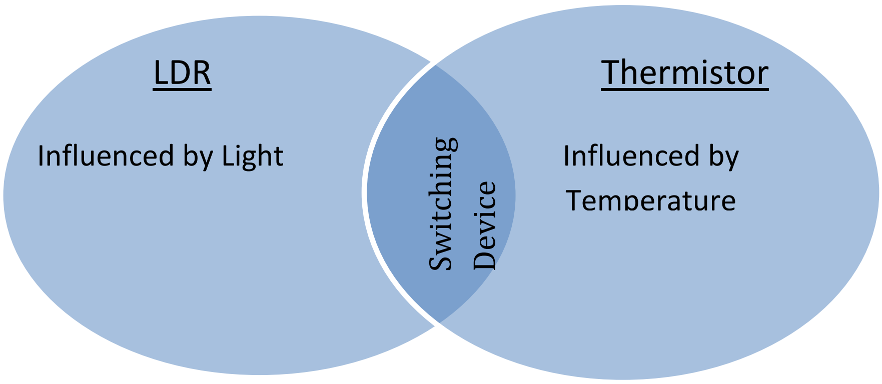


Figure 10: Illustration of similarities and differences between an LDR and thermistor

I discovered that these components were unpopular with pre-service teachers. They kept on referring to me during their research stage, wanting to be sure of the application and the appearance of these components. The Technology department was compelled to exhibit these components as part of tuition, so that participants could have a feel for them. Amazingly, they were surprised to see the sizes of components in comparison to their function:

S37: *How come that such a small thing is able to control lights with an enormous voltage without blowing?*

I referred them to the presentation of group 2 where they indicated that an LDR is influenced by light and a thermistor is influenced by temperature. As an element of surprise, pre-service teachers were inquisitive of how components are protected against electrical damage. A simple demonstration was done to experiment an identification of various components, proper connection of components on a breadboard and relevant measuring units for each kind (e.g. measuring potential of a cell, resistance of a carbon resistor, capacitance of a capacitor etc.). In preparation for simulation in phase 3, a table of components and their symbols was highlighted (Figure 11).

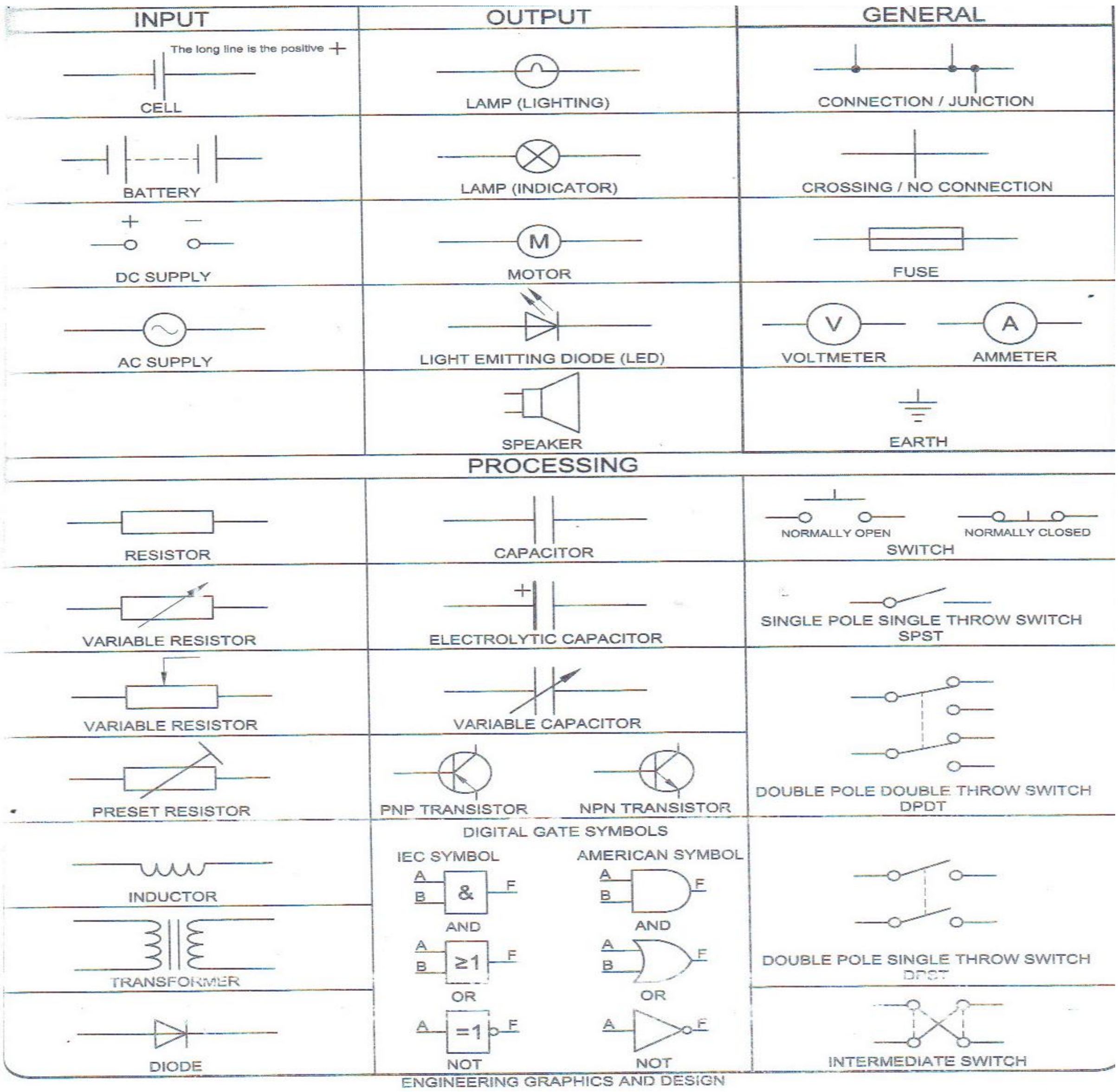


Figure 11: Scan of electronic symbols

6.5 Areas of importance

There were three areas of importance that were highlighted during the presentation and discussion: (a) storing of charges, (b) controlling of charges, and (c) the switching devices.

6.5.1 Storing of charges

The capacitor was identified as an essential component for energy storing in conjunction with the battery. Groups scrutinised a capacitor as a device that stores electrical energies as a result of two conducting plates separated by a dielectric insulator. During demonstration I had to move around to see how groups were managing tasks. I kept on asking questions that provoked checks and balances to ensure that objectives of each lesson were accomplished.

Interview with Group 3

Researcher: Explain what the difference is between a capacitor and a cell.

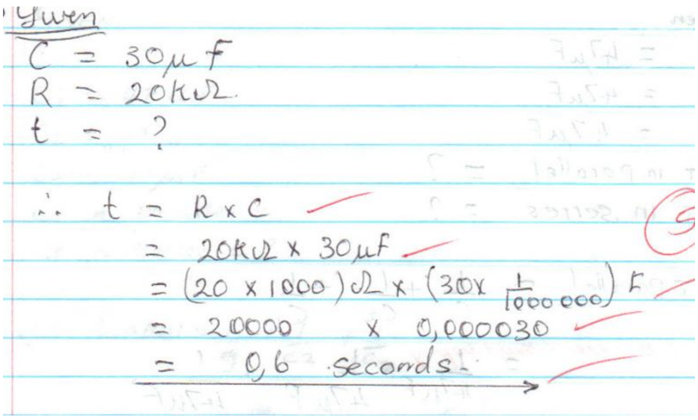
S26: *...No chemical solution was deposited to a capacitor and it could only store electrical energy after the energy was initiated from a battery of cells. Polarity on the capacitors are sometimes shown by legs, legs are not of the same length while identification of polarities in cells are clearly signposted on the outside of cells.*

It was interesting to observe that pre-service teachers were of an understanding that a cell depended on the chemical solution to provide electrical energy while a capacitor would be subject to electrical charge delivered, spurring the operation of the circuit. The group insisted that a capacitor would not keep these charges for a long time but the storage would depend on its capacitance. Pre-service teachers termed capacitor plates as ‘legs’ and identified that connectors of plates were not of the same length. These connectors were differentiating a direction of the flow of charges.

Theoretically groups mentioned that electrons flow from the negative terminal of the battery to the one plate, allowing it to be more negative. Electrons are attracted from the other plate to the battery, making it deficient of electrons and becoming positively charged. This process takes place when a capacitor is connected to the battery through the circuit. All groups omitted the determination of capacitance and time, which was an essential element in the identification of components for design. This was a proper determination of a capacitor's conductivity in a crucial selection of a capacitor value.

It was paramount that Q = C × V be brought to their attention, where C is the capacitance measured in farads and V is the potential difference across the plates, while Q refers to stored charges.

Pre-service teachers were given an exercise as part of their tuition. While they were working on the exercise as groups, I kept on asking questions around their endeavour. I noticed a response provided by group 11 after they completed an exercise.



Text 5: Written response of group 11 to illustrate a calculation of a time constant

Interview with S11

Researcher: What is a significance of identifying a correct formula?

S20: *A formula provides a guideline in a required procedure to follow when we were calculating. I think a formula is developed after experimentation and is provided as a theory behind the outcomes for that matter, a right formula will provide indicators for the correct answer.*

Researcher: Why is it important to manipulate the subject of the formula?

S23: *It is not always the case that you will be required to calculate a time constant as it given in No. 3. You may be required to calculate a resistance or a capacitance as the need arises. Manipulating a formula to me is like knowing how to synthesise a formula and to separate a formula correctly according to arithmetic principles. It is important to do it the correct way so that it will yield to a correct answer through a correct procedure.*

Researcher: How do you ensure that the answer is correct?

S3: *Firstly: is to know a relevant formula off by heart. Secondly: to convert factors properly according to the requirement of the formula. e.g. kilometres, micro, centi etc. Lastly, is to be careful in the substitution of the formula and to know elements that are involved in the section you are dealing with.*

Researcher: What are the implications of arriving at a correct answer?

S16: *To score all the marks. We need to be sure that when we choose a capacitor for a circuit, it is within a range of a power supply. There is no need of using a small or a big capacitor that will not be relevant for a circuit to function.*

Pre-service teachers were able to provide an understanding of components found in the calculation of time constant. In their explanation of components involved they said a farad is regarded as a capacitance of a capacitor when a charge of one coulomb of electricity charges the potential between the two plates by one volt, while the factor used to measure the time taken to charge a capacitor through the resistor circuit is termed a time constant (McGowan, 2012). In calculating time constant $t = R \times C$ where't' is time in seconds, R is resistance in ohms and C is capacitance in farads.

Interview with Group 6

Researcher: What is meant by time constant in capacitors?

S35: *Is the time that a capacitor would need to charge up when connected to the working circuit.*

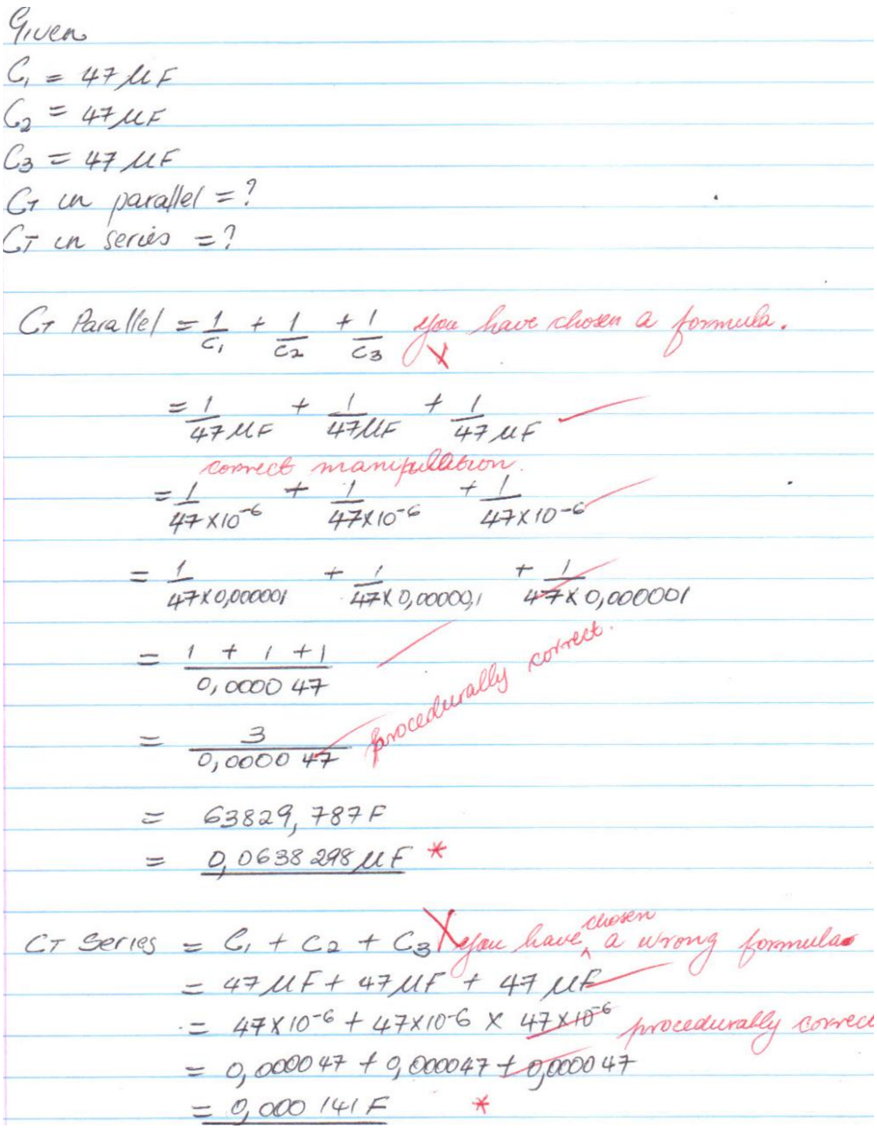
Pre-service teachers did not include a graphical representation of their explanation in showing a relationship between charge and time constant.

Interview with Group 6

Researcher: Why is it important to calculate time constant in capacitors?

S 24: *…amount of time that determines the ability for a capacitor to charge up or to discharge may assist in storing charges in case of voltage supply failing to sustain the circuit.*

Groups argued that when capacitors are connected in parallel, they will possess fixture of resistors connected in series, as indicated in 4.2.4.1.1.1 series combination, while capacitors connected in series will possess fixture of resistors connected in parallel. Figure 14 illustrates a response of group 8 when they were calculating three capacitors in both a parallel and series connected arrangement.



Given
$C_1 = 47\ \mu F$
$C_2 = 47\ \mu F$
$C_3 = 47\ \mu F$
C_T in parallel = ?
C_T in series = ?

C_T Parallel $= \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ you have chosen a formula. X

$= \frac{1}{47\mu F} + \frac{1}{47\mu F} + \frac{1}{47\mu F}$

correct manipulation.

$= \frac{1}{47 \times 10^{-6}} + \frac{1}{47 \times 10^{-6}} + \frac{1}{47 \times 10^{-6}}$

$= \frac{1}{47 \times 0{,}000001} + \frac{1}{47 \times 0{,}000001} + \frac{1}{47 \times 0{,}000001}$

$= \frac{1+1+1}{0{,}000047}$

$= \frac{3}{0{,}000047}$ procedurally correct.

$= 63829{,}787\ F$

$= 0{,}0638298\ \mu F$ *

C_T Series $= C_1 + C_2 + C_3$ X you have chosen a wrong formula

$= 47\mu F + 47\mu F + 47\mu F$

$= 47 \times 10^{-6} + 47 \times 10^{-6} \times 47 \times 10^{-6}$ procedurally correct

$= 0{,}000047 + 0{,}000047 + 0{,}000047$

$= 0{,}000141\ F$ *

Text 6: Written response of group 8 to illustrate calculation of capacitors in parallel and series

I observed that about 25% of the groups were confusing a calculation of equivalent resistance in a parallel and a series circuit with an equivalent capacitance in series and in parallel as shown in Figure 14. I conducted an interview with group 8 when I was doing random check.

Interview with group 8

Researcher: why did you calculate equivalent capacitance in parallel in the form of a fraction?

S15: *I believe that for parallel calculations we need to represent our items in a fraction form; capacitor are connected in parallel and require this approach.*

Researcher: When do you think it is necessary to calculate an equivalent capacitor?

S15: *... when there is no single capacitor, we can combine different capacitors to form a desired value.*

I observed that a confusion of formulas by some pre-service teachers did not strain mathematical skills required for parallel and series calculation in general. However, it was paramount for pre-service teachers to take into cognizance the issue of characteristic behaviour of a component when there are employed in designs of particular circuits.

6.5.2 Controlling of charges

The two categories of components to facilitate charge control are (i) the resistor family (variable resistor, carbon resistor) and (ii) the semi-conductor family (diode and light-emitting diode (LED)).

6.5.2.1 Resistor family

When charges flow through a resistor, electrical energy is converted into heat energy allowing electrical power to be degenerated, justifying linearity between current and resistance in the circuit. As groups were presenting assertions about resistances, they underlined that resistors are used to protect the next component against charges from the source. Among many uses, resistors are used to divide voltage to split current. Resistors could be added either in parallel or series connection in the case of providing equivalent resistor value.

Resistors were considered under two categories, fixed and variable resistors. Basic information pertaining to fixed resistors was provided since it encapsulated numerous implications for a positive asymptote. Emphasis was not placed on the actual manufacturing but on the characteristics and operation of the resistor in the circuit. For fixed resistor, colour code was the point of departure as an international standard for identification. Codes were displayed as selected coloured bands encircled on a particular resistor. Table 7 was used to clarify arrangement of colours.

Resistance values (First three bands)	Tolerance (Fourth band)
Black = 0	Brown = 1%
Brown = 1	Red = 2%
Red = 2	Gold = 5%
Orange = 3	Silver = 10%
Yellow = 4	None = 20%
Green = 5	
Blue = 6	
Violet = 7	
Grey = 8	
White = 9	
Gold = +0,1	
Silver = +0,01	

Table 7: Resistor colour code

Analysis of resistors was that the first two bands were representing digits while the third band suggests the number of zeros and the fourth band represents the tolerance of the resistor. I observed that groups were able to identify mathematical adaptations in resistor values based on colour codes. When resistors were given in colours, groups were able to provide resistor values, as that was a criterion for collection (Table 8).

Colour codes	**Brown**	**Green**	**Orange**	**Gold**
Values	1	5	3	5%
Interpretation	1^{st} digit	2^{nd} digit	Number of zeros	Tolerance
Application	1	5	000	+0.1
Resistor value	15000 Ω			

Table 8: Illustration of colour code implication for group 10

Instead of writing 15 000 Ω, groups were able to apply mathematical skills of representing 15 000 Ω into 15k Ω which could be denoted by 15×10^3 Ω.

Group 2 was able to draw inference on Table 6 where prefixes and factors were essential to identify relevant symbols for a particular resistance value. As factor 10^3 implies 1000 in Table 8, exponents were made effective and applicable to Electronic Systems design when group 2 was selecting resistors required in their particular circuit.

Ultimately pre-service teachers were familiar with the use of prefixes, e.g. kilo, centi, milli, micro, etc., and factors 10^{3}, 10^{2}, 10^{-3}, 10^{-6} respectively as a required mathematical skill for problem solving in Electronic Systems design.

6.5.2.2 Semi-conductor family

During the session when we interrogated the semi-conductor family, pre-service teachers insisted that a diode only conducts in one direction allowing a current to flow from anode to cathode. The principle of doping prevailed in the manufacturing of the semiconductor diodes, as indicated in 2.8. Groups argued that the forward bias is evident when an anode is connected to the positive terminal of the battery of cells and the cathode to the negative terminal of the battery of cells, while the reverse bias is vice versa. This was concluded by group 4 when they experimented with this process after a great struggle to get their simulation to work. No group went to a terrain of numerical representation of operation of the diode, but they all insisted on the importance of polarities to effect forward biasness of both the diode and the light-emitting diode.

6.5.3 Switching devices

Generally it was observed that the pre-service teachers classified the switching devices into two categories: (i) environmentally influenced components; and (ii) power-reliant components.

6.5.3.1 Environmentally influenced components

This category entailed LDRs and thermistors as components that depend on atmospheric influence. Nothing much was said about the LDR, with the exception that it closes the circuit as the day becomes darker. It reduces the resistance in the dark atmosphere and increases resistance when it becomes lighter.

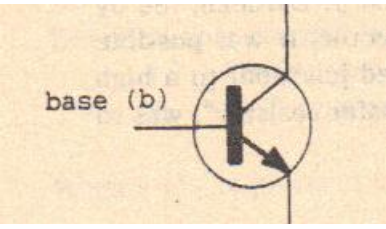
With the thermistor, temperature was the guiding factor that allowed for the forward biasness in the circuit through the thermistor.

6.5.3.2 Power-reliant components

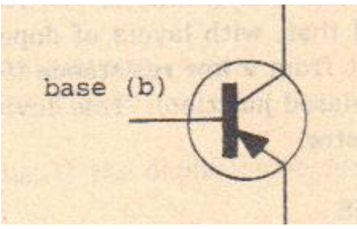
These components were described as those which operate under the influence of power supply. Typical components were transistors and relays.

6.5.3.2.1 Transistors

Groups were able to identify that transistors combined the P-type and the N-type materials to form the NPN or the PNP material, and that all factors of semi-conductors were dominating transistor formulations as they were analysed in 2.8. Groups further identified that the formation of transistors was the combination of two NP or PN junction semi-conductors, intersecting at P or N position, letting three terminals (emitter, collector and base) be available in a component. I recognized pre-service teachers' understanding of transistors when they drew and labelled relevant symbols (Figure 13).



NPN transistor symbol



PNP transistor symbol

Figure 13: Illustration of the NPN and PNP transistor

When the question was thrown to the cohort generally about understanding of the base and the function of it on a transistor, S 11 said:

> *I guess a base is a position where anodes or cathodes of two transistors are connected to form the third leg of a transistor component but I am open to criticism. I hope two transistors may be used instead of a transistor, I don't know how.*

I was convinced that pre-service teachers' understanding was appropriate when they identified the location of the base terminal irrespective of the NPN or PNP semi-conductor. Furthermore their enthusiasm in providing detailed explanations of relevant functions was an indication that they were clear about the reason for such formulations.

6.5.3.2.2 Relays

Groups did not delve much into the operation and function of a relay, and could not link it to reliable functions of the circuit operations. Relays operate under the principle of magnetism. In the process of induction, substances that can be magnetized contain permeable material called dipoles (Hall & Hall, 2004). Permeable material is placed inside the coil, allowing dipoles to align with magnetic lines of force produced when a direct current passes the coil. All groups analysed components in words and pictorial drawings with a very shallow numerical connotation.

6.6 Simulation

A clear understanding of drawings was paramount in phase 3. Drawing is a method of communication that serves Technology for communicating ideas in the form of graphics language. Graphics language will entail universal and standardised methods of graphics communications without verbal utterances. Drawing skills were paramount to pre-service teachers for them to be able to read and interpret circuit diagrams according to the South African Bureau of Standards code of practice for engineering drawing set out in SANS 10111 – 1. Table 9 provides some code of practice in relation to electrotechnology pertinent to Electronic Systems.

Standards	Description
DIN/VDE 0611-1 (EN 60 947-7-1)	Low-voltage switching devices, terminals for copper conductors
DIN/VDE 0660-210	Low-voltage switching devices; safety of machinery; electrical EMERGENCY-STOP devices: safety-related construction regulations
DIN 19226	Open and closed-loop control technology, Part 1 to Part 6
DIN 40719	Circuit documentation, Part 2: Identification of electrical equipment
DIN/EN 50011	Industrial low-voltage switching devices; port identifications, reference codes and code letters
DIN/EN 60073 (VDE 0199)	Coding of display and operating units by means of colour and ancillary means

DIN/EN 60617-2 (IEC 617-2)	Graphic symbols for circuit diagrams, Part 2: Symbol element, designations and other circuit symbols for general use
DIN/EN 60617-4 (IEC 617-4)	Graphic symbols for circuit diagrams, Part 4: Symbols for passive components
DIN/EN 60617-5 (IEC 617-5)	Graphic symbols for circuit diagrams, Part 5: Symbols for semiconductors and electron tubes
DIN/EN 60617-7 (IEC 617-7)	Graphic symbols for circuit diagrams, Part 5: Symbols for circuit and safety devices
DIN/EN 60617-8 (IEC 617-8)	Graphic symbols for circuit diagrams, Part 5: Symbols for measuring and signalling devices
DIN/EN 61082-2 (IEC 1082-2)	Electrical engineering documentation, Part 2: Function-related circuit diagrams

Table 9: Code of practice in relation to electrotechnology. (modified from Prede & Scholz 2002)

Although standardised codes were not used strongly for this module, these pre-service teachers were capacitated for research design for this project, and hence were made aware of them (code) as part of a universal language and a means to communicate specifics in packaging. Nevertheless, interpretation of components into symbols and the application of that information into circuit diagrams were key to simulation.

To instigate a sense of knowing the major steps for project design, I acted as a store man where members of the groups were to come to collect relevant components for each simulation. Simulations were grouped into units with different activities. Pre-service teachers were overwhelmed when fragmented portions of activities were integrated into simulations. Figure 14 shows the simulation of group 5; this was the group that struggled most with everything.

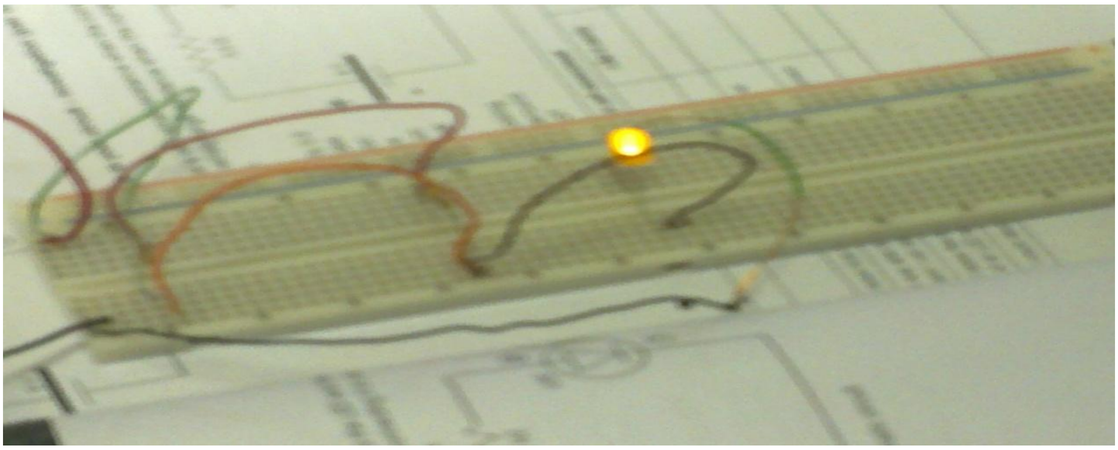


Figure 14: Simulation model of group 5

I ordered all groups to reflect on their experiences during the process of simulation accomplishment. Group five was pleased when their simulation worked, and their reflection is provided in Table 10.

Quick self-assessment			
	I did it easily	I did most of it	I tried but did not get it right
I knew how to connect an LED so that it lights up.			✓
I was able to use resistors in series to make an LED dimmer and I can explain the effect in terms of electric current.		✓	
I knew the effect of using resistors in parallel on the brightness of an LED and I can explain it.		✓	
I could describe the effect of placing a diode in a circuit		✓	

Group comments: Our understanding developed through trial and error method. Until we follow a procedure, our LEDs stopped burning. We are know understanding the effect of parallel and series connection of resistors by looking at the brightness of LED and by the measurement using a multimeter

Table 10: Group 5 assessment of a simulation process

I observed that a theoretical approach to parallel and series connected circuits was ambiguous to pre-service teachers until they interrogated practical experimentation. In 5.3.2.2.1, when pre-service teachers were working on arithmetic principles of connections it was not clear to them that a current is common in a series circuit but divides in a parallel circuit. As part of a classroom experiment groups connected accumulating bulbs (ranging from one to four bulbs) in a series format. It was observed that when we increased the number of bulbs, the brightness was reduced even further. When the same bulbs were accumulated in parallel, there was no change in brightness. A comment provided by pre-service teachers was that:

> **S 30:** *Series circuit shares the voltage among all bulbs. As bulbs increased, voltage was decreasing but in the parallel circuit an opposition of a current was less on the fact that a current had options of flowing to other branches.*

I recognized that the simulation exercise emphasized effective identification of components, proper terminology used to describe components, and the interpretation of circuit diagrams into simulation circuits. Pre-service teachers gained confidence as they gradually participated in more challenging simulations, as groups were not frequently consulting. In the process of developing simulation groups, they were taught the proper way of calculating and measuring resistances, capacitances, voltages and currents within one circuit. Pre-service teachers discovered that values found through calculations and those found through measurement concurred, which gave them an assurance that calculations are paramount for design.

6.7 Design of artifact

The design of artifacts required pre-service teachers to apply a design process. There was a need for pre-service teachers to work as a team in accomplishing the final product. This exercise compelled pre-service teachers to have one common goal in each group. They were compelled to engage on all aspects of design, as stipulated in 1.5. All information acquired from the previous activities (simulation exercises) assisted the pre-service teachers to navigate through essential design processes. Figure 15 illustrates the iterative approach to the design of artifacts.

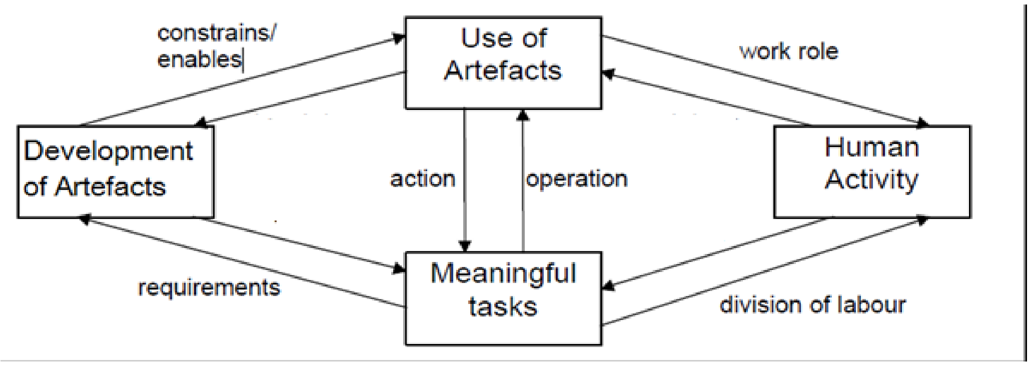


Figure 15: Iterative approach of pre-service teachers to design of artifacts (modified from Wasson & Mørch (1999))

Groups had the mammoth task of incorporating different aspects of design into artifacts. Knowledge of graphic design was also paramount to actualise the meaningfulness of developmental stages of artifacts. This approach touched on issues of isometric drawing, orthographic projection drawing and perspective drawing trends, to put what was in the mind onto paper in consultation of all knowledge, skills and the assumption of the groups. The design of artifacts was creating a scenario where pre-service teachers were challenged to provide a technological solution to crime within the context of advancement of Technology.

Unity was important to synchronous interaction between group members' activities and it facilitates collaboration through maintaining awareness, coordination, communication and information sharing since there was a noticeable diversity in their academic abilities. Groups were expected to design circuit diagrams and verify their diagrams with me (researcher) to check if symbols were used appropriately and equivalent values were selected for their design. Illustration skills were paramount to portray a true imagining of a single room with at least one window and one door. Nevertheless, the main focus for groups was on the circuit diagram of an alarm system fitted in the room. Groups ended up providing pictorial drawings alongside with circuit diagrams to enhance their conceptual understanding of the components and their application in a circuit. It is, however, difficult to conceptualise a mechanism of operation when a circuit is connected. I kept on referring them back to circuit diagrams when they came for consultations in trying to explain their previous steps. A typical example of a connected circuit is shown in Figure 16 below

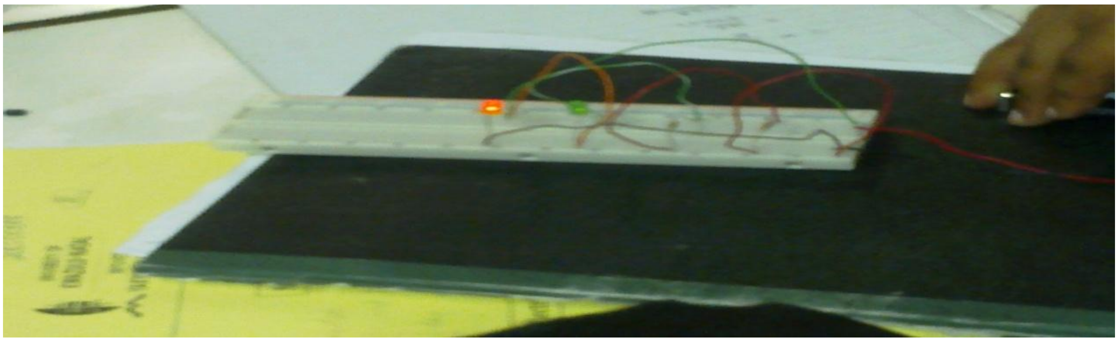


Figure 16: Simple connected circuit

A challenge was posed to pre-service teachers when they were issued with a problem without prescription of a routine. However, groups were encouraged to consult companies and/or electronics shops for research around alarm systems to enhance their understanding. Groups were expected to collect as much information related to the development of the alarm system as they could. Information accumulated during research of components' behaviour needed to be enhanced with new knowledge from specialists. This approach was expected to provide a multi-view of how a circuit is designed and/or what the circuit entails in order to fulfil the desired outcome. Groups also came with complicated circuit diagrams that were exceeding the estimated budget. Although they had wonderful designs, financial constraints and the suggested list of components provided limitations on their decisions about the project.

As groups came for consultation I observed enormous interest of wanting to produce a working artifact. After discovering huge damage to buzzers and LEDs when they were simulating their designs, I kept on referring them to quantities of measurement and calculations in their designs in order to focus them on content and suggest specifications for design of artifacts. Most groups saw a challenge in defying procedures even after their design was approved. Findings from their visits were complicated circuits that needed to be narrowed down into at least a single room with one door and one window. When groups were assembling their projects, the issue was a dry joint that provided discontinuity. It was a struggle to conduct a fault-finding exercise. Nevertheless, this focused their skills on the effective use of measuring instruments, as illustrated in 5.3.3 in Figure 8.

Figure 17: Elimination of a multimeter by group 6

Figure 17 shows group 6 struggling to assemble their project. There were trying to visualise a discontinuity after soldering. I discovered that they were using trial and error. When asking them the reason for doing this they said “on the breadboard this project worked, but after soldering there is no buzz going on”. I asked if they tested continuity; they said “but it worked. There is no need of it not working now if the buzzer went on initially”. After insisting on the continuity testing, they discovered that components were not connecting properly on the circuit boards. Some groups preferred to stick to doing both a simulation of their final design of the artifact concurrently with the actual artifact.

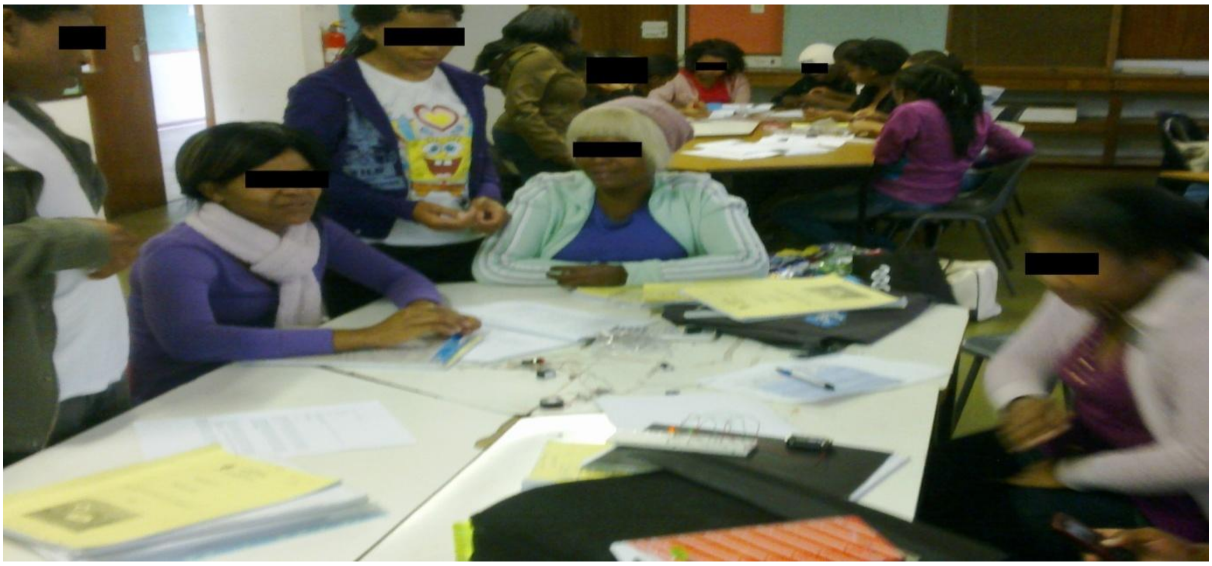


Figure 18: Group 1 completing a project in collaboration with simulation of artifacts

Figure 18 shows group 1 members, who assembled from their simulation in order to complete a working project. All groups knew that I expected then to account for all steps and phases they went through. I had a very tight schedule during this period. Most groups provided a number of ideas that assisted them to come to the final solution. They drew circuit diagrams with relevant symbols and voltages required to operate circuits.

6.8 Conclusion

This chapter looked at all aspects of design that emanated from the knowledge of components and simulation. It highlighted similarities and differences in components after grouping them according to their characteristics. The following chapter focuses on the design of an artifact which incorporates circuit diagrams and a model of a house. It highlights aspects that were covered during the concluding developmental stages of the artifacts.

CHAPTER 7

DISCUSSION OF DATA: MODEL AND CIRCUIT DIAGRAM INTERPRETATION

7.1 Introduction

This chapter focuses on aspects of the model and the interpretation of circuit diagrams. The installation of circuit diagrams into model houses adopted during the process of design shows the pre-service teachers' approaches during the developmental stages and touches on aspects of design that took place as the project unfolded.

7.2 Aspects involved in design of a model

The main intention of introducing Technology to pre-service teachers was to prepare them for teaching Technology in schools, particularly to empower learners to be able to design for problem-solving purposes. A problem statement given to them was more demanding on graphics communication and following particular patterns as prescribed universally. Technological process and problem solving provides a common goal for Technology and Mathematics; hence the integration of Technology and Mathematics becomes essential for a working model. However, in the process of design there were three areas of importance: isometric drawings (three-dimensional drawing and oblique drawings); angles and measurements and shapes; and circuit diagrams and interpretations

7.2.1 Isometric drawing (three-dimensional drawing and oblique drawings)

It was essential for pre-service teachers to communicate their designs graphically where the manufacturing of their model was manifested mathematically, and where proportions and accuracy were depicted. The graphical representation was paramount to guide their models, as to where their circuits were going to be installed. Furthermore, graphical designs were relevant in describing shapes and sizes of their models without any ambiguity. As expected, groups were in a position to integrate cognitive and manipulative skills pertinent to design and communications through the combination of lines and symbols. However, their attempts were to communicate their models using isometric drawing and orthographic projection.

Isometric drawings are pectoral drawings that use three primary axes separated 120^0 apart from each other, while their depth and width axes are 30^0 away from the plane respectively (Engelbrecht, 2008). Submission of their designed artifact was accompanied by the portfolio file as evidence of chronology in their design. Pectoral drawings, photographs and measurements were included in their reports. Groups attempted to show their orientation of the models. They intended to provide 3D and orthographic drawings in order to indicate the development of the model and the installation trends of the alarm system. Nevertheless, their drawing for isometric objects used non-isomeric lines (which are inclined and neither vertical not at 30º), which made it challenging to affirm the true length of all the sides (Engelbrecht, 2008) and to predict the true size of the model of most of the houses. There was no evidence of training afforded to pre-service teachers when they engaged to this project design, since it was assumed that previous modules covered strength of materials and graphic communications.

Although there was an element of oblique drawing in their reports, groups' drawings were not qualifying precisely to categories of oblique drawings. Oblique drawings are also pectoral drawings and would have one side placed on horizontal and vertical lines as the main axes with a receding axes at 45º (Engelbrecht, 2008). This distinction of isometric drawings and oblique drawings is part of lettering used in the discipline of graphics and engineering as an international standard conveyed by the SABS Codes of Practice 0111 for engineering drawing and 0134 for building drawing.

Groups attempted to illustrate their plans of models in the form of civil drawing layouts. Their drawings attempted to show an elevation of the model, where the front views and the side views were identified. It was, however, remarkable that most groups did not stick to a single room but expanded to more than one room, which placed demands on their critical thinking capacity. When groups were striving to analyse their models, some employed orthographic projection, but there was an ambiguities in distinguishing between a first-angle and a third-angle projection. However, I observed that appropriate measurements were not evident in their actual models based on the non-isometric lines.

7.2.2 Overall completed artifacts

I observed that most groups did not pay much attention to elevation of their models. However they eliminated the gist of their graphic communication as stipulated in the SABS code of practice. Detailed plans of most of their model developments were not included in the portfolio. Although their model houses had different roofs and different numbers of rooms, their endeavours were focused on the effectiveness of the alarm system and the aesthetic appearance of the house.

Figure 19: Different roofs used in design of artifacts

Different roofs were identified in their models, which indicated a proper knowledge of material and angles. Figure 19 shows houses with different roofs designed for the project. As an endeavour to instil a culture of reasonableness and proper workshop managements for safety, it was essential that I monitor groups when making their models.

I discovered that pre-service teachers could not identify much of the geometry during manufacturing of their models. Groups organised waste material to develop models, e.g. cardboard, cheap wood, etc. Their models were developed from plans as the basis from which their walls would be mounted. In observing different stages of their models, my attention was captured by the floors, walls and roofs.

7.3 Floor plans

About 80% of groups developed models with more than one room, as illustrated in Figure 20.

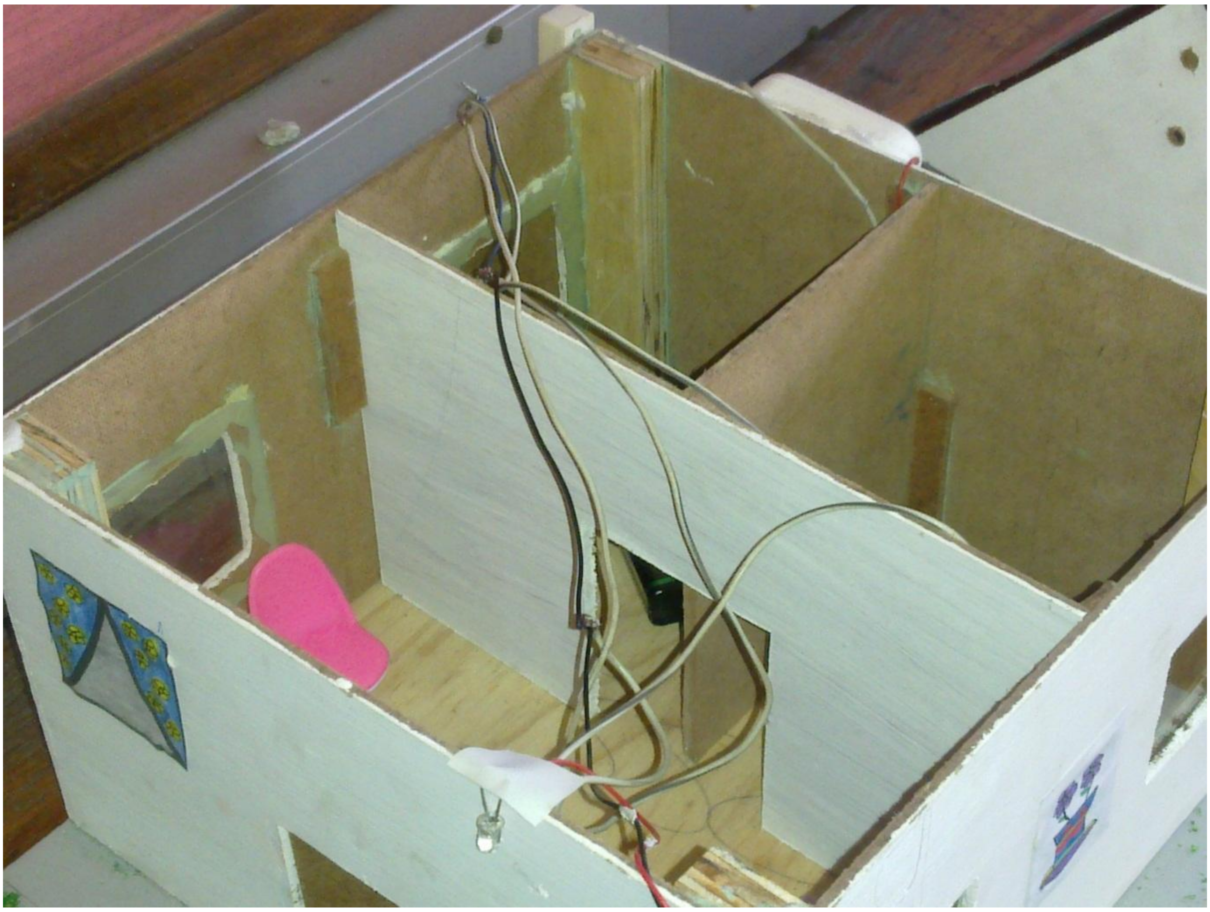


Figure 20: Typology of a floor plan

One remarkable thing about their floors was that on both drawings and walls corners were made 90º, which was an indication of accurate measurement as a basic essential skill for Mathematics. Pre-service teachers glued their walls on the lines marked on the plane, making their models proportional inside.

7.4 Walls

The roofs, sizes and shapes of their model houses were not the same, but the individual models portrayed a well thought out design. Cutting out of doors and windows was done from a whole piece of the waste material, and accurate angles of 90º were evident in the design of their corners (Figure 21).

Figure 21: Evidence of 90º cutting from complete wall of a model house

Irrespective of how groups were cutting windows and doors, directly opposing walls were congruent and similar in shape, making the gable sides suitable for a pitched roof in groups 5 and 3. I was interested in knowing the reasoning behind their approach in order to verify the Mathematics recognition applied to their design. I asked the following of the pre-service teachers as I was moving around:

(a) Did you involve any measurement when you were designing walls?

(b) Why was it important to approach the design of your walls in the way you did it, and how did you keep them in a similar shape?

> **Group 7: …***we were guided by the availability of material and we needed to cater for our circuit board. We traced the second side after constructing the first two.*
>
> **Group 9: …***we had to measure a reasonable size that will carry to and from school by public transport. In mind we knew we had to install a circuit board and buzzers and it should be easy for us to mount our circuit. The same measurement we used for the first sides were accurately used for another two.*

Groups responded differently, depending on how they drew their designs. They had different purposes in approaching the developments of their models, and that was observed in the models they produced.

7.5 Geometry exhibited in their models

Although groups used different types of waste material to develop their models, about 90% of groups produced similar-shaped model houses. I observed that models developed by pre-service teachers highlighted familiarity, by depicting township houses. Their models combined various geometrical structures, e.g. squares, rectangles, triangles and parallelograms. When groups were preparing walls, their cutting was done separately from the floor plan. It was paramount for pre-service teachers to do measurements, so that they could ensure proportionality between their plans and their model structures. Teamwork advocated division of labour among members of individual groups, as indicated in Figure 15, thus tasking all members according to their expertise. The following responses were provided by pre-service teachers when developing their models:

> **Group 5:** *It was essential that we provide two pairs of walls of our model in a similar shape, so that when I cut the gable part of the roof, we won't mix sides.*
>
> **Researcher:** How did you cut gable sides to an equal size?
>
> **S23:** *I divided smaller sides into two unequal sizes. I divided the smaller sizes into two equal halves. I then drew lines from the top marked centre to direct opposite corners that guided my cutting, that will create a gable in a form of a v- shape both sides.*
>
> **Researcher:** Did you measure a particular angle to form the gable that was in your mind?
>
> **S23:** *I intended to produce the same shape on gables that will carry a roof without a gap on the sides. Although it would be removed when we install the circuit, it should be accurate so as not to spoil our model.*

I observed that pre-service teachers wanted to showcase accuracy in their models. They had an idea of structural components, e.g. plans, walls, gable, etc., and that the importance of accuracy based on effective measurement and sameness indicated congruence.

7.5.1 Angles

Looking at the complexity of the model in group 10, I purposely measured corners of their model. I discovered that the corners constituted 90º and were forming proper parallelograms. A roof was constructed similar to the floor, where walls were mounted. Vertical opposite angles were identified in both the roof and walls. A roof constructed for the model in group 10 was congruent to the floor plan, making the roof suitable to fit accurately to a said perimeter of walls, and appropriate for a removable roof. In trying to verify angles identified in this model, the following questions were asked:

Researcher: Why did you make it flat?
S27: *We intended to model a house with an open space for entertainment*
Researcher: How did you ensure that the roof is overlapping accurately with walls?
S27: *We were guided by our floor plan. We started by drawing the floor and developed a roof according to the floor size. It was easy to than cut a roof according to size.*

7.5.2 Parallelism

Although groups provided different structures, the directly opposite walls of structures were parallel to one another. The gabled sides of individual models provided similarity and parallelism exhibited congruence on the isosceles triangle formed on the pitch of the gable. The height of the other two walls was equal to the base of the transverse line that identifies a gable of the model. In wanting to verify accuracy in maintaining sameness in height on the direct opposite side, an explanation that S23 gave was as follows:

S23: *I developed pair sides to be congruent to one another. The gable pair was longer than the other remaining pair, making the gable sides higher than the other pair. On the gable pair, is where I designed triangular shapes to form identical gables that would carry the roof.*

Researcher: Do you recognise any geometry in your design?

Group 3: *Yes sir, our pitched roof is forming a triangle and angles formed at the two opposite sides look alike. I wanted our pair sides to be the same in height and in width so that they will appear the same in size and shape. In order to avoid a challenge in roof design, we had to make our structure in a rectangular shape.*

Pre-service teachers showed different ways of developing their models. They were not conscious of the Mathematics skills behind their endeavours.

7.6 Circuit diagrams and interpretations

No specific size was prescribed for circuits in the groups, and their designs of circuit diagrams were unique. Solutions to a problem were guided by a designated budget of an average of R150.00 that needed to be spent for a project. Numerical skill was paramount when rating components. A component list with a receipt was required to validate a proper estimation of construction of the artifacts.

7.7 Algebra exhibited in the design of circuit diagrams

When groups were verifying the voltage required in a certain portion of the circuit, they were manipulating formulas, making the required entity a subject of the formula. Groups were able to estimate lengths of conductors required to cover a required perimeter for wiring the alarm systems in line with a ratio and proportion approach.

Figure 22: A member of group 8 estimates conductors required for wiring the model house

S31 of group 8 is working on the estimated length of wire required to wire their model. They were cutting wires according to the size of their model. Groups were able to interpret values of components in consultation with arithmetic conversions, e.g. a 47 µF capacitor = 47×10^{-6} farads = 0.000047 F

farads, 15000 Ω = 15×10^{3} Ω 15k Ω, etc. Pre-service teachers were able to manipulate reactance in circuits and apply outcomes into linearity of Ohm's law and conductivities.

Groups were able to plant components into their board. However, some projects (alarm system) did not work effectively. They attempted to draw a pictorial circuit to trace equivalent connections, but that did not work for all groups. At a later stage groups preferred to assemble circuits before they installed them into their model houses.

Figure 23: Typology of a circuit of an alarm system

A greater challenge was checking continuity using proper instruments; instead, groups preferred connecting buzzers for sounds, which was irritating and disturbing to other classes.

I observed that soldering was also a challenge; groups were either heating a board too much on the same spot or put little solder around the component's legs, ending up with a dry joint. Group 11 resorted to using a breadboard instead of a Vero board, as illustrated in Figure 24. Their circuit board was destroyed and could not provide continuity; they resorted to a breadboard, which alleviated their soldering challenge.

Figure 24: Use of a breadboard as an alternative to circuit board by group 11

While other groups were mastering the soldering exercise on the circuit boards, other groups were observing the proper way of doing it. I observed that the groups who were soldering first were doing great damage to their boards. Nevertheless, groups ultimately identified the appropriate, effective soldering on the basis of human activity as stipulated in Figure 15.

Engaging pre-service teachers in research of component behaviour was of great benefit since they could expect each component to behaviour in a particular way. Groups kept on referring back to their research projects for clarity. They could argue the positioning of the component with valid reasoning based on facts. All polarity components provided a challenge to most group members. They quickly expurgated legs in components before they were certain about connection and continuity.

Figure 25: Installation of an alarm system in a model of a house

It became easier for groups to expand connections to other parts of the room that needed security, e.g. windows and doors. This involved a mere extension of wires to other parts of the room, as evidence of a parallel connection, as shown in Figure 25.

7.8 Conclusion

Groups capitalised on the strengths of individual members to integrate their efforts. They identified all meaningful tasks that were paramount for the effectiveness of the artifacts. They identified roles and distributed labour-related tasks according to their potential. Ultimately they were able to develop working artifacts. The following chapter pays attention to the interviews that took place after their presentation of the working artifacts.

CHAPTER 8

FINDINGS AND RECOMMMENDATIONS

8.1 Introduction

The aim of this chapter is to provide findings and recommendations after the whole process of the design of artifacts was executed. As mentioned in chapter 4, this study is based on a qualitative paradigm in adhering to the process of qualitative research that seeks to understand and explain the nature of phenomena through the evidence of literature and data grounded on observations and interviews (Neuman, 2011). Qualitative participant observation and interviews were paramount to triangulate data on fulfillment of submission the working artifacts. This study took a period of six months, covering the duration of the module. It focused on all aspects pertinent to design, including graphical communications, mathematical proficiency and numerical representations.

8.2 Revisiting the critical research question

During the design and construction of an artifact in Technology Education by pre-service teachers at the University of KwaZulu-Natal, it was found that many mathematical concepts were utilized. This study was done in the light of exploration of utilisation of Mathematics skills by Technology Education pre-service teachers to enhance conceptual understanding of Electronic Systems. These mathematical concepts enforced conceptual understanding of Electronic Systems. I grouped the mathematical notions into two categories: (a) geometry skills, and (b) algebra skills.

8.2.1 Geometry skills

Design of a working artifact entailed graphic communication and Mathematics. Graphic communication is another method of representing a thought in a non-verbal but visual way, in the form of a picture and/or symbols that may represent more than a thousand words (Engelbrecht, 2008). I witnessed diverse shapes of model houses provided by different groups in the EDTE 210 pre-service teachers' Electronic Systems module, and discovered use of different geometrical structures, e.g. parallelograms, squares, rectangles, triangles and congruencies.

8.2.1.1 Parallelograms

It was paramount for pre-service teachers to have a pre-knowledge of basic graphic communication from the Civil Technology perspective. There were no specific guidelines for the model layout, with the exception that a single room with one window and one door should be developed for the project. The pre-service teachers were able to draw their floor plans, which were used to guide development of their models. Through measurement I discovered that directly opposite sides of their plans exhibited parallelism. Groups highlighted the fact that it was essential for their plans to be drawn accurately on planes so that the mounting of the sides would align properly without living gaps between adjacent sides.

8.2.1.2 Rectangles

On each floor plan designed by the pre-service teachers, lengths and breadths were clearly identified. Those dimensions were exhibited in the finished models, even though the model houses were all different. As an indication of a rectangle, I discovered that each angle drawn for corners formed 90º, making plans rectangular and a parallelogram in shape. Through measurement I discovered that corners were squared and all were 90º.

8.2.1.3 Triangles

Of the models, 91% of the houses had gables. I observed that each roof had a different shape, with the angle of the roof ranging between acute and obtuse. I noticed proper coherence between walls and gables on the roof sides. This was a clear indication of accurate measurement at a chosen scale. Triangles were evident in their construction of the pitch of the roof. Angles on opposite sides of the individual model houses were equal. When members in group 3 were asked if they could identify types of triangle formed in the gable of their model house, S8 said:

> **S8:** *I believe it can be an acute angle or an obtuse angle.*

Researcher: How do you make a difference between an acute angle and the obtuse angle?

S8: *One is less than 90 degrees and the other one is more than 90 degrees, depending on the positioning of the triangle.*

It appeared that group 3 did not make any reference to angles and triangles required for their gables when they were designing gabled sides. Group 3 just cut gabled sides accurately according to the availability of waste material. Angles that were observed in the models included acute, obtuse and complementary angles, co-interior and complete revolutions. Triangles that were identified were isosceles triangles.

8.2.1.4 Congruencies

When pre-service teachers were asked to comment on the sides of their models, they indicated that two opposite sides were equal in size and shape. Groups purposely provided similar sides so that it would be easier to place roofs on their structures. In explaining an approach, S4 said:

S4: *I looked at the available material for our project and drafted an estimate of four sides. I tried to draw on the material the two different sides and thereafter I placed them on the remaining material for outlining. It was important to cut accurately...*

Model houses had evidence of congruence which is mostly found in geometry. Pre-service teachers used accuracy unknowing that geometrical concepts were involved in their designs.

8.2.2 Algebra skills

Electronic Systems employs components for design and maintenance of electronic circuits for this project requirement. The essence of the designed circuit was rooted on a fixed structure to which the circuit would be mounted. It was therefore imperative for a model of a house to be available, to harness the operation of the alarm system. Nevertheless the main focus of all groups was on the design of a circuit diagram that would ultimately produce an effective alarm system for the artifact.

Activities that were involved in identifying an effective circuit diagram were proper drawings of a relevant circuit diagram, identification of proper components that would produce desired outcomes, soldering components on the Vero boards and determination of the voltage to drive charges for the forward biasness of the circuit.

Most groups exhibited reasonable knowledge of proper drawing for the circuit diagram. They indicated an understanding of the characteristics of individual components in conjunction with the behaviour of a circuit in parallel or in series. As groups were brainstorming around circuit diagrams I observed that they preferred pictorial drawings instead of symbols for component representation. Their selection of components was based on theoretical behaviour of components instead of calculations.

Where groups had to connect LEDs or diodes, most frustration was with circuits that were not providing forward bias. Fault-finding exercises indicated that pre-service teachers ignored knowledge about polarities and conductivities of components. I observed discontinuity between the knowledge of components provided by pre-service teachers during their simulation stages and application of that knowledge to design. Most groups were able to identify relevant formulas when they were approaching components individually, but on complex circuit diagrams they encountered some challenges.

Pre-service teachers could provide detailed explanations of each component used in their designed circuits. Their circuits contained a combination of algebraic concepts like fractions, exponents, equations and substitutions and manipulation of equations for the subject of the formula.

8.2.2.1 Fractions

When pre-service teachers interrogated parallel resistors and series capacitors, they had to understand the operation of fractions. It was essential for them to know how to add, subtract multiply and divide fractions according to their principles. I observed that some pre-service teachers were confusing the concept of fractions required for resistors and capacitors.

8.2.2.2 Exponents

Factors used for components like micro (µ), kilo (k), milli (m), etc. contain exponential connotations like 10^{-6}, 10^{3}, 10^{-3}, etc. respectively. Pre-service teachers applied this information in shortening long numbers and avoiding ambiguity. Factors like 10^{-6} were written in the form of a decimal fraction, e.g. 0.000001, or a proper fraction, e.g. $\frac{1}{1000000}$. I observed that pre-service teachers were using these algebraic concepts of fractions without noticing the dynamics of their application in circuit design as they appear in Table 6.

8.2.2.3 Equations

I observed that the pre-service teachers were coping very well with equations. They were able to memorise formulas according to their section in Electronic Systems. Some teachers were developing lists of formulas as we were completing each section in Electronic Systems. In their explanation for this activity they said:

> **S9:** *I prefer to extract formulas from notes so that I will keep on looking at them without any pressure for a test of examination.*
>
> **S21:** *I don't want to forget a formula because there is no other way to attempt a problem if you don't know a formula.*
>
> **S30:** *A formula gives me an assurance that my answer is correct. Once I remember a formula, I know I have full marks for a problem.*

Substitution of values into formulas was a tricky exercise, because it entailed a conversion of values into a uniform format. Pre-service teachers would sometime work with k **Ω** without changing them into ohms, yet kilo is used to shorten an expression in an arithmetical manner.

8.2.2.4 Manipulation of an equation for the subject of the formula

Changing the subject of the formula was used when unknown values were not placed at obvious positions. I observed that some pre-service teachers found it challenging to remove expressions needed for the subject of the formula by applying their inverses. Based on their memorisations pre-service teachers would want to have formulas written in relevant forms without a logical application to manipulate them.

8.3 Implications and recommendations for teaching

8.3.1 Implications for teaching

A theoretical introduction in 5.3 identified the elementary understanding of mathematical concepts by pre-service teachers. An exercise was able to prepare the cohort for accomplishment of the task to calculate resistors in parallel or series using arithmetical principles of fractions. Pre-service teachers were able to work on the conductivities of different valued components using gradient information. The effectiveness of interrogation of fractions with all four operations was paramount to extend to ohms using mathematical principles.

The understanding essential for pre-service teachers of the meaning of fractions was extended to another form of fractions, e.g. decimal fractions that may be converted to negative or positive exponents ($0.000001=10^{-6}$). These were discussed in subsection 6.5.2.1. Application of different operations (addition, subtraction, multiplication and division) to fractions, conversions (from exponents to decimal fractions) and manipulation of values to different arithmetical principles will continue to play a pivotal role in assisting pre-service teachers' meaningful understanding of other mathematical skills used in Electronic Systems.

Foundational Mathematics skills that were covered in schools which are compulsory for all learners in the GET band could be included in Technology modules.

There is a need for developing activities that are emphasising gradients. In exercises for representing graphical linear relationships for Ohm's law, participants did not have a clue as to the layout of axes, and hence did not know what to allocate to the x- or y-axes between current and voltage. Simultaneous analysis of graphs in Figure 6 clearly indicates that $R_B > R_A$ based on the shape and values of their gradients. Such conductivity $\frac{\Delta I}{\Delta V}$ suggested an inverse proportion to resistance, i.e. $\frac{1}{R}$. Therefore an understanding of graphs (linear, parabolic and/or hyperbolic) is paramount in facilitating the application of such understanding in conductivity of material.

Lecturers should design tasks which compel pre-service teachers to carry out certain calculations without the use of calculators.

8.3.2 Recommendations

Factual indications are that pre-service teachers are soon going to assume autonomous positions in teaching Technology, guided by policies. Moreover, interdependency will exist in the application of their teaching skills acquired on a professional basis. Electronic Systems is a practical, demanding area of learning that is rooted on mathematical concepts. I recommend attentiveness to four areas of importance pertaining to the interrogation of practical connotations of any project in Electronic Systems: conceptual understanding, procedural fluency, strategic competency and adaptive reasoning.

8.3.2.1 Conceptual understanding

This area encapsulated comprehension of mathematical concepts, operations and relations. It will always be difficult to separate any form of design in Technology from Mathematics, hence in designs numerical values and units of measurement will prevail. It is essential that fractions are dealt with in a proper way, since they form a major part of load distribution in parallel and series circuits. In the analysis of circuit diagrams handling of fractions should be unpacked chronologically and logically to avoid challenges during design. It should be highlighted that all factors influencing such circuits (parallel and series) for capacitors and resistors depend on the concept of fractions. Importantly, it should be emphasised that all exponential functions entail both negative and positive exponents and have a direct connotation with fractions when converted and applied to a problem-solving process.

8.3.2.2 Procedural fluency

This area entails flexibility in carrying out procedures, accuracy and appropriateness. An accommodation of calculators in schools should not perpetrate a generation that will depend on calculators at the expense of formulas provided for logical approaches in their problem solving. Sometimes they would eliminate exponents when computing values in their calculators which defied appropriateness in their applications. Some of pre-service teachers argued that “if numbers are computed as they appear in the formula, they are likely to resort to right answers”. Although formulas were highlighted in all calculations, pre-service teachers disregarded their functionalities which depicted inadequate arithmetic aptitude. For that matter procedural fluency should be enunciated at all levels of education in problem solving and design.

8.3.2.3 Strategic competency

This area encapsulates an ability to conceptualise, represent and solve mathematical problems found in any area of knowledge. Electronic Systems is one learning area that demands a specific language and terminology. The pre-service teachers abandoned technological terms used in Electronic Systems but exploited words like “this thing and/or that thing”. It is typical of most learners to generalise concepts. Those practices harm the essence of a particular learning area. As evidence, it was a great challenge for pre-service teachers to translate word problems into comprehensible data suitable for arithmetic. This scenario has a negative transferable influence on the analysis of given problems into arithmetical logic. If words like milli, micro, kilo, etc. are not given enough emphasis for their arithmetical connotation, they deviate from the originality of a problem to be resolved. Because of the specific language required in Mathematics and Electronic Systems, such prefixes need to be represented mathematically correctly in order to facilitate effectiveness in problem solving.

8.3.2.4 Adaptive reasoning

This is a capacity reflected in logical thinking. It is expected to be reflected in explanations that learners provide when they are justifying their responses. I discovered that responses were not adequate as I interacted with pre-service teachers in groups while they were developing their artifacts in different stages. Each time I questioned a step during a consultation period, I observed that they were reluctant in giving a confident response even if they were correct. As members in group 9 were expected to apply mathematical principles, they were hesitant in going to a direct applications that required a recall of arithmetic principles.

It is indisputable that Mathematics itself is taught using a transition model where procedures are remembered and consulted as they represent knowledge required for use (Cangelosi, 1996). Learners should be encouraged in integrating factual information about components and their related nature pertinent to calculations, thus making it essential for learners to enhance numerical communication through mathematical concepts. This will prohibit restricted reasoning on mathematical theory or practical application that has potential to dislocate the relationship between numerical connotation and practical applications for project execution.

8.4 Conclusion

The origin of tension nested in the opposing thought that existed in the class in that this was not a Mathematics class, and the pre-service teachers intentionally did not register for a Mathematics module but for Electronic Systems. A greater task lies in identifying common areas for Mathematics language and the preciseness of Technology, particularly Electronic Systems. I observed that pre-service teachers applied arithmetic concepts unconsciously while they were designing their artifacts. Cumbersome use of terminology in Electronic Systems and misconceptions of concepts in Mathematics deviated confidence in the process of designing artifacts.

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ANNEXURE 1

Letter of Consent

To: Participant(s)

Research Project:

Year:
Mr Thabethe B. M (final-year Masters Student) is conducting a study through the **School of Education, Technology Education at the University of KwaZulu-Natal** under the supervision of **Dr Deonarain Brijlal**. Proposed research looks towards a better understanding of "**the utilisation of mathematics skills by Technology Education pre-service students**" for the **enhancement of conceptual understanding of electronic systems**. In particular, this inquiry looks at the integration of Mathematics skills and Electronics principles that leads to an effective design of a project in an electronic system at a tertiary level.

Students from the EDTE 210 electronics class are requested to assist through participating in this research project as it would be of benefit to curriculum design, practitioners and interested educationalists in Technology as a discipline and/or Technology teachers. Participation is completely voluntary and has no impact or bearing on evaluation or assessment of the students during the process of data collection. Participants may be asked to take part in open-ended interviews after the final project is completed. These interviews will be recorded as the time progresses. All participants will be noted on transcripts and data collections by a *pseudonym* (i.e. fictitious name). The identities of the interviewees will be kept strictly confidential. All data will be stored in a secure password protected server where authentication will be required to access such data.

Participants may revoke from the study at any time by advising the researcher of this intention. Participants may review and comment on any parts of the dissertation that represents this research before publication.

I,____(*Please print NAME)*

N.B. Tick ONE
Agree. ☐ Disagree. ☐

to participate in the research being conducted by:__________________ concerning **An exploration of utilisation of mathematics skills by Technology Education pre-service students to enhance conceptual understanding of electronic systems.**

____

(*Researcher's Signature*) (*Date*)

ANNEXURE 2

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Science and Technology Cluster

The ethical clearance office

Edgewood Campus

<u>Permission to conduct research in Technology Education</u>

Dear Dr Davids

I hereby give permission for Mr. BM Thabethe to conduct research in the Technology Education

Discipline of the Science and Technology education cluster. He will collect data for his master's dissertation titled: **An exploration of utilisation of mathematics skills by Technology Education pre-service students to enhance conceptual understanding of electronic systems.**

Sincerely

Dr Michèle Stears

(Academic leader: Science and Technology Education)

ANNEXURE 3

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

6 September 2012

Mr Bhekisisa Maxwell Thabethe 206525561
School of Science, Mathematics and Technology
Edgewood Campus

Dear Mr Thabethe

Protocol reference number: HSS/0831/012M
Project title: An exploration of utilisation of mathematics skills by Technology Education pre-service students to enhance conceptual understanding of electronic systems

EXPEDITED APPROVAL

I wish to inform you that your application has been granted Full Approval through an expedited review process.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Professor Steven Collings (Chair)

/px

cc Supervisor Dr D Brijball
cc Academic leader Dr D Davids
cc School Admin. Mrs S Naicker

Professor S Collings (Chair)
Humanities & Social Sc Research Ethics Committee
Westville Campus, Govan Mbeki Building
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ANNEXURE 4

SEMI-STRUCTURED OBSERVATION SCHEDULE

Participant observation (A theoretical introduction/ Measuring instruments and orientation)

The cohort was taught in the form of a normal class and the arrangement was a traditional setting. Qualitative participant observation took place at constant intervals including the tuitions that occurred in the classroom. Both theory and practical had an inventiveness to observe. For a theoretical introduction, a mathematical orientated section was interrogated. A normal teaching was conducted in a full scale where behaviour of loads in either series or parallel was observed theoretically. Participants' responses were kept anonymous but were identified as student 1, 2, 3… (S1) etc.

After a full blown theoretical introduction was exhausted, participants were organised in the form of a group of four members in order to cater for a space and a maximum control of the equipment. Groups were given a package of three 1.5 cells, six crocodile leads in different colours, three small bulbs and bulb holders, and a multimeter. Because of the sophistication of the equipment the cohort had to be orientated on how to handle and operate the equipment.

Simulation and a design of artifact

At a simulation stage groups were given a chance to collect equipment and component as per requirement of a particular simulation. I made it a policy that each member in a group is conscripted to come and place an order of relevant components for the group. I assumed a position of a store man. Participants were compelled to provide a list of component, echo them before collecting them. Circuit diagrams were provided and structured to empower them to be able to handle activities of designs hence these activities constituted a complete tuition for pre-service teachers

A simulation stage went by ushering in a design stage. Groups were given a task as follows:

Artifact Specification, burglar alarm

Many people feel anxious about leaving their home and cars unattended at night and during the day in their absence because of the risk of burglaries. Design and construct a burglar alarm system for a model of a house of at least one door and one window for a single room.

The alarm should be activated if either the door or the window is opened. The alarm should continue to sound even if the door or the window is closed again.

This data collection strategy will be divided into two phases:

Written submissions of designs of artifacts

Two different tasks involving the design and construction of artifacts will be developed for the purpose of this study. The tasks involve objects that the pre-service teachers are familiar with, and a single-storey house from the previous module on Material and Structures. The students were asked to design the house first on paper, using drawings showing the floor plan and, if possible, some views of the room / house, materials used in a circuit diagram for an alarm system, and then to construct the model of the house.

Pre-knowledge

This project will be undertaken with students having basic prior knowledge of constructing and wiring electrical circuits. Students were taught during theory lessons about resistance, current, voltage, conductors, insulator and semi-conductors, switches and switching and series and parallel circuits. Further, these concepts were reinforced, were students had to draw various electrical circuits and wire them accordingly. They had to test for quantities such as resistance, voltage and current and observe their behavior in series and parallel circuits.

A report for their final project

A finished/complete artifact

Phase one

Participants will have to provide a design brief that will guide specifications essential for the logical development of the final product to ensure that it meets the needs of people as the main purpose of technology.

The following guiding points are provided as rubrics to guide both their project development and assessment.

This is a list of all the requirements of the product:

It should contain details of the functional and design features of the finished product, as well as information on cost and profit margin.

The specification for an electronic product should include electronic factors such as component details, maximum working voltages, maximum currents, and temperature or frequency ranges.

The design brief and specification are used to continually test and evaluate the product.

This ensures that the product meets the needs of the customer.

Phase two

In this phase participants will supply a report for their final project that will provide chronological development emanating from the originality of the problem. The format of the presentation can be as follows:

• Introduction

How did the problem originally present itself to you in the first place, and how did it evolve over the course of the project? Give a detailed summary of the problem.

• The solution

Describe your solution in detail.

• The implementation process/results

Describe the process you went through to complete the project and compare what actually happened with the goals you were trying to achieve. Highlight any major variations from your original plans. Discuss the behaviour of the finished project, and show some of its functionality.

• Conclusion

What has been accomplished and what are the major things that you learned from this project? What work still needs to be done on the system and how can it be improved and/or enhanced? Do you have any future plans for this software package?

• References

Include here all materials referenced within your report.

This will provide the final working product as a finished/complete artifact

Observation of pre-service teacher's during the whole process

What are the pre-service teacher's levels of self-motivation?

What are the daily tasks habits?

Pre-service teacher's levels of participation in the activities/discussion/questions

Any underlying feelings towards mathematics involved in electronic systems (anxiety, boredom, enthusiasm, level of interest)

Any underlying feelings towards practical connotation involved in electronic systems (anxiety, boredom, enthusiasm, level of interest)

Suggestions /comments made by pre-service teacher's during observations

Group dynamics (behaviour in groups, acceptance of each other, willingness to work together)

The level of interest and belief in ability to pursue a career involving electronics and mathematics

Pre-service teacher's personal views of the relevance of mathematics to electronic systems and to their own lives

Pre-service teacher's perception of the methodology of the worksheets and activities in the electronic systems

Aspects of pre-service teacher's identity as having changed because of participation in the module EDTE 210

ANNEXURE 5

LEARNERS' INTERVIEW SCHEDULE (Personal Interviews)

Typical Openers: Typical Prepared Questions to structure the interview for candidates

Tell me a little about yourself /experience in Technology?

Why did you take Technology as an area for teaching?

What is your personal philosophy of electronics?

How do you prefer being taught Electronic Systems? Why?

Which electronic systems lessons did you find the least beneficial? Why?

How much time do you spend on your Electronic Systems extra activities?

How did you feel about Electronic Systems before problem solving (calculations) was introduced?

What changes did you notice within your own way of thinking and doing calculations during the course of the problem solving programme (if any)?

How did you feel about electronic systems after completing your design of the artifacts?

Tell me about interactions you've had with other pre-service teachers which can indicate to me how you can work as part of a team to meet artifact goals in Electronic Systems.

Plans/outlines for cooperative learning experiences

Do you prefer working on your own or in a group? and why?

Tell me about a teachable interest or hobby you have and indicate how your experiences outside a classroom would enrich your classroom teaching

How would you create a positive learning environment in the electronic systems class?

Select a mathematics topic and tell me how you would teach it to enhance your understanding in the electronic systems. How would you maintain discipline in your classroom?

What resources will you bring to the class beyond the text?

What are your long range plans as a teacher in teaching Electronic Systems?

What is meant by calculation?

What is a significance of calculation in the Electronic Systems?

Why is it important to manipulate the formula?

How does a substitution of electrical technology values affect the logic in the calculation?

Why is it important to arrive at the correct answer when calculating in the Electronic Systems?

How can a correct answer in Electronic Systems affect a safety of a component in the circuit?

ANNEXURE 6

Dissertation Participants' list			
Student Identification		**Student No**	**Group No**
S1	A. JJ	209533851	1
S2	A.ME	209511917	6
S3	B N	209533429	11
S4	C.ME	209509926	3
S5	C.TP	210531298	10
S6	D.GN	208520878	9
S7	D.PN	210508278	7
S8	G A	209526686	3
S9	G.HM	208510551	6
S10	H K	209517611	1
S11	I.JC	210546526	7
S12	J.WD	209514622	6
S13	K P	209514101	2
S14	L M	208526841	6
S15	M X	210536454	8
S16	M S	209501135	11
S17	M K	209526877	9
S18	M.TF	209516862	10
S19	M.SM	208500844	8
S20	M.MT	209521454	11
S21	M.SA	210546526	7
S22	M.MI	210511045	7
S23	M.NC	208511076	11
S24	M.BDS	208527576	6
S25	M N	209515550	1
S26	M.LJ	209514150	3
S27	N.QI	210505532	10
S28	N.NM	203508697	8
S29	N.NF	208504049	6
S30	N.PN	208510543	9
S31	N.ZK	208511335	8
S32	O.CN	209520314	3
S33	R R	2095155551	2
S34	R R	208519439	10
S35	S S	208518242	6
S36	S.ZMF	207527659	9
S37	S P	210503764	2
S38	S.KG	209514406	2
S39	W.TA	208526363	1

ANNEXURE 7

L. Gething, M. Phil. (Science & Technology Journalism) (*cum laude*)

WHIZZ@WORDS

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DECLARATION OF EDITING OF RESEARCH DISSERTATION:

An exploration of utilisation of mathematics skills by Technology Education pre-service students to enhance conceptual understanding of electronic systems

By Bhekisisa Maxwell Thabethe

7 December 2012

I hereby declare that I carried out language editing of the above proposal by Bhekisisa Maxwell Thabethe.

I am a professional writer and editor with many years of experience (e.g. 5 years on *SA Medical Journal*, 10 years heading the corporate communication division at the SA Medical Research Council), who specialises in Science and Technology editing - but am adept at editing in many different subject areas. I am a member of the South African Freelancers' Association as well as of the Professional Editors Group.

Yours sincerely

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ANNEXURE 8

Turnitin and report

An exploration of utilisation of mathematics skills by technology Education pre-service students to enhance conceptual understanding of electronic systems

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