UNIVERSITY OF KWAZULU-NATAL

DRAWING TO LEARN AS AN ALTERNATIVE TEACHING STRATEGY TO ENHANCE INTERPRETATION AND UNDERSTANDING OF ELECTRICAL DRAWINGS.

By
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ABSTRACT

Industry requires electrical artisans to be competent in designing, reading and interpreting schematics. However, curriculum guidelines at Technical Vocational Education and Training Colleges do not provide this aspect of teaching and learning. Most students can draw; however, they rote learnt circuit diagrams for examination purposes because they were not trained to read and interpret schematics. This study endeavoured to address this learning gap by introducing an alternative teaching strategy.

This study explored drawing to learn as a teaching strategy to improve teaching and learning at a Technical Vocational Education and Training College. This study examined how drawing to learn rather than learning to draw enhanced students' interpretation and understanding of electrical schematics using a patterned learning format. It also evaluated whether drawing to learn addressed electrical misconceptions. The focus was on drawing as a product of the learning process.

This action research project adopted the critical paradigm using an inductive approach. The conceptual frameworks underpinning this study were Shulman's (1986) pedagogical content knowledge (PCK) and Lave and Wenger's (1991) situated learning. Focus group discussions, a rating scale questionnaire and a structured observation schedule were used to generate data from the conveniently chosen eighteen participants.

The findings revealed that proper conceptual tools aided knowledge construction. A cognitive teaching strategy using pattern learning helped students learn intricate and complex numbering concepts by implementing drawing to learn. Electrical drawings enhanced visual awareness and simplifying perceptual tasks. Self-efficacy was evaluated against student understanding of knowledge and teacher knowledge of instructional strategies. Systemised knowledge is effectively transferred by creating a logical and functional path that students can follow. The drawing to learn teaching strategy simplified complicated processes and unmasked electrical misconceptions by addressing dissonance. The recommended imperatives are that new and innovative teaching strategies like drawing to learn using pattern learning will develop students' cognitive

abilities. Practical activities should be conceptualised and contextualised to enhance knowledge construction. Visual literacy must be evaluated and assessed by educators with these assessments mandated through the revised curriculum. Educators must systemise knowledge by organising, arranging, and creating a logical yet functional path that students can follow.

DECLARATION

Submitted in fulfilment of the requirements for the degree of **Master of Education**, in the Graduate Programme in **Teacher Development Studies**, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

I**, Mark Sanjeevy** declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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a) Their words have been re-written, but the general information attributed to them has been referenced.

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5. This thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the thesis and in the References sections.

Mark Sanjeevy **31 May 2021**

Student Name Date

Name of Supervisor Signature

DEDICATION

This thesis is dedicated to my loving wife for her encouragement and support, and for the commitment to see it through.

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I would like to thank my Heavenly Father for wisdom, understanding and knowledge as I navigated down this path.

My sincere thanks and heartfelt appreciation to the following people and institutions for their tremendous contribution to the successful completion of this study.

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PREFACE

The research study described in this dissertation was carried out with eighteen students at a TVET college. The project commenced in January 2019 and concluded in May 2021 under the supervision of Dr J. Naidoo of the Pietermaritzburg campus of the University of KwaZulu-Natal.

This study represents the original work completed by the author and has not been submitted in any form for any diploma or degree to any other tertiary institution. Where the author has made use of the work of other authors, this has been duly acknowledged in the text.

[redacted] 31 May 2021

Mark Sanjeevy Date

As the candidate's supervisor I agree/do not agree to the submission of this dissertation.

____________________________ _________________

Dr J. Naidoo Date

Supervisor

Pietermaritzburg Campus

LIST OF ACRONYMS

Acronym	Description
CK	Content Knowledge
DBE	Department of Basic Education
DHET	Department of Higher Education and Training
DK	Disciplinary knowledge
DTL	Drawing to Learn
FET	Further Education and Training
GPK	General Pedagogic Knowledge
NCV	National Certificate Vocational
NQF	National Qualifications Framework
PCK	Pedagogical Content Knowledge
RQ	Research question
SETA	Sector Education and Training Authorities
STEM	Science, Technology, Engineering and Mathematics
SMK	Subject Matter Knowledge
TVET	Technical and Vocational Education and Training
VET	Vocational Education and Training

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CHAPTER ONE: ORIENTATION TO THE STUDY

1.1 Introduction

Technical Vocational Education and Training (TVET) are crucial for delivering post-school education and training in South Africa. TVET colleges progressively expand skill sets for the public sector, industry, and commerce as indicated in the White Paper for Post-School Education and Training (2013). It is vitally important that all students gain access to skills and knowledge to comprehend complex processes. Delamare, Le Deist and Winterton (2005) argue that to become competently skilled requires the complex collaboration of education, training, technology, and skill, stimulating innovation and new ideas in the student and helping them gain meaningful employment (Brennan et al., 2014; McGrath & Akoojee, 2009). Vocational Education and Training provides this opportunity.

This research study examines implementing drawing to learn as an alternative teaching strategy to enhance interpretation and understanding of electrical drawings in the National Certificate Vocational (NCV) curriculum. The research centres on how students engaged with this new teaching strategy and whether it improved their learning. This chapter commences with the purpose of the research and explaining the intentions and reasons for undertaking this research study. The background of the study follows. The rationale clarified the need, intentions, significance, novelty and justification for this study. A personal rationale follows contextualising how my professional development as an educator/researcher influenced this study. Next, the research questions which guided this study and the research methods followed. The key concepts helped to contextualise and distinguish this study from existing research. The synthesis of ideas, trends and issues surrounding this research are briefly elaborated in the literature. The conceptual frameworks underpinning this study are students' cognitive development through Shulman's (1986) pedagogical content knowledge (PCK) and the implicit transfer of knowledge through Lave and Wenger's (1991) situated learning. Both these frameworks are introduced in this chapter. Action research, the methodological approach used, is then outlined. The chapter concludes with an overview of the dissertation together with the content structure of subsequent chapters.

1.2 Focus and purpose of the study

This study explores drawing to learn as a teaching strategy to improve teaching and learning in NCV Electrical level 2. The study also analysed the extent to which drawing to learn enhances student's interpretation and understanding of electrical schematics. It examined how students' misconceptions of electrical circuits contributed to their challenges in interpreting and understanding electrical drawings. The views and opinions of the eighteen participants were collated from multiple data generation tools. This research is significant as it offers an alternative teaching method to improve students' conceptual learning practices. This alternate teaching strategy has not been implemented at TVET colleges in South Africa. This action research study could contribute to best practices and the findings could be used by other educators to improve teaching and learning in vocational education.

1.3 Background to the study

Many students cannot read and interpret electrical schematics (Tytler, 2002; Ainsworth, Prain, & Tytler, 2011; Templeman & Pilot, 2011; Roth, Mavin & Dekker, 2014). Industry argues King, McGrath, and Rose (2007) require electrical artisans to read and interpret schematics. The NCV electrical syllabus contains numerous electrical drawings. There are also many symbols which assist students to identify various components. Additional schematics are also given to students to undertake practical assignments, which are evaluated as summative tasks. The students' final practical examination at level three and four are based on complicated electrical schematics. The curriculum includes many simple to complex circuit diagrams which students need to know for their final examination. However, the NCV curriculum does not provide for conceptualising this essential aspect of teaching and learning. There are no clearly defined pedagogical strategies to teach this knowledge content. Educators are required to identify teaching strategies to assist with teaching this knowledge content to students. Reading and understanding circuit diagrams is a vital component of any good electrician's repertoire. Most, if not all, students can draw alludes Fan, (2015); however, they rote learn schematics for examination purposes without understanding what they had drawn. This study addresses this pedagogical dilemma.

This study was designed to assess whether students improved their interpretation of electrical schematics, using a pattern format in a drawing to learn teaching strategy. Willis (2007, p.312) contends that "Effective teaching uses strategies to help students recognise patterns and then make the required connections to process the new working memories so they can travel into the brain's long-term storage areas". The strategy employed was to use an action research design that engaged action and change. The new teaching strategy was drawing to learn, which was implemented through pattern learning.

1.4. Rationale

The rationale for this research justified the significance and addressed the need for this study (Rojon &Saunders, 2012). The pedagogical issues and gaps that this research endeavoured to address are explained hereafter.

Electric circuits are difficult to understand due to their abstract construct. You cannot see inside a circuit. Current, resistance and potential difference are closely linked and interchangeably used, yet often misunderstood. Educators must identify teaching methods that explain these concepts. My curiosity motivated further exploration to identify alternate teaching methods outside the world of conventional electrical pedagogy. How did educators guide, support and scaffold conceptual development of understanding skills and knowledge in other fields of study? I realised that schematics were electrical maps similar to building plans or architectural design. The similarities spurred my curiosity, and I read *'A pattern language: Towns, buildings, construction'* (Alexander, Ishikawa, Silverstein, Jacobson, Fiksdahl-King, & Shlomo, 1977). This book described an unorthodox method to teach town planning. Alexander *et al.* (1977, p.x) explain the application of patterns within architecture.

> The elements of this language are entities called patterns. Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice.

This study explored how a solution to town planning could be revised and utilised as a teaching strategy to promote reading, understanding, and electrical circuit interpretation. The study evaluated the effectiveness of using this alternate teaching strategy. The pedagogical focus at our institution was on practising drawing of schematics to pass assessments. Adams (2017, p.245) concurs that "the emphasis has been on learning to draw rather than on drawing to learn in most institutes of higher learning." This study addressed this flawed pedagogy. The conceptual change was implemented by introducing a drawing to learn teaching strategy to restructure existing knowledge, developing a deeper understanding of scientific concepts. Quillin and Thomas (2015, p.1) suggest that "visual representations are a powerful tool because they help to make the unseen seen and the complex simple."Action research was the most suitable vehicle to assess the efficacy of this innovative teaching style.

The rationale was also motivated by the awareness of misconceptions and their role in constructing knowledge (Sencar & Eryilmaz, 2004; Pesman & Eryilmaz, 2010). Although illustrations, analogies, and models address inaccurate conceptions or dissonance, students are still confused by misunderstanding the basic concepts. Could identified misconceptions, when addressed, promote conceptual change to construct new knowledge? Moodley (2013) argues that due to completing the syllabus in a limited time, existing misconceptions can pass unnoticed and unaddressed. This motivated me to explore how educators overcame these hurdles. This action research study employed drawing to learn using a pattern learning format.

The rationale also addressed the gap or lack of empirical studies on electrical schematics in the TVET sector. Most empirical studies on drawings concentrated on schools. The originality value of using pattern learning to improve reading, understanding and interpretation of electrical schematics cognitively must be stressed as no other similar empirical studies were found within TVET.

My personal rational is that I am an NCV electrical lecturer at one of the campuses of a TVET College. I have worked in the electrical industry for the past 28 years. During my tenure in the trade, I engaged with commercial, corporate, domestic, industrial and educational aspects of this occupation. Nundkumar (2016) argues that the TVET sector was known for its failure to attain vital strategic industry goals and was plagued by poor pass rates. Mesuwini (2015) and Nzimande (2012) contend that although the government had spent billions of rands on the TVET sector, there is an industry perception that most colleges cannot fulfil the country's skills development needs that still exists. I am a subject matter expert in the electrical field. This study was contextualised by my knowledge of industry and my role in tertiary education. From students' performance and observations, I noticed that students experienced difficulty reading, understanding and interpreting schematics. This study explored whether a drawing to learn teaching strategy conceptualised teaching practice and students' interpretation and understanding of electrical drawings in NCV Electrical Level 2.

1.5 Research questions

The following research questions guided this research project:

1. How does introducing a drawing to learn teaching strategy using patterns improve teaching and learning in NCV Electrical Level 2?
2. To what extent does drawing to learn using patterns address student misconceptions of electrical circuits?

1.6 Research objectives

The key objective of this research study was to utilise action research to implement a drawing to learn teaching strategy to improve teaching practice in NCV Electrical Level 2. This study examined whether drawing to learn improved student's conceptual understanding and interpretation of electrical schematics rather than rendering drawings within learning activities. The focus was on drawing as a product of the learning process. The drawing to learn teaching strategy implemented a patterned learning format to examine whether it enhanced cognition and whether pattern learning addressed student misconceptions.

1.7 Key concepts from the literature review

The following vital concepts underpin this study and are discussed below: The discussion commences with the global importance of vocational education and training and its impact on economic growth in first and third world countries. Pavlova (2014) contends that vocational education liberates nations from poverty and connects them with the modern world, paving the way for additional growth and success. Well-qualified artisans must be skilled to improve the competitiveness of regions, countries, companies and institutions. Examining how the South African structure of Technical Vocational Education and Training (TVET) has been modelled ensues. The discussion then examines the complex nature of TVET, exploring how it is used in South Africa for social equity providing knowledge and skills. Mesuwini (2015) concurs that although technical vocational education and training are not the only avenues of human resource development, it was crucial to the countries' educational, social, and economic development. Diraso et al. (2013) suggested that an essential objective of TVET programs was the delivery of practical skills and relevant knowledge for employment in an occupation or trade. In South Africa**,** TVET colleges are vital for providing post-school training and education and are strategically important in developmental plans for the country. This section concludes by examining the National Certificate Vocational (NCV) curriculum.

The literature then discusses drawing as a teaching strategy. The purpose of drawings was first acknowledged. Through drawings, argue Quillin and Thomas (2015), students think more explicitly and expressly, developing analytical skills engaging critical thinking to problem-solve. The literature then examines how drawings create a vital link to perform practical tasks and how drawings are used to communicate collaboratively. Fan (2015, p.174) argues that "diagrams are schematic drawings that convey structured relationships between parts of a system." The importance of drawings, and how it improves cognition follows. The literature on drawings concluded with how drawing skills are scaffolded to meet the goals for drawing-to-learn. Maries and Singh (2018) argue that students who draw and understand diagrams are better problem solvers.

The use of patterns as a teaching strategy was the following aspect reviewed in the literature. Mor et al. (2014) assert that they construct significant foundations for memory retention when students learn and explore patterns. The literature examined the advantages of pattern learning and the application of patterns to improve comprehension and understanding. Konovalov and Krajbich (2018) contend that in comprehending patterns, students grasp scientific relationships using graphs, charts, tables and drawings during the process of analysing data and solving complex scientific problems. Pattern identification to improve knowledge construction concludes this stage. Mor et al. (2014) argue that the capacity to distinguish, create and recognise patterns assists in the fabrication of predictions from observations.

The literature then explores students' misconceptions about electrical circuits. Throughout the learning process, students may perform poorly due to deficiencies in knowledge. Chang, Liu and Chen (1998) categorised these deficiencies as incompleteness, discrepancy, and uncertainty. Incompleteness and reservations in learning can be remedied by remedial instruction. However, discrepancies must be corrected. If not, they result in misconceptions that could form worrying barriers to learning. The literature then examines how misconceptions can be understood and the factors that influence misconceptions. The chapter concludes with how students can be assisted to confront their misconceptions. The key argues Martin, Martin and Southworth (2015) to overcome student misconceptions is based on reconstructing and constructing correct frameworks for knowledge acquisition.

The literature concludes with a discussion on blended learning. So (2009) contends that blended learning is a hybrid methodology of teaching that combines e-learning and social networking with traditional and conventional classroom practices. The literature examined the benefits of blended learning and how to create a blended learning environment. Huang, Ma and Zhuang (2008) state that tutorials and online assistance are vital to providing support to students, while network infrastructure must accommodate students working within and outside the institute. Blended learning concluded with a discussion on the impediments. Gunawardena et al. (2009) argue that poor signal strength made it impossible to utilise online platforms without internet access.

1.8 Conceptual framework

The conceptual frameworks underpinning this study were Shulman's (1986) notion of pedagogical content knowledge (PCK) and Lave and Wenger's (1991) Situated Learning Theory. "Lee Shulman in 1986 published the paper that coined the phrase pedagogical content knowledge (PCK) describing the knowledge that teachers create by transforming their content into a teachable form" (Rollnick et al., 2008, p.1365). Shulman distinguished three types of knowledge, i.e., subject knowledge, pedagogical knowledge, and curricular knowledge. Shulman (1986, p.9) described PCK as "the ways of representing the subject that make it comprehensible to others." The focus of this study was to explore the use of drawing to learn as a teaching strategy to improve teaching and learning in the National Certificate Vocational (NCV) electrical program. The study assessed the extent to which drawing to learn rather than learning to draw enhanced students' interpretation and understanding of electrical schematics using a patterned learning format. Therefore, Shulman's notion of PCK was a suitable conceptual framework.

The second conceptual framework aptly used in this study was situated learning. Lave and Wenger developed it as an instructional approach that claims that learning was more successful when students actively participated in the learning experience. situated learning implicitly transferred knowledge, argues Contu and Willmott (2003), with students learning content through activities rather than acquiring information in discrete packages organised by instructors. The content was inherent in doing the task. This framework assisted in creating meaning from the abstract activities of drawing, justifying its use for this study.

1.9 Methodological approach

The critical paradigm underpinned this research study. Cohen, Manion and Morrison (2007, p.26) contend that the purpose of the critical paradigm "is not merely to understand situations and phenomena but to change them. In particular, it seeks to emancipate the disempowered, to redress inequality and to promote individual freedoms within a democratic society." The significance of the findings is derived from the participant's responses gathered from the various data collection instruments. Data was generated from an alternate teaching strategy in an electrical workshop from an NCV class of students. Creswell (2014, p.38) argues that critical theorists engaged in:

> [a]n action agenda for reform that may change the participants' lives, the institutions in which individuals work or live, and the researcher's life. Moreover, specific issues need to be addressed that speak to important social issues of the day.

This research study examined lived experiences and used a mixed methods (qualitative and quantitative) approach that engaged participants' views about the phenomenon studied (Stolz, 2013).Dunn, Lyman and Marx (2003) described the research results as findings, where various data collection tools are used to collect detailed data. The data is then coded, analysed and interpreted to determine the emerging themes. Qualitative research examined how drawing to learn could be used as an alternative teaching strategy to enhance the interpretation and understanding of electrical drawings. This approach is appropriate for this study, as it contemplates the outcome of changing existing teaching and learning methods utilised in my class. The data collection instruments used were focus group discussions, rating scale questionnaires, likert questionnaires, structured observation schedules and a reflective journal.

Action research was the approach utilised for this study. Action research, argues Cohen, Manion and Morrison (2007, p.298), "is a process in which participants examined their educational practice, carefully and systematically, using the techniques of research." Cohen, Manion and Morrison (2007, p.299), argue "to do action research is to plan, act, observe and reflect more carefully, more systematically, and more rigorously than one usually does in everyday life". This study used convenience sampling, where the researcher selected participants who were available and willing to provide the necessary information for qualitative research. Cohen, Manion and Morrison (2007) contend that this sampling method is appropriately aligned with the critical paradigm, where participants could examine the use of alternate teaching and learning strategies.

1.10 Overview of the dissertation

This dissertation comprised five chapters:

Chapter One outlines the background, purpose, rationale, research questions and key concepts from the literature. A brief discussion of the conceptual framework and methodological approach is also presented. To conclude, the chapter outlines the overview of the dissertation.

Chapter Two examines the literature review, which encompasses Vocational Education and Training globally and locally. The literature review also discusses the significance of TVET and its part to accomplish the South African government's economic goals. This chapter then explores the conceptual use of drawings, followed by patterns, as a teaching strategy to enhance meta-cognition. Student misconceptions and blended learning are then presented. The chapter concludes with a discussion of the two conceptual frameworks underpinning this study; students' cognitive development through Shulman's (1986) notion of pedagogical content knowledge and the implicit transfer of knowledge through Lave and Wenger's (1991) situated learning.

Chapter Three describes the methodological approach utilised in this study. The critical paradigm, together with the qualitative approach using action research, is explained. This chapter justifies the use of action research and provides a detailed description of the stages of action research. The data generation methods, sampling strategy, data analysis and ethical issues are discussed.

Chapter Four presents the data and discusses data analysis. The research findings related to the two research questions guiding the study are discussed. The significance of thematic analyses is explained.

Chapter Five summarises the key findings of the study and discusses the recommendations and conclusion. This chapter examined how the research questions were addressed. It also examined implications for further research and addressed the study limitations. The research recommendations are outlined to improve pedagogy, share best practices, and identify future research areas.

1.11 Conclusion

This chapter outlined the purpose of the research followed by the background of the study. The rationale clarified the need, intentions, significance and justification for this study. A personal rationale followed contextualising how my professional development as an educator/researcher influenced this study. Next, the research questions guiding this study were presented. The research objectives described in detail how the purpose was achieved and the key concepts helped to contextualise and distinguish this study from existing research. From literature, the synthesis of ideas, trends and issues surrounding this research was briefly elaborated. The conceptual frameworks underpinning this study are Shulman’s (1986) notion of pedagogical content knowledge (PCK) and Lave and Wenger’s (1991) situated learning. Both these frameworks were introduced in this chapter. Action research, the methodological approach used, was then outlined. The chapter concluded with an overview of the dissertation together with the content structure of subsequent chapters. Chapter Two that follows examines the literature relevant to this study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This study aimed to explore drawing to learn as a teaching strategy to improve student learning and my teaching in NCV electrical Level 2. The previous chapter introduced the research and discussed the background and rationale for this study. This chapter engages different literature and discusses vocational education and training and how the TVET has evolved in South Africa. It examines various concepts related to drawing as a teaching strategy and explains various aspects of pattern learning and how it assists in interpreting and understanding pedagogical concepts. The chapter also describes the challenges students encounter due to misconceptions. Blended learning and online platforms complete this literature review. The chapter concludes with a discussion of the two conceptual frameworks underpinning this study. They are students' cognitive development through Shulman's (1986) pedagogical content knowledge (PCK) and the implicit transfer of knowledge through Lave and Wenger's (1991) situated learning.

2.2 Vocational education and training

2.2.1 Globalisation and the significance of vocational education and training

Globalisation has fixated on skills as an essential element to sustained economic growth. McGrath and Akoojee (2009, p.149) contend that economic success is contingent "on the ability to create, attract and deploy human capital more effectively than competitor nations or regions." However, Moloi, Gravett and Petersen (2009, p102) argue that "a parallel growth of globalisation of knowledge is also taking place." Globalisation endeavoured to improve levels of education (Meyer, Bushney & Ukpere, 2011; Moloi, Gravett and Petersen, 2009; Price, 2010). The benefits envisaged would be employability, improved incomes, reduced crime and a reduction in social delinquency. Politically, globalisation aimed to achieve social cohesion, assert Meyer, Bushney and Ukpere (2011) through economic viability and competitiveness. In the process, education became an essential policy tool. Rasool (2006) highlights that policymakers recognised that knowledge and skills increased international prosperity through competitiveness and job creation. McGrath and Akoojee (2009, p.150) maintain that South Africa's economic and geopolitical position in Africa has had extensive influence regionally. South Africa's sustainability is not just important domestically, but failure or success is critical to the entire continent in terms of "African viability."

Price (2010) describes how the fall of communism, democracy formation throughout Asia, South America and Africa, and the elimination of apartheid in South Africa, have fostered a perspective that globalisation is imperative to higher education. Meyer, Bushney and Ukpere (2011) argued that global higher education had become more commercial with rapid advancement of the internet, science and technology. Furthermore, Meyer, Bushney and Ukpere (2011) contend that constructive global trends must become an explicit part of curriculum and planning; and alliances should be created with other similar professional international institutions, especially in emerging markets such as Africa and Asia. This, they suggest, will reduce relying on Western ideals to curriculum approach while maintaining a balance between local and global content. Local students should be encouraged to develop a global mindset. Mesuwini (2015) stipulates that South Africa's higher education sector should develop a measurement system to evaluate progress towards increased levels of globalisation at a post-school level. One of the vehicles to accomplish this is through vocational education.

Pavlova (2014) contends that vocational education liberates countries from poverty and connects them with the modern world, thus paving additional growth and success. Well-qualified artisans must be skilled to improve the competitiveness of regions, countries, companies and institutions. Mesuwini (2015) contends that although technical vocational education and training are not the only avenues of human resource development, it is crucial to a country's educational, social, and economic development. Diraso et al. (2013) suggest that the critical objectives of TVET programs are the delivery of practical skills, relevant knowledge and manners for meaningful employment in an occupational area or specific trade.

In South Africa, TVET colleges are vital for providing post-school training and education and are strategically crucial in developmental plans for the country. Nundkumar (2016) asserts that this form of education, although primarily focused on students who have completed their secondary school education, also caters for those who want to finish Grade 12 through a vocational route. A well-designed vocational curriculum substantially impacts the formative and summative assessments of student's practical work (Mesuwini, 2015; McGrath, 2011; Abrahams, Reiss & Sharpe, 2013). However, Mentzer, Becker, and Sutton (2015) disagree, arguing that students performed tasks without comprehending the outcomes in many instances. This led to students fixated on a single solution rather than alternatives. Similarly, Millar (2004, p.176) contends that:

> As practised in many schools, it [skills development] is ill-conceived, confusing and unproductive. For many students, what goes on in the lecture theatre contributes little to their learning … At the root of the problem is the unthinking use of practical work.

2.2.2 Social justice in vocational education and training

McGrath (2011) argues that Vocational Education and Training (VET) is an education-work policy framework utilised globally. It is intimately linked to economic and social upliftment. In Africa, provisions were made to revise prevailing colonial education to address African challenges. (McGrath, 2004; Chisholm & Leyendecker, 2008). McGrath and Akoojee (2009) draw attention to the current worldview that VET liberates countries from poverty and connects them with the modern world, thus paving the way for additional growth and success. Well-qualified artisans must be skilled to improve the competitiveness of regions, countries, companies and institutions. In most African countries, argues McGrath (2011), the focus has swung from jobs to employability. This is due to the movement to a service knowledge economy, requiring a different skill set. Welfarism has collapsed; however, Chisholm and Leyendecker (2008) explain that the focus is on education and employability to rescue nations from social exclusion and poverty. Most policymakers have embraced the notions of boundaryless careers, lifelong learning, and employability.

2.2.3 TVET 'genesis' in South Africa

The predecessor of TVET Colleges in South Africa was the Further Education and Training Colleges (FET), established post-apartheid. McGrath and Akoojee (2009) affirm that in 1994 the newly elected democratic South African government inherited a fragmented college sector. In his 2009 State of the Nation Address, the President pronounced that the 50 colleges and 250 campuses of the FET sector would become the leading site for skills training. In 2009, the new Department of Higher Education and Training (DHET) emerged (TVET College Times, 2015). In South Africa, TVET has several elements that complicatedly interlink. Zungu (2015) elaborates that these structures comprise the Department of Higher Education and Training (DHET) Sector Education and Training Authorities (SETAs), and several TVET bodies that undertake and provide training. How these various elements interact within the TVET space determines the transfer of skills and knowledge. In South African society, TVET is commonly viewed as inferior education, not sharing parity with universities. McGrath and Akoojee (2009, as cited in Zungu, 2015) explained that TVET in South Africa has been deemed the means to plug the skills gap between artisans and growth in the economy. TVET colleges are vital for providing post-school training and education and are strategically crucial in South Africa's developmental plans. Nundkumar (2016) asserts that this form of education, although primarily focused on students who had completed their secondary school education, catered to those who wanted to achieve Grade 12 through a vocational route.

2.2.4 Core principles of an effective TVET system

The White Paper for Post-School Education and Training (2013) stressed that TVET colleges have a pivotal task to develop a skilled and knowledgeable populace that contributes to the economic and social growth of the country. MacDonald, Nink, and Duggan (2010) contend that a responsive and modern TVET structure must include industry and the informal and formal sector to produce the required results to transform the country. These aspects speak critically to this research. Successful TVET is built on effective teaching and learning. This type of pedagogy, argues MacDonald, Nink and Duggan (2010), is adjusted based on industry needs, especially in crucial occupations and trades. Mesuwini (2015), together with McGrath (2011) and Abrahams, Reiss and Sharpe (2013), allude to a well-designed task-oriented curriculum that will substantially impact the formative and summative assessments of student's practical work.

2.2.5 National Certificate (Vocational) (NCV)

The transition to NCV dramatically transformed colleges; however, its sustainability and impact are yet to be determined. In South Africa, TVET must gear toward the effective assessment of competence, particularly in the training and testing of artisans. This envisioned goal of the TVET must be realised to address the enormous social challenges confronting this country. I am an NCV lecturer. The NCV programme aims to implement the necessary practical skills, knowledge, understanding and competence essential for work at an elementary or intermediate stage of a particular trade or occupation. "The National Certificate (Vocational) at Levels two to four on the NQF offer programmes comprising subjects that consist of academic knowledge and theory, integrated with the practical skills and values specific to each vocational area." (Umalusi, 2013, p.11). It is imperative that effective teaching and learning to develop and enhance conceptual understanding take place. If there are any unaddressed curriculum gaps, they are addressed through work experience. However, Johanson and Van Adams (2004) argue that NCV graduates are only ready to receive work experience after a 3-year program. Skilled educators must find innovative methods to address these gaps, ensuring that a better calibre of student is integrated into the country's workforce. This research endeavours to identify avenues to address this conceptual shortfall.

2.3 Drawings as a teaching strategy

Fan (2015, p.170) describes drawings as visual literacy and states that "when we understand something, we say that we "see" it. We solve problems through "insight." Ainsworth, Prain and Tytler (2011, p.1096); concur that "visualisations are integral to scientific thinking." Quillin and Thomas (2015, p.2) define drawing as "a learner-generated external visual representation depicting any content, where the structure, relationship, or process, is created in static two dimensions in any medium." Quillin and Thomas (2015, p.2) express that "visual literacy" is the ability and aptitude of students to explain ideas presented by educators, likewise to craft, construct and create "visual representations" by themselves. Improving visualisation competencies enhances teaching, learning and engagement in the classroom, especially in environments where visual methods of comprehension have traditionally been side-lined to numeric and linguistic ones. Fan (2015) highlights that the most rudimentary visualisation skill, drawing, assimilates with cognitive functions fundamental to scientific rationale.

2.3.1 Drawings as a vital link in practical tasks

When students have insufficiently engaged or observed concepts in their daily lives, practical work is crucial, vital and irreplaceable, argues Millar (2004), to students who have not perceived the phenomenon being taught. Abrahams, Reiss and Sharpe (2013, p.2) describe practical work as a "teaching and learning activity which at some point involves the students in observing or manipulating the objects and materials they are studying." Practical work, by and large, motivates pupils by stimulating thought-provoking curiosity and enjoyment. It also teaches skills and enhances the acquisition of scientific intelligence, which improves students' competency (Miri & Fu, 1993; Smith, et al., 2007). Furthermore, Hofstein and Kind (2012, as cited in Abrahams, Reiss & Sharpe, 2013, p.2) argue that "there is a need to acquire appropriate and meaningful guidance for practical work."

It is widely acknowledged that the use of practical tasks enhances understanding in engineering. Smith et al. (2007) assert that linking theory to practice was problematic, but when realised, students spoke of being enlightened and seeing the social sciences from another perspective. They conclude that deep learning is a product of this mode of study. Roth, Mavin and Dekker (2014, p.522) contend that preference is given to "Knowing-of-practice rather than knowing-in-practice in many institutions." Their research examined how teaching and training were evaluated and enacted, encompassing theory into practice through the relevant experiences. Tempelman and Pilot (2011, p.262) researched the synthesis of theory and practice, aspiring to assist students to utilise "facts, theories and insights into their design projects." They found that students and instructors concurred that theory is better learnt and understood when applied in practice, reflecting in the results.

Practical work encourages students to engage in personal studies and draw on their instinctive curiosity. Through your endeavours, exploring for yourself is natural and progressive, rather than coercive, and it assists in memorisation. It seems to offer a way

of holding up evidence as the grounds for accepting knowledge. Practical work enables, instead of being dismissive. It encourages individual ability in the pursuit and understanding of knowledge. Based on these findings, most countries have adopted vocational education and training (VET) as an integral part of curriculum development.
Fan (2015, p.174) argues that “diagrams are schematic drawings that convey structured relationships between parts of a system.” These basic representations are vital and valuable when delving into complex calculations. Herein lies the potential of drawings and diagrams. Larkin and Simon (1987) argue that they facilitate cognition that relieves the working memory load by absolving it to keep track of the different factors relating to the problem. In an empirical study undertaken by Larkin and Simon (1987), they compared the verbal description of solving physics and maths problems against the benefits of referring to a diagram. They found that an adequately constructed diagram assisted the ability to process by restricting flawed, inaccurate perceptions, as in Venn diagrams.

Wiggins and McTighe (2006, p.12) assert that the efficient use of drawings in education and the effectual measure of schematics as a tool depends “on the alignment between desired outcomes, assessment, and activities.” Educators need to employ support that will assist students to master the skills required on their own. Fan (2015) insists that it is critical to commence with an endpoint in mind. Quillin and Thomas (2015) argue that novice students tend to memorise models; however, expert students engage models as intellectual, flexible, reflective tools.

Improving visualisation competencies contends Rosengrant, Van Heuvelen and Etkina (2009) enhance teaching, learning and engagement in the classroom. Mainly in environments where visual methods of comprehension have traditionally been side-lined to numeric and linguistic ones. However, Ainsworth, Prain, and Tytler (2011) have observed that in classrooms, student’s primary focus has been on interpreting the drawings of others. Rarely are students motivated and encouraged to develop and create their drawings or visualisations that depict or enhance understanding. Wammes, Meade and Fernandes, (2016) mention that this becomes a crucial objective of technical studies, where students are schooled or taught to develop an understanding from their observations. Fan (2015) contends that drawings are one method whereby students enhance cognitive ability, progress past or beyond making assumptions to comprehensive qualitative understanding.

Fan (2015) further maintains that omissions and inclusions can be analysed when students omit or include specific details. However, Rosengrant, Van Heuvelen, and Etkina (2009) argue that every line or mark made by a student can be a diagnostic determining what students may or may not be learning. Empirical studies have confirmed that the accuracy and quality of drawings link and correlate with subsequent tests on reasoning about what was just learnt. (Bhatt, 2011; Wammes, Meade & Fernandes, 2016; Larkin & Simon, 1987; Uesaka et al., 2007). The goal of drawing mediations is to develop self-directed student activities that assist them in identifying and detecting their mistakes and comprehension gaps. Van Meter (2001) alludes to a higher-order where mental models are constructed from thought recall instead of lower-order learning, where students engage in recognition by memorisation. However, it must be explicitly stated that there must be clear, concise instructions and guidance combined with multiple learning sources to increase understanding of concepts for these exercises to be successful.

Cox and Brna (2016) analysed the rough work or preliminary drawings students produced while engaged in problem-solving. The research supported the idea that distinguished problem solving originates from the ability to harness drawing techniques and select from them the best suited to meet the demands of the problem. They concluded that students could improve their ability to problem solve not by rote learning or accumulating more facts but by practising and improving drawing skills. Bhatt (2011) mentions that better integration of verbal, graphical and symbolic representations in engineering curricula can assist students in understanding various ways of communicating given concepts, thus leveraging their understanding to problem solve.

2.3.2 Drawing to collaboratively communicate

Larkin and Simon (1987) describe how visual explanations had more significance than writing a paragraph under certain circumstances. Bobek and Tversky (2016) analysed and compared verbal and graphic descriptions, in other words, writing a paragraph versus drawing a diagram. They identified that both groups profited from the explanations; however, the group that drew outperformed the other in the post-test. Thus, a drawing is an external or outer representation that is tangibly observable beyond the designer's mind. Mayer (2009, as cited in Quillin & Thomas, 2015, p.2) suggests in his "cognitive theory of multimedia learning" that students create mental models in their working memory by undertaking three cognitive exercises. First, from learning materials provided and prior knowledge; second, by structuring visual and verbal information and third, integrating the first and second into a mental pattern. This aspect of creating patterns is pertinent to this study and is extensively discussed in the ensuing chapters. Van Meter and Garner (2005, as cited in Quillin & Thomas, 2015) concur that conceptual visualisations occur after creating a mental pattern or model. However, the contradictions in literature must be noted. Leutner, Leopold and Sumfleth (2009) witnessed that many students who fashioned and crafted a mental pattern or model acquired significant learning gains compared to students engaged in creating drawings only. However, Koba and Tweed (2009) oppose this frame of thinking, stating, "drawings can be used to offload information to free up working memory."

There are two fundamental aspects of drawing; namely, they can be abstract or representational. Abstract drawings are analogical or analytical, whereas representational drawings are said to be true to life. Ainsworth, Prain and Tytler (2011, cited in Quillin & Thomas, 2015, p.3) state that other authors "refer to any learner-generated visualisations, including those with quantitative information, such as graphs," as drawings. The latter approach is supported for the drawing to learn teaching strategy, adopting the complete continuum from abstract to representational. Engineering subjects tend to relate more to analogical or analytical drawings. However, in the sciences, there is a combination of abstract and figurative. Ainsworth, Prain and Tytler (2011, p.1096) explain that visual modes play a critical role in knowledge construction in addition to talking, reading and writing. They identified that student's perceptions were expanded and deepened, especially when working with graphs. Students grasped and understood that line graphs displayed "continuous quantitative information." Students realised that drawings in the sciences and engineering were better when condensed, compact and coherent.

2.3.3 The importance of drawings

Formative assessments are used to observe and monitor students' comprehension and learning, thus providing ongoing advice, criticism, and feedback utilised by teachers to improve pedagogy and enhance student learning. However, Mohler (2007) argues that students believe that drawings are part of art and not the sciences even though they may enjoy it. Thus, students undervalue this teaching strategy, and they fail to utilise it. When drawings were used in formative assessments, it helped students recognise their weaknesses and strengths in their knowledge acquisition and helped them focus on aspects requiring more attention. Faculty, through formative drawings, promptly identified challenged or struggling students, and consequently addressed student challenges immediately (Ligorio et al., 2017). However, students also resisted using drawings because they lacked self-confidence. Quillin and Thomas (2015, p.8) highlighted a common refrain amongst students that "I am not good at drawing." These low self-esteem students suffered anxiety and feared strict appraisal of their classwork. Uesaka, Manalo, and Ichikawa (2007) highlight inaccurate student perceptions that drawing models are demanding even though they were more likely to get the correct answer when utilised.

Mohler (2007) asserts that information and data can also be used formatively, specifically when faculty or students employ assessments to influence subsequent programmes' activities and efforts. Baldwin and Crawford (2010, as cited in Quillin & Thomas, 2015, p.5) explained that a common aim of formative drawings was their use to develop and enhance observational skills. "Seeing and communicating are distinct but aligned goals. With more practice, observation skills will be better equipped to communicate what has been seen." The aim here is to develop graphic models to assist in the creation and understanding of knowledge. These models aid students design and understand experiments; problem solve, process data, connect concepts into a complete picture and learn and remember content knowledge. Uesaka et al. (2007) maintain that drawing and constructing models also motivates and makes students conscious of their own or personal tuition.

2.3.4 Drawing improves cognition

Ainsworth, Prain, and Tytler (2011, p.1097) contend that scientists clarify ideas for the public, colleagues and students by drawing. They also add that "In externalising private knowledge more permanently, visual representation is one way to enable broader dissemination." Quillin and Thomas (2015) argue that through drawings, students could think more explicitly and expressly. This improved their ability to communicate, clarify and exchange concepts or ideas among their peers. Wiggins and McTighe (2006) explain that when students created and openly shared their views on a public platform, they also enhanced personal development when their drawings were critiqued on their visual representations' coherence, content, and clarity. Educators should utilise these portals into student thinking for formative, summative and diagnostic assessments. Fan (2015, p.174) elaborates that "drawings, unlike our private perceptual images, were observable to all. Drawings could be shared; therefore, they could be utilised effectively to facilitate scientific thinking." However, some students had unenthusiastic attitudes to drawings due to negative experiences, associations, or do not enjoy drawing. Baldwin and Crawford (2010) concur that some students do not want to participate because they felt uncomfortable about drawings. Schwartz (1995) concluded that when secondary school students were paired to solve problems, they were more likely to succeed than students who worked alone. The study found that when students attempted to model the performance of mesh gears, paired students performed better at deriving a numerical equivalence than individual students. This study also concluded that paired students generated improved conceptual visualisations such as graphs compared to individual students who were more inclined to produce pictorial drawings. Schwartz (1995) surmised that the reason for this difference originated from a negotiated mutually derived drawing from the paired students. Schwartz (1995) contends that this resulted in more prodigious abstraction. Healey et al. (2001, cited in Fan, 2015) found that real-time interactions (where paired members were allowed to modify or erase lines or marks of the partners drawing) between participants encouraged more generalisable and abstract drawings compared to non-interactive (taking turns) scenarios.

Fay, Garrod, Roberts and Swoboda (2010) researched a game of Pictionary. Initially, participants drew detailed drawings that closely resembled the designated items. However, in consecutive turns, a minimal number of strokes were used to convey similar meanings. This resulted in the drawings becoming increasingly symbolic. It was also noted that as synergy developed between the paired students, their thinking and thus drawing patterns meshed. Whereas, in individual students, no patterns could be identified. The study concluded that the resulting practices developed due to the history of interaction between the paired students. Fay et al. (2010) argue that these studies have provided merged evidence that strong, vibrant social interactions develop and refine graphic representations. Garrod, Fay, Lee, Oberlander and MacLeod (2007) confirm that without these interactions' drawings can develop more complexity over time.

Hupet and Chantraine (1992) also suggested utilising a more collaborative teaching methodology in class. They advocated a two-way approach between educators and students instead of the outdated method of lecturing. Learning and student engagement can be promoted by using a physical or virtual whiteboard. Students and educators could utilise this board to settle uncertainties, provide information and ask questions in real-time. They promoted using technology to facilitate collaborative learning. Referring to this as graphical communication, they believe that this will be a productive endeavour employing new innovative teaching methodologies. Ainsworth, Prain, and Tytler (2011, p.1096) concur that many students lost interest in science because they were forced to adopt passive roles. This was a result of traditional teaching methods and rote learning. Progressive educators promoted enquiry and more interactive based learning. Ainsworth, Prain, and Tytler (2011, p.1096) identified that when "students draw to explore, coordinate, and justify understandings in science; they were more motivated to learn than from conventional teaching methods. They also concluded that "The use of drawing caters to individual learner differences, as a drawing is shaped by the learner's current or emerging ideas and knowledge of visual convention."

2.3.5 Scaffolding drawing skills to meet the goals for drawing-to-learn

Adams (2017) contends that educators need to employ support that will assist students to master the skills required on their own. It is critical to commence with an endpoint in mind. Novice students tend to memorise models; however, expert students engage models as intellectual, flexible, reflective tools. Maries and Singh (2018) described the cognitive load theory, suggesting that students who draw and understand diagrams are better problem solvers. Serra and Dunlosky (2010, p.699) referred to "metacognitive judgments" as one of the types of informative sources people require to determine their ability to perform a task. Adams (2017) asserts that drawing was both a process and a product, and students' capabilities were evaluated through performance, corroborated by their achievements.

Quillin and Thomas (2015) describe drawing as an effective learning strategy that assists students in surmounting limitations in curricula, effectively organising their knowledge, and successfully integrating existing and new knowledge. Ainsworth, Prain and Tytler (2011, p.1096) added that "inventing representations (including drawings) acts as preparation for future learning because it can help students discern key features and challenges of new tasks." Lessons that impart the skills of rendering verbal to visual data, including accepted symbols, enabled students to utilise cognition on crucial principles and concepts rather than simply drawing for examination purposes. Quillin and Thomas (2015) argue that, ultimately, students' ability to draw models to problem solve increased without being prompted. However, Anning (1999) contends that educators seldom used drawing as a problem-solving tool, therefore, students were unfamiliar with its learning potential. There is much that we need to know about drawing to learn. Many of the proposed hypotheses in this research study need to be tested, creating a wealth of opportunity for more research.

2.4 The use of patterns to enhance teaching and learning

Researchers argue that when students learn and explore patterns, they construct significant foundations for memory retention (Alexander et al., 1977; Mor et al., 2014). The capacity to distinguish, create and recognise patterns, argues Bennedsen (2006), assists in the fabrication of predictions from observations. Fernández (1998) concurs explaining that patterns are used to aid children in learning intricate, complex numbering concepts and mathematical theories in kindergarten. Patterns are also found in art, nature, literature and music.

2.4.1 The advantages of pattern learning

"A pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice," (Jones, Stewart, & Power, 1999, p.5). Fernández (1998, p.1) simplifies this further stating, "a pattern is a recurring combination of meaningful units that occurs in some context." Lockyer et al., (2009) surmise that patterns correlate and identify regularities and allow students to perceive relationships helping them develop generalisations. Empirical studies by Mor et al. (2014), Dehaene et al.(2015) and Jones, Stewart, and Power (1999) concluded that identifying and understanding recurring patterns allows us to formulate knowledgeable, educated deductions, hypothesis assumptions and guesses. Patterns create a perception of order in what appears chaotic and assist, foster and develop vital logic and critical thinking skills. The comprehension and knowledge of patterns are easily assigned and transferred into various curricula, thus opening doors to applying this knowledge. Jones, Stewart, and Power (1999, p.2) contend that "patterns are a way of recording the knowledge of experienced practitioners, best practice and lessons learned." Jones, Stewart and Power (1999) argue that pattern identification and use originated and became prevalent in architecture. Although its uses have broadened, there has not been a broad acceptance and implementation of it. Alexander et al. (1977, p13) argue that:

> In short, no pattern is an isolated entity. Each pattern can exist in the world, only to the extent that is supported by other patterns: the larger patterns in which it is embedded, the patterns of the same size that surround it, and the smaller patterns which are embedded in it.

Fernández (1998) adds to this, highlighting the importance of pattern reuse, especially with sub-patterns. Sub-patterns help to clarify and simplify macro complexities. Lockyer et al. (2009, p.12) explain that the utilisation of patterns originated with Christopher Alexander and his associates, working in town planning and architecture. Together with the team, Alexander constructed compelling patterns that competently aided the study of "built form."Alexander et al. (1997) combined social, mathematical, aesthetic and moral methods to assessment and analysis, elicited from years of practical experience and professional training. They were adept at honing language and other representations utilised to deconstruct built form.

2.4.2 The application of patterns to improve comprehension and understanding

Gamma, Helm, Johnson and Vlissides (1993) assert that recurring patterns help resolve explicit design problems, developing reusable, elegant, flexible designs. They also offer a process to authenticate and reuse expertise and experience. Dehaene et al. (2015) concur that patterns provide a common language by which practitioners can share and discuss ideas and thus reduce the effort involved in discovering new and applicable ones. Jones, Stewart and Power (1999) reiterate that patterns document abstract solutions to common problems, which can be implemented differently. Gamma (1997) argues that designers acquainted with these patterns can employ them immediately to address design issues.

Patterns, argue Gamma et al. (1993), are recognisable and predictable and can be recorded and identified by employing a specific format. These formats illustrate the pattern rationale. Using reliable, consistent formats that describe and explain patterns makes learning, comparing and using patterns easier. (Dehaene et al., 2015; Jones, Stewart, & Power, 1999; Mor et al., 2014). Some patterns are articulated and developed better than others. Some are derived from expert voices, while others are sourced from researchers (Mor et al., 2014). However, Gilovich (1993) argues that humans are uneasy with chaos and chance and undoubtedly see patterns where they do not exist. Jones, Stewart and Power (1999) assert that patterns are also constructed on knowledge acquired from "mining" existing practice and literature. Findings from a study undertaken by Konovalov and Krajbich (2018) concluded that the human brain processed pattern learning differently from probabilistic learning. The research also construed that humans engage in pattern detection continually in their daily lives. However, De Hevia and

Spelke (2010) argue that very little was known about how humans unravelled these patterns or the rules of pattern engagement that guide human decisions, making them quicker, accurate and more spontaneous.

2.4.3 Pattern identification to improve knowledge construction

Konovalov and Krajbich (2018) contend that learning from patterns is universal in decision-making. In comprehending patterns, students grasp scientific relationships while manipulating, learning, and recording patterns using graphs, charts, tables, and drawings to analyse data and solve complex scientific problems. Konovalov and Krajbich (2018, p.1289) assert that "the brain divides all possible patterns into specific groups (structures or pattern types), assigns beliefs to each group, and updates them during the learning process." Dehaene et al. (2015, p.2) concur that at least five different categories represent sequence knowledge at enhancing degrees of abstraction. These are:

Transition and timing knowledge (knowledge of the transitions from one item to the next), chunking (the grouping of several contiguous items into a single unit that can be manipulated as a whole), ordinal knowledge (knowledge of which item comes first, which comes second, and so on, independently of their timing), algebraic patterns (abstract schemas that capture the sequential regularities underlying a sequence of items) and nested tree structures (characteristic of human languages, according to abstract grammatical rules into a set of groupings, possibly embedded within each other, forming a nested structure).

However, Shermer (2008) argues that our human brains have progressed and evolved, becoming pattern recognising machinery, creating patterns and meaning that we perceive or think we envisage in day-to-day life. Shermer (2008) acknowledges that frequently, the patterns are genuine and authentic; however, they are often displays of chance.

De Hevia and Spelke (2010) reiterate that pattern use is plain and simple, particularly when incorporated within a productive, constructive template. The continuous evaluation of pattern teaching, argue Dehaene et al. (2015), encompasses a reflective, evaluative process lacking in many current teaching and learning practices. Gamma et al. (1993) describe how design patterns are simple to demonstrate and explain to practitioners. This is due mainly to the unassuming appeal of patterns and their focus on solutions to frequent problems. Konovalov and Krajbich (2018) explain that patterns tend to breach barriers to acceptance, application and skilled professional development.

Dehaene et al. (2015) acknowledge that educators are confronted by design challenges continuously throughout their practice. There is a critical need to source effective methods to share successful design knowledge, especially if educators build on the success of others cumulatively. One of the effective ways of accomplishing this is to employ the use of design patterns. Mor et al. (2014, p.1) argue that "Design patterns provide a way of addressing this issue by providing guidance which is abstracted from practice and informed by theory in a way which makes them more easily translated into effective practice".

Despite patterns being recognised in academia, it has not been broadly accepted and implemented. In the TVET sector, studies on its use and application are very scarce, and in the South African context, no studies could be identified. This research endeavours to address this gap.

2.5 Students' misconceptions about electrical circuits

Educators, argue Potvin and Cyr (2017), are sometimes bewildered that many students cannot grasp vital concepts covered during lessons despite their best efforts. Turgut, Gürbüz, and Turgut (2011) acknowledge that numerous studies indicated that students attend classes with existing knowledge of preconceived ideas relating to their chosen subjects. Tytler (2002) contends that students completing a science module can emerge with diverse understandings from what the educator intended. Moodley and Gaigher (2019) describe how students can use algorithms to solve scientific problems without understanding the scientific fundamentals. Even high performing students tend to display different conceptual understanding when applying scientific knowledge to out of classroom situations. Turgut, Gürbüz and Turgut (2011) refer to this prior knowledge as preconceptions, which in certain instances, conflict with scientific assessments. Tytler (2002) defines preconceptions that conflict with scientific opinions as misconceptions.

Chang, Liu and Chen (1998) explain that throughout the learning process, students may perform poorly due to deficiencies in knowledge. They categorised these deficiencies as incompleteness, discrepancy, and uncertainty. Incompleteness and uncertainties in knowledge can be remedied by remedial instruction. However, Potvin and Cyr (2017) argue that discrepancies must be corrected. If not, the discrepancies will result in misconceptions that could form prominent barriers to learning. Preconceptions, argue Turgut, Gürbüz and Turgut (2011), are derived from different experiences, cultures, teaching and learning and misconceptions created from flawed interpretation and understanding of pre-existing knowledge must be identified.

2.5.1 Understanding misconceptions

Turgut, Gürbüz and Turgut (2011, p.15) describe misconceptions as “mistaken beliefs,” “alternative conceptions as different but valid ways of looking at the world,” and “interpretive frameworks as coherent ways of looking at the world.” Merriam-Webster (n.d.) describes misconceptions as “a wrong or inaccurate idea,” culminating in an incorrect opinion or view created by flawed understanding or thinking. Sencar and Eryilmaz (2004) argue that the phrase misconception infers that students have incorrect or contradictory concepts compared to objective scientific evidence or models. However, Potvin and Cyr (2017, p.1121) argue that in the minds of some students, “scientific knowledge does not necessarily erase or alter initial non-scientific knowledge but rather coexists with it.” The worst-case scenario is that misconceptions will impede students to acquire additional knowledge, or they could inaccurately coexist with scientific knowledge.

The Committee on Undergraduate Science Education (U.S.) (1997, p.28) identified the following types of misconceptions encountered by students as outlined in Table 2.1 that follows:

Table 2.1 Student misconceptions (The Committee on Undergraduate Science Education (U.S.) 1997, p.28).

	MISCONCEPTIONS	EXPLANATION
1.	Preconceived notions	are common concepts experienced daily.
2.	Non-scientific beliefs	are ontological views students develop epistemically from religious teachings.
3	Conceptual misunderstandings	occurs when students develop inaccurate models from non-scientific beliefs and preconceived notions. Generally, in this scenario, students are insecure or uncertain about their beliefs.
4.	Vernacular misconceptions	are words, phrases, and terminology used daily but have a different scientific context.
5.	Factual misconceptions	are inaccuracies learnt early in life and preserved unchallenged into adulthood.

The following vital characteristics of misconceptions as indicated by Turgut, Gürbüz and Turgut (2011, p.1965):

> Misconceptions of students who have different culture, religion and language are frequently similar to each other. Misconceptions may deeply penetrate students' minds and resist change. Daily language, culture and religion can cause the formation of misconceptions. Misconceptions can be parallel to the explanations made by earlier scientists in interpreting scientific phenomena. Misconceptions may develop after formal teaching.

2.5.2 Factors that influence misconceptions

Moodley and Gaigher (2019) contend that, as early as 1973, studies exposed misconceptions among students regarding electrical circuits. Misconception models were identified by students in several countries by Chang, Liu and Chen (1998), Pesman and Eryilmaz (2010) and Sencar and Eryilmaz (2004). Factors that influenced misconceptions included lack of knowledge, curriculum design, culture, background, gender, language, and cognitive perspectives. (Sencar & Eryilmaz, 2004; Rollnick et al., 2008).

Importantly, this study recognised the prominent role of social injustice that influenced misconceptions from the legacy of apartheid, as alluded by du Plooy and Zilindile (2014).

Larkin (2012) contends that students must be shown the reasoning process in the formulation of conceptual generalisations; however, Potvin and Cyr (2017) argue that this does not exclude using helpful examples or hypothetical test questions to problem solve. Although students had misconceptions, many had acquired partial scientifically correct ideas. Turgut, Gürbüz and Turgut (2011) suggest that this could be the foundation to address misconceptions. Many students had an inaccurate grasp of vital concepts from the commencement of their studies. Larkin (2012) contends that these limitations interfered with subsequent learning.

Wichard and Hans (2012) contend that once misconceptions have been identified, they can be corrected. The Committee on Undergraduate Science Education (U.S.) (1997) argue that professional societies have improved conceptual tests to identify misconceptions while contending that group discussions can effectively identify misconceptions. Larkin (2012) concurs that teachers can probe student conceptions by merely listening without humiliating the student. Assignments that probe student's reasoning can also be used. However, they should not be utilised for grading but rather to determine student thinking.

Taylor (2017) acknowledges that misconceptions occur in how students organise scientific knowledge and their comprehension of scientific methods. In this regard, students performing scientific experiments were disappointed that the experiment had not worked. They could not comprehend that experiments should test hypothesis and ideas and not necessarily conclude an anticipated result. However, to scientists, the experiment always works, whether good or bad, but the findings must be interpreted.

Potvin and Cyr (2017) argue that it might be easy for students to correct factual and vernacular misconceptions, however, Turgut, Gürbüz and Turgut (2011) contend that it is erroneous for teachers to ask students to dismiss entrenched non-scientific views or beliefs. They argue that new concepts cannot be easily adapted or learnt if alternate models explaining phenomena exist in the student's mind. Sencar and Eryilmaz (2004) assert that scientists view these inaccurate models with contempt and disdain, yet students favour them because they seem more acceptable to their reasoning. Larkin (2012) argues that students must challenge their opinions, contradictions, limitations and enigmas before embracing scientific concepts. Then only will they be able to recreate the information based on the scientific model posed successfully. Taylor (2017) concurs and reiterates that the teacher should ascertain student misconceptions, and then create a student environment or forum to confront them. Lastly, students need to be assisted with internalising and reconstructing facts and information constructed on scientific patterns.

2.5.3 Helping students confront their misconceptions

Turgut, Gürbüz and Turgut (2011) suggest that teachers should analyse new curricula for potential misconceptions before introducing and teaching them. This can be done during class discussions. Students surprisingly will disclose many of them, so it is vital to listen carefully to their responses. Larkin (2012) asserts that students should be asked for evidence to support their reasons when returning to misunderstood and complex concepts during revision. Sketches and drawings also help unmask certain preconceptions. Fan (2015, p.174) elaborates that "drawings, unlike our private perceptual images, were observable to all. Drawings could be shared; therefore, they could be utilised effectively to facilitate scientific thinking." After students have drawn models, they should be asked to explain how the scientific concepts relate to what they have drawn, allowing the teacher to locate and dismantle misconceptions. However, Potvin and Cyr (2017) argue that misconceptions are vigorously defended, mostly unexplained and habitually held. They further reiterate that an effective teacher will address these impediments even though confronting them is complicated for the teacher and student.

Martin, Martin and Southworth (2015) contend that it is imperative to overcome student misconceptions to construct correct frameworks for knowledge acquisition. One type of framework suggests Wichard and Hans (2012) is to get students to create conceptual maps. Using this method, students learn how to visualise and develop conceptual relationships. The concept map directly correlates to pedagogical patterns discussed in chapter one, preceding this Chapter Two of the literature review. However, certain studies have suggested that concept maps do not improve significant learning (Kamp et al., 2012; Moust, van Berkel & Schmidt, 2005). Nevertheless, other studies have shown conclusive evidence of conceptual improvements (Martin, Martin & Southworth, 2015; Jablokow et al., 2015). Abi-El-Mona and Adb-El-Khalick (2008) concluded that concept maps constructed in cooperative groups were engaged more successfully than students working alone.

Martin, Martin and Southworth (2015) contend that it is a challenging and time-consuming task to get students to reconstruct their conceptual thinking. However, if it is done correctly, misconceptions can be dispelled. Taylor (2017, p.1) suggests the following method to overcome misconceptions. Teachers should develop:

> [a] pre-test of misconceptions. Always commence with the facts and not the misconception. Only speak of the misconception once the facts have been established. Then refute the inaccuracy. Then discuss why the misconception was so easily accepted. Last, inoculate the newly established knowledge through reinforcement.

Turgut, Gürbüz and Turgut (2011) assert that lack of knowledge, culture, curriculum design, background, gender, cognitive perspectives and language are some of the root causes of misconceptions. If these aspects are addressed, many students will enhance their learning capabilities and become more proficient in many of the pedagogical tasks they encounter.

2.6 Blended learning

Imbriale (2013, p.31) contends that blended learning happens “any time a student learns, at least in part, at a supervised brick-and-mortar location away from home and, at least in part, through online delivery with some element of student control over time, place, path, or pace.” Said (2008) concurs that blended learning is a hybrid methodology of teaching that combined e-learning and social networking with traditional or conventional classroom practices. Gunawardena et al. (2009, p.4) defined social networking “as the practice of expanding knowledge by making connections with individuals of similar interests". Bates (2015) contends that in many aspects, the focus of education has shifted from original and critical thinking, alternative viewpoints and exploration of ideas to merely information presentation or transmission.

2.6.1 The benefits of blended learning

Blended learning is an educational style of learning that students learn via a combined system of traditional classroom education and online and electronic media (Macdonald, 2003; Jugoo, 2014; Huang, Ma & Zhuang, 2008). Welker and Berardino (2007) concur that "blended learning is any combined use of electronic learning tools that supplement but do not replace face-to-face learning." Nair (2019, p.1) maintains that "Hybrid learning or blended learning refers to applying theoretical concepts taught in a classroom in a practical world by employing tech mediated activities". So (2009, p.59) posits that "the next generation of distance learning can be characterised as the use of interactive two-way technology that enabled students to interact synchronously or asynchronously with their teachers and other students." Jugoo (2014) adds that blended educational learning must result in students actively participating in a deeper learning approach.

Various terms have been associated with blended learning, such as flipped classroom, blended education and hybrid learning (Macdonald, 2003); (Jugoo, 2014); (Huang, Ma & Zhuang, 2008). This has led to many debates and disputes on the correct definition of blended learning. As alluded to by Welker and Berardino (2006), the general definition of blended learning regularly used is the amalgamation of electronic teaching and learning tools combined with face-to-face interaction. Graham (2006, as cited in Jugoo, 2014, p.23) describes blended learning as "technology-mediated instruction." Figure 6 illustrates how a blended learning environment is achieved when these two modes are integrated. Ultimately blended learning encompasses online technology with face-to-face interaction intending to accomplish the educational objectives while improving the teaching and learning experience. Banci and Soren (2008) contend that the focus has progressed beyond technology to create an effective learning environment.

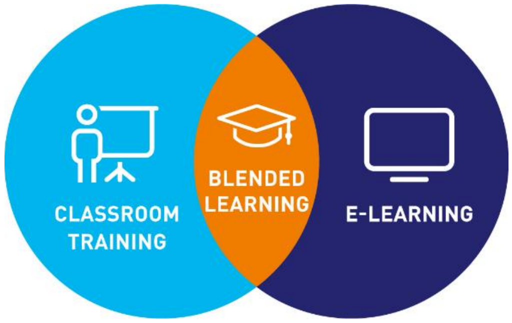


Figure 2.1. Blended Learning (Nair, 2019) **http://www.cvo-europe.com/**

2.6.2 Creating a blended learning environment

So (2009) argues that consideration must be given that students don't want only an online approach or an entire face-to-face method when developing a blended learning programme. Macdonald (2003) emphasises that crucially important to effective blended learning is the approach and manner it is developed and set up. The model should include textbooks, assessment guidelines, classrooms, workshops and online access. Nel and Wilkinson (2008) postulated a South African blended learning framework. They commenced with a plan, followed by a design and setup and concluded with students utilising the Learning Management System (LMS). Ning and Wuzi, (2011, as cited in Jugoo, 2014, p.25), highlight five main aspects of their framework. First, teachers must be "enthusiastic and take the initiative to promote learning." Second, teachers must use "online materials as a means to support and supplement the work carried out in class." Third, teachers must divide the online component into "two parts, namely, basic knowledge to help build the foundation of programming concepts, and advanced knowledge." The penultimate step focused on "teaching of concepts through the use of interesting examples." The fifth step encouraged independent or collaborative work undertaken through "online classes and materials."

Watts and Hammons (2003) argue that it is vital that post-school institutes integrate classroom and technology utilising learning management systems such as Moodle, Blackboard or Google Drive. These platforms can be used for posting materials by the teacher or for interactive learning and teaching with students commenting and discussing their work. Harasim (2012, p. 90) adds that on these platforms:

> [s]tudents are encouraged and supported to work together to create knowledge: to invent, to explore ways to innovate, and, by so doing, to seek the conceptual knowledge needed to solve problems rather than recite what they think is the correct answer.

However, Huang, Ma and Zhuang (2008) explain that tutorials and online assistance are vital to providing support to students. Network infrastructure must accommodate students working within and outside the institute.

2.6.3. Impediments to blended learning

Nel and Wilkinson (2008) maintain that the negative aspects of online platforms cannot be ignored. They contend that many students were not enthusiastic about their participation. This created pressure on other members of the group, where group work was undertaken. Nair (2019) acknowledged that other students believed that face-to-face learning platforms helped facilitate decision-making quicker instead of a cumbersome online process. Gunawardena *et al.* (2009) concurred that no internet access and poor signal strength made it impossible to utilise online platforms. Tucker and Umphrey (2013) asserted that blended learning is also more time consuming for the teacher. This is especially true regarding the preparation, implementation and execution of new teaching material. The proper assignment and development of teams requires additional time, not in traditional chalk and talk lessons.

Many teachers only utilise the conventional “talk and chalk” method, argues Bouroumi and Fajr (2014, p.72). However, they note that empirical studies have concluded that improvements in education can originate from a combination of e-learning, cooperative and collaborative learning strategies implemented and applied correctly. These findings, according to Imbriale (2013), advocate a paradigm shift in teaching and learning. Learning environments become key, where learning is constructed through experimentation, engagement and communication with the teacher, not the primary source of knowledge and skills.

In a blended study undertaken by Said (2008), students overwhelmingly approved and were satisfied using the online platform. Student motivation improved in the process of constructing their knowledge. However, as alluded to by Nel and Wilkinson (2008), most students deemed face-to-face interaction vital for teaching and learning, not only with teachers but also with their peers. Ultimately, students felt online tutoring could not replace human interaction, especially when learning critical skills. This interesting dilemma requires additional research to determine how this balance between human interaction and online platforms could be achieved.

2.7 Conceptual framework

This study adopted two conceptual frameworks to analyse the research questions, namely, pedagogical content knowledge and situated learning.

2.7.1 Pedagogical content knowledge

Rollnick et al. (2008, p.1365) assert that "Lee Shulman in 1986 published the paper that coined the phrase pedagogical content knowledge (PCK) describing the knowledge that teachers create by transforming their content into a teachable form". Shulman (1986) distinguished three types of knowledge, i.e. subject knowledge, pedagogical knowledge and curricular knowledge. Grossman (1990) developed four domains of knowledge from Shulman's (1987) revised categories of knowledge types. Grossman (1990, p.5) refers to these four domains as "the cornerstones of the emerging work on professional knowledge for teaching." These four types of knowledge, argues Magnusson, Krajcik and Borko (1999), should be used by teachers in their teaching preparations. This study elaborates on these four different knowledge types, which are general pedagogical knowledge (GPK), subject matter knowledge (SMK), pedagogical content knowledge (PCK), and knowledge of contexts. However, the conceptual engagement of this study will be through PCK. Shulman (1986, p.9) describes PCK as "the ways of representing the subject that make it comprehensible to others." Grossman (1990) describes PCK as the knowledge that teachers develop through experience over time developing teachable content to improve student understanding. Bucat (2005, p.11) defines PCK as “knowledge about the teaching and learning of the particular subject matter, taking into account the particular learning demands inherent in the subject matter.”

Thulasiraman (2003) contends that PCK endeavours to enhance facts, concepts, theories and principles and blends well with the analysis and design of circuit theory. Christie and Trinidad (1998) add visualisation as another aspect that speaks specifically to this study. Christie and Trinidad (1998) argue that many students have no intuitive understanding of electrical circuits. Bucat (2005) further adds that there is a vast difference between knowing about a topic (content knowledge) and knowing about the teaching and learning of that topic (pedagogical content knowledge). Kind (2009, p.12) argues that many poorly skilled teachers:

> [p]aid scant regard to what and how pupils were learning. In many lessons, teachers simply passed on information without any expectation of pupils’ direct engagement in the process. The objective appeared to be to get notes into books and leave the learning to the pupils.

This type of teaching did not actively aid student learning. Kind (2009) postulates that teachers resort to these teaching practices due to their lack of a wide range of knowledge types to transform subject matter knowledge (SMK) to students successfully. Shulman (1986) argues that these knowledge types include understanding students’ prior knowledge, effective teaching strategies, diverse alternative representations, and the synergistic importance of a subject or topic to the complete curriculum. Thus, PCK is not viewed as knowledge of one entity in teaching but rather a sound understanding of all types of knowledge related to how a subject is taught (Marie, Jan, & Fien, 2015; Bucat, 2005).

Grossman (1990) contends that PCK has four fundamental components: knowledge and beliefs on purpose for teaching a subject at different grades, knowledge of students’ understanding of concepts and their misconceptions in the content that is taught, curricular knowledge that includes curricular programmes and materials or topics of a specific subject at a given level or across the grades and knowledge of instructional strategies that are the teaching methodology that teachers use to teach and explain specific topics. Windschitl’s (2004) categories of knowledge also have four elements. Windschitl

(2004) adapted Shulman’s categories of knowledge and described four types of knowledge: content knowledge (CK), general pedagogical knowledge (GPK), pedagogical content knowledge (PCK) and disciplinary knowledge (DK). These four knowledge types were developed to conceptualise practical work. PCK develops from students’ prior knowledge at different ages and supports their reasoning processes to conceptualise science concepts and ideas (Windschitl, 2004). This involves the teacher’s ability to choose appropriate practical tasks to help students conceptualise ideas, concepts and evaluate the practical work.

Moodley and Gaigher (2019) argue that studies on PCK showed that teachers are often unable to link PCK to SMK. Larreamendy-Joerns and Leinhardt (2006, p.24) postulate “that knowledge rests not on facts or isolated skills but principles of inquiry. In this view, learning a discipline implies coming to understand not only its substantive structure (i.e., facts, concepts, theories), but also its syntax—that is, the questions that guide inquiry, the tools that allow inferences and interconnections, and the actions and principles (rules) that validate knowledge.” Through PCK, students are given opportunities for participatory practice and, as competencies develop, they seek and obtain supporting skills and concepts. Thus, from the onset of learning, the student engages in questioning, makes connections, draws inferences, and validates knowledge.

2.7.2 Situated learning

The second part of this conceptual framework built on Lave and Wenger’s (1991) notions of situated learning theory and Contu and Willmott’s (2003) situated conceptualisations. Besar (2018) affirms that situated learning was first defined by Brown, Collins and Duguid and then developed by Lave and Wenger as an instructional approach that claims that learning is more successful when students actively participate in the learning experience. Lave and Wenger (1991) reiterate that group members jointly share and develop practices within a community, learn from their interactions with group members, and gain opportunities to develop personally, professionally, or intellectually creating meaning from daily activities living. Stein (1998, p.1) explains that situated learning has four guiding activities:

(1) Learning is grounded in the actions of everyday situations; (2) knowledge is acquired situationally and transfers only to similar situations; (3) learning is the result of a social process encompassing ways of thinking, perceiving, problem-solving, and interacting; and (4) learning is not separated from the world of action but exists in robust, complex, social environments made up of actors, actions, and situations.

These four aspects differentiate situated learning from other experiential forms of acquiring knowledge. Lave and Wenger (1991) clarify that students learn content through activities rather than acquiring information in discrete packages organised by instructors in situated learning. Content is inherent in the doing of the task.

Stein (1998) affirms that situated learning uses cooperative and participative teaching methods to acquire knowledge. Lave and Wenger (1991) explain that knowledge is created or negotiated through the student's interactions with others and the environment. Subject matter emerges from the dialogue among the learning community. The practice is refining and perfecting the use of acquired knowledge. When applied to the classroom, Besar (2018) contends that situated learning is not only reflecting upon and drawing implications from previous experiences but is the immersion in and with the experience.

Gu and Day (2007) explain that the situated dimension is affected by local conditions. These might be the school's challenges and the behaviour of the students. Lave and Wenger (1991) concur that teachers' knowledge is always in a state of flux, changing with the situation or the context. Lave and Wenger (1991) argue that teacher success depends on how accommodating and friendly the classroom situation or context is; thus, teacher's knowledge construct is experience and situation dependent. This situated dimension conceptualises and contextualises teaching, examining issues that hinder or promote learning as the environment or context influences student experiences.

Contu and Willmott (2003) found that embedded learning in the social and physical context is more effective than non-situated learning and contend that learning is "an integral part of generative social practice in the lived-in world where tasks performed, are acquired, shared, and elaborated," thus becoming a community of knowledge (Contu & Willmott, 2003, p.284). They argue that the learning structure is implicit in the experience rather than in the subject matter. Contu and Willmott's Situated Conceptualisations illustrated in Table 2.2 was adopted to address both research questions.

Table 2.2 Situated conceptualisations compared. Contu and Willmott (2003, p. 294)

Conceptualisation	Established	Situated
Learning	Cognitive/ passive/ selective.	Interactive/participative and pervasive
Form of knowledge	Canonical/ codified/ theoretical distilled in texts and manuals.	Tacit/ embedded/ Practical embedded in community and identity.
Understanding developed	Abstract/ universal	Embodied/ context sensitive.
Outcome of Learning	Acquisition of information or skill.	Transformation of identity.
Transmission	Vertical/ instruction by authorities.	Horizontal /collaboration with peers

2.8 Conclusion

This chapter engaged with a range of literature and discussed vocational education and training and how the TVET has evolved in South Africa. It examined various concepts relating to drawing as a teaching strategy and explained various aspects of pattern learning and how it assisted in the interpretation and understanding of pedagogical concepts. The chapter also described the challenges students encounter due to misconceptions. Blended learning and online platforms were also discussed in this literature review. The chapter concluded with a discussion of the conceptual frameworks utilised in this study, namely, pedagogical content knowledge and situated learning. The conceptual significance of both these frameworks were outlined in this chapter. The next chapter discusses the methodological approach used in this study.

CHAPTER THREE: RESEARCH METHODOLOGY AND DESIGN

3.1 Introduction

This study explored drawing to learn as a teaching strategy to improve teaching and learning in NCV electrical level 2. The study also examined the extent to which drawing to learn enhanced student's interpretation and understanding of electrical schematics. In addition, this study examined how student's misconceptions of electrical circuits contributed to their struggle to interpret and understand electrical drawings. Students should have a firm theoretical grasp of their field of study and the practical ability to apply the knowledge in class and industry. Many TVET students were prone to learn how to draw electrical schematics for examination purposes. Unfortunately, they could not interpret what was drawn. Industry requires electrical artisans to be competent in reading, interpreting and designing schematics. May (2011, as cited in Nundkumar, 2016, p.111) contends that "research is more than a reflection on our opinions and prejudices: it substantiates, refutes, organises or generates our thinking and produces evidence that may challenge not only our own beliefs but those of groups and societies in general". This chapter discusses the methodological approach and research design adopted in this study. This methodology chapter furnishes the information necessary to replicate this study and explains how the research design structured the research. The chapter commences with an explanation of the methodological approach. Next, the critical paradigm and its suitability for this study is explained. This is followed by a discussion of the action research design, justifying the use of action research and explaining its strengths and weaknesses. This is followed by an outline of the research setting and the sampling strategy. Next, the data collection instruments, the procedure of data collection and data analysis are discussed. The chapter concludes with a discussion of issues of trustworthiness, ethical considerations and limitations. The methodological approach, research design and methodological choices are justified and substantiated by relevant literature.

3.2 Methodological approach

Methodology argues Cohen, Manion and Morrison (2007), refers to how knowledge is procedurally discovered, identified, selected, processed and analysed. The methodology evaluated the reliability and validity of this study and focused on how the data was collected and analysed. Bertram (2008, p.63) explains it succinctly by querying: "How can the inquirer go about finding out the nature of the reality?" The actions taken to address both research questions and examine the research problem are detailed (May, 2011; McLeod, 2019). Data were obtained from an action research project. Since a new innovative teaching strategy was introduced, this methodology chapter endeavoured to provide detailed information to other researchers who would want to implement or replicate this study. The problems experienced and the steps to minimise them are clarified (Garg, 2016; Hakim, 2012). This chapter described the ontological and epistemological underpinning. The relationship between theories and methods were delineated (Garg, 2016; Akinyode, 2018). Theories, argue Creswell and Creswell (2018), characterised the social world researched, and methods unravelled how the data about that social world was generated, analysed and interpreted in Chapter Four. The approach, together with the research instruments and procedure, are described.

3.3 Research paradigm

Bassey (1999, as cited in Kajee, 2011, p.31) contends that a paradigm is a "network of coherent ideas about the nature of the world and the functions of researchers that condition the patterns of their thinking and underpins their research actions." Kuhn (1970) describes a paradigm as a shared collection of collective agreements and beliefs among scientist about how complex problems are comprehended and addressed. Guba (1990, as cited in Creswell 2014, p.35) defines a paradigm as "a basic set of beliefs that guide action." Bunniss and Kelly (2010, p.360) concur that paradigms are:

> [s]ets of beliefs and practices shared by communities of researchers, which regulate inquiry within disciplines. The various paradigms are characterised by ontological, epistemological and methodological differences in their approaches to conceptualising and conducting research in their contribution towards disciplinary knowledge construction.

Kuhn (1970, as cited in Weaver & Olson 2006, p.460) contends that "all disciplinary research is conducted within paradigms." Researchers employ different classes of paradigms. Creswell (2014, p.54) outlines "positivism, post-positivism, critical theory, constructivism and participatory.” The paradigm adopted in this study is the critical paradigm.

3.3.1 Critical Paradigm

Social science research is interpreted meaningfully when decisions about the research outcomes are clarified. Researchers use a philosophical approach to provide notions of theoretical thinking, developing a reality of knowledge to conduct, analyse, and interpret research. Figure 3.1 below illustrates the links that were adopted for this study.

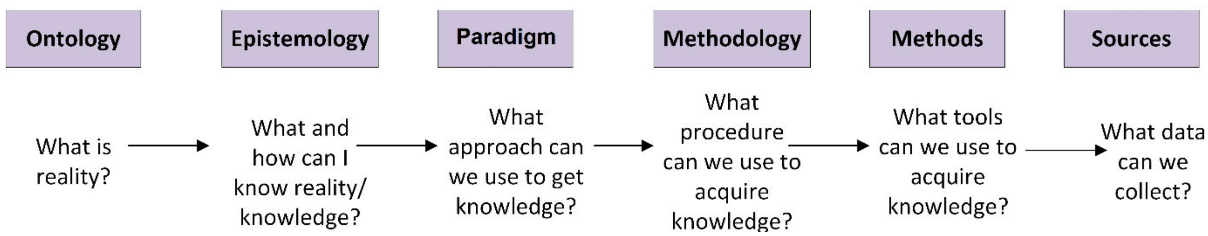


Figure 3.1The links in research philosophy (Patel, 2015, p.1).

One of the critical aspects underpinning this study is the research philosophy. The three prominent characteristics of philosophy are ontology, epistemology and methodology. Although these theoretical concepts are complicated, argues Hammond (2004), they establish specific fundamental attributes developed within the framework of the research philosophy and their associated complex integration. Different kinds of research are founded on different beliefs of what we think the truth is or what is true. Ontology, argues Taylor (1959), examines what exists in our social world and evaluates the nature and form of that societal reality. Ontologies are frameworks representing compelling, shareable, helpful knowledge across a domain, making them the basis for quality and coherently linked data.   (NurseKillam, 2015; Fleay, 2018).

Epistemology asserts Al-Saadi (2014), evolves from the researcher's relationship with the research and how knowledge is discovered and acquired. Ontological beliefs will influence epistemological beliefs. Hill (2018) concurs that what the researcher believes about the nature of reality influences the kind of relationship the researcher has with what is being studied. Epistemology explains the means and preconditions for knowledge acquisition. The ontology underpinning action research is relativism. Relativists believe that meanings and experiences create the truth, and the subjective experience is reality. To understand someone's experiences and the context that has shaped them, you need to dialogue and interact with them (Buckley et al., 2014; King & McInerney, 2019). As the lecturer in my class, I was empowered and I believed that my epistemological position adopted many truths that constitute a system of socio-economic power. My students engaged in a transformative teaching strategy which endeavoured to emancipate them from their learning challenges. My ontology and epistemology are closely aligned to the critical paradigm detailed as follows.

This study was located in the critical paradigm since "the purpose of critical educational research," argue Cohen, Manion and Morrison (2007, p.45), "is intensely practical [and]… transformative". This drawing to learn teaching strategy empowered students and was utilized to bring about a change in their learning. This paradigm addressed critically relevant social issues. Ledwith (2007, p.597) refers to critical practice "as any practice that has a transformative social justice intention and happens in a range of contexts from grassroots community activism to more institutionalised settings, such as hospitals or schools."

The critical paradigm is also referred to as the transformative paradigm. "The transformative paradigm is a meta-physical framework that directly engages the complexity encountered by researchers and evaluators in culturally diverse communities when their work is focused on increasing social justice" (Mertens, 2012, p.804). Mertens (2007) argues that the transformative paradigm is a research framework centred on the marginalised experience, linking research findings to intended actions that mitigate inequalities. Romm (2015) contends that researchers who embrace the transformative paradigm consider social justice issues and champion fair social fabric actions. Mertens (2012) argued that researchers should be conscious of prejudice and discrimination, understanding communities adequately to confront the status quo, providing a source for social change. This study promoted a transformational new teaching strategy, engaging students from disadvantaged communities to facilitate teaching and learning.

Bertram and Christiansen (2014) claim that the critical paradigm has an emancipatory purpose. Weaver and Olson (2006, p.461) reiterate that “research becomes a means for taking action” where the desired focus is on “the combination of reflection and action to effect transformation.” Besides critical theory having its peculiar enquiry agenda, Cohen, Manion and Morrison (2007, p.47) contend that “it also has its research methodologies, in particular ideology critique and action research.” The critical paradigm is most suited to an action research design.

Cohen, Manion and Morrison (2007, p.26) argue that this paradigm “seeks to emancipate the disempowered, to redress inequality and to promote individual freedoms within a democratic society.” Creswell (2014, p.38) contends that “the research contains an action agenda for reform that may change lives of the participants, the institutions in which individuals work or live, and the researcher’s life.” Koshy, Koshy and Waterman (2011) assert that action research is underpinned by critical theory. Action research’s key focus and impact centres on practice. Action research is practitioner research, especially by teachers and curriculum developers and gives these practitioners a voice since it is emancipatory and empowering. This research endeavoured to be transformative, emancipatory, containing an action agenda for reform and change in participants’ lives. Its impact centred on practice, justifying why the critical paradigm was most suitable for this action research study.

3.4 Methodological approach

Action research was the design chosen for this study. The study explored the efficacy of introducing drawing to learn as a new teaching strategy to improve reading, interpreting and designing circuit diagrams. The open-ended focus group questions and observation reflections generated qualitative data. The likert scale questionnaire and observation schedule summative task with close-ended questions generated quantitative data. Rigorous, appropriate procedures were used to collect and analyse data according to each methods tradition. Fetters, Curry and Creswell (2013) argue that this could be done sequentially or concurrently within the conceptual frameworks. In this study, both qualitative and quantitative data were collected and assessed concurrently and then jointly displayed in the interpretation of data in the analysis chapter. Both data types validated each other and created robust underpinnings for the conclusions (Fetters, Curry & Creswell, 2013; Creswell, 2014; Mertens, 2010).

The qualitative data built directly on the quantitative results; thus, the quantitative results were explained in detail through the qualitative analysis (Johnson & Christensen, 2014; Cohen, Manion & Morrison, 2007).

3.5 Action research design

Mertens (2010) contends that the outline, structure or overall framework of a research study is described as the research design. Action research was the research design used in this study.

3.5.1 Defining action research

Cohen, Manion and Morrison (2007, p.298) contend that "action research is a process in which participants examine their educational practice, carefully and systematically, using the techniques of research." Kurt Lewin, in 1944, coined the phrase action research to describe an enquiry process that occurs when action is taken to resolve a problem (Schrueder, 1997; Schuiling & Vermaak, 2017). He included a series of spiral steps, contends Craig (2009), each of which constitutes a cycle of planning, action, analysis and reflection. Kemmis and McTaggart (1988, as cited in Cohen, Manion & Morrison 2007, p.299) argue that "to do action research is to plan, act, observe and reflect more carefully, more systematically, and more rigorously than one usually does in everyday life." Action research is a spiral process that you repeat over and over until you find a solution that satisfies (Elliott, 1981; Schuiling & Vermaak, 2017). However, researchers have expanded on Lewin's action research method, differing on the cyclic process of action and reflection (Elliott, 1981; McKernan, 1991; Kemmis, 2006; Craig, 2009).

Coghlan and Brannick (2010) argue that action refers to the intended implemental change, while research refers to the improved grasp and comprehension of the investigation. Creswell and Creswell (2014) extricate action research from daily activities stating it is not the regular reflection teachers engage when thinking about their teaching. Action research is more collaborative and systematic. Action research is the process of posing a problem, question, issue, doubt, dilemma, or challenge. Then, gathering information or data about the situation, reflecting on that data, and then making decisions to correct the problem. Schuiling and Vermaak (2017) concur that we engage in action research not exclusively for problem-solving; conversely, it can begin with passion, interest, or curiosity. Action research is research that any of us can do to improve on his/her practice. It is practitioner-based and focuses on the researcher undertaking research within their context. It can be conducted with the assistance or guidance of professional researchers to improve strategies, practices, and knowledge of their practice environments. The primary objective of the researcher argues Altrichter, Posch and Somekh (1993), is to explore their practice and identify ways to improve it. A critical element of that process is self-reflection. Wadsworth (1998) concurs that it identifies challenges or difficulties and explores various options to eliminate the complexities identified in the problem encountered.

Bertram and Christiansen (2014, p.45) assert that action research involves a "change generating style" by "action and reflection." Macintyre (2000) adds that the researcher conducts action research on their professional practice to improve their pedagogy. Koshy, Koshy and Waterman (2011) also refer to the O'Leary model in which action research adopts an empirical learning method embracing change. The aim is to continually improve the interpretation, processes, and data of the perceptions acquired in each prior cycle. However, Elliot's model is similar to that of Kemmis and McTaggart and includes identifying a specific concern, fact-finding or investigating, preparation, acting, assessment, amendments to plans and taking further actioned steps in a cyclical pattern. Teams of colleagues or individuals can undertake action research. The team approach is called a collaborative inquiry. This type of research can generate genuine and sustained improvements in education (Koshy, 2005; Schreuder, 1997; Schuiling & Vermaak, 2017).

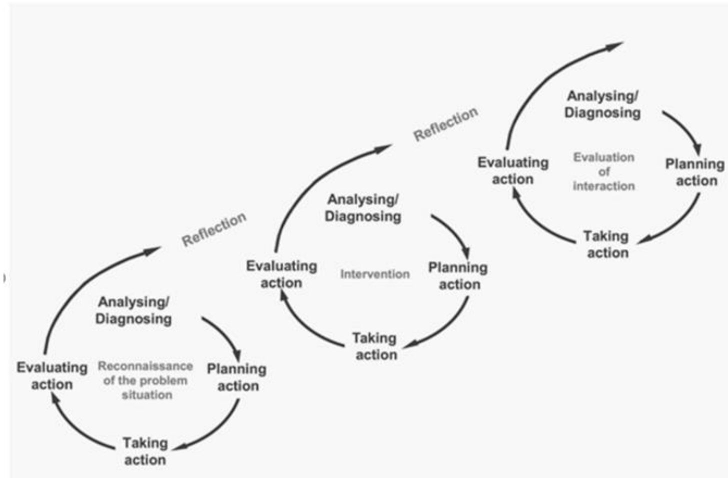


Figure 3.2 The cycles of action research (Coghlan & Brannick, 2001, p.19).

In traditional research, argue Altrichter, Posch and Somekh (1993), the literature is examined for identifiable gaps. Traditional research also contributes to knowledge in a field; however, action research endeavours to address the experienced problem. Hakim (2012) contends that action research improves professional practice by solving practical problems. Craig (2009) argues that participants in action research are actively involved from the commencement to the study's conclusion. In traditional research, participants are typically engaged during the data collection stage. The researcher comes from the outside and is distant and formal. However, through action research, Schuiling and Vermaak (2017) argue that the researcher and participants are intimately involved with the process. Action research democratises the process of research, giving the participant a voice to share their challenges and solutions, while traditional research dictates the process.

Koshy, Koshy and Waterman (2011, p.5) outlined the four steps of action research and contend that action research entails: "Planning a change. Acting and observing the process and consequence and then re-planning. Reflecting on these processes and consequences and then re-planning, acting and observing and reflecting and so on." This study used Lewin's cyclic five stages of action research as outlined by Adelman (1993), which include identifying the problem, designing a plan, action the plan, reflecting on the actioned component, and capturing the learning.

3.5.2 The engagement process using action research

A good starting point for action research is identifying an uncomfortable tension (Coghlan & Brannick, 2010; Altrichter, Posch & Somekh, 1993). Teachers develop set working routines that become second nature which they do not question any longer. Sometimes, these practices work against what they aim to achieve. Self-reflection is critical to overcoming this. Cohen, Manion and Morrison (2007, p.298) contend that "Action research involves problem-posing, not just problem-solving". As the practitioner, I paused, thought about what I was doing, and contemplated what I wanted to achieve. Koshy and Waterman (2011) argue that you need to consider an alternate method to action what you want to achieve to change an essential requirement. Macintyre (2000) contends that action research focuses on change, making it different from other types of research. Coghlan and Brannick (2010) assert that action research goes beyond analysing a situation and carries a solid moral and social justice discourse to implement change for the better.

The process of action research, as outlined earlier, is generally a four-stage cycle. However, Lewin's five-stage cycle, explained by Adelman (1993), was used in this study. The five-stage cycle instead of the four was chosen because Lewin's fifth stage incorporates capturing the learning. The captured learning supported an inquiry-based approach. This approach argues Babaci-Wilhite (2017) implies that evidence linked to students learning goals are well documented and systemised to track progress and can easily be accessed to evaluate learning and re-address planning and professional development. The importance of capturing learning for this study was to systematically evaluate the assessments and outcomes, track progress, and report the findings accurately and timeously.

Figure 3.3An adaptation of Lewin's five-stage cycle of action research (1946, as cited in Adelman, 1993)

Step One - Identifying the problem

The initial reconnaissance stage identified the issue or the problem. This action research project commenced with the challenge that most TVET Level 2 students could not read, interpret or design electrical schematics competently. Craig (2009) asserts that action research embarks from three points of origin. The first is your proactive approach to seeking a solution. The second, you are reactive; therefore, you pursue a resolution. Third, you are innovative; thus, you generate a solution. This research was innovative, taking a proactive approach. Macintyre (2000) argues that a design strategy must be developed to deal with the problem irrespective of the origination. Not all issues are appropriate for this approach to problem-solving. Easily identifiable matters are not suitable for action research. Action research requires wicked problems. Sherman (2016) says social scientists categorise wicked problems as some of the most difficult to solve.

The characteristics of a wicked problem are that they are generally recurring, essential and complex, consisting of many interdependent parts. They have multiple causes and often lead to unusual solutions. On reflection on my pedagogy, it was evident, as alluded by Kunene (2009) that students practised rote learning of electrical drawings and could not interpret what was drawn. Muijs (2006) suggests that class assessments be checked to determine if they were a true reflection of ability rather than achievement. I had to determine whether students were memorising copious amounts of information rather than constructing knowledge actively (Ramnarain & Ramaila 2012; Willis, 2007).

Step Two - Designing the plan

The second step entailed designing the plan. Craig (2009, p.4) argues that "An action plan is a framework or blueprint that is implemented to improve practice." The goal was to implement a new teaching strategy to improve students' ability to read, interpret and design electrical schematics. I endeavoured to explore and test new ideas to determine effective conceptual change through this action research study. The plan incorporated the goal, objectives, and steps to accomplish the purpose, as suggested by Coghlan and Brannick (2010). I reframed the problem to change my perspective. Euchner (2019) contends that many questions reframed with new words and phrases give a unique insight into the issue. It also helped me to look at the problem from different perspectives. I endeavoured to place the question into several different situations to gain a different perspective. I looked at the problem from an industrial perspective. Acosta (2006) advises looking at the problem from the perspective of a career, the impact of social injustice or a third world economy. What would this problem look like to an engineer, schoolteacher, farmer, or migrant worker?

Step Three: Action the plan

The third step outlined how the plan was actioned. According to Coghlan and Brannick (2010), action is the heart of action research, and goals without action are worthless. The plan was developed and actioned. Craig (2009) highlights the three things done during the action phase. First, I controlled and kept track of the progress while observing whether there was a decline or improvement in student performance. Second, data were collected, and third, I recorded the progress of the implemented plan in a journal.

Step Four: Reflecting on the actioned component

Step Four detailed the reflection from the action taken. Jugoo (2014, p.61) describes "reflection as thinking analytically, critically and evaluatively." As a competent educator, I explored all avenues, as Kemmis (2006) suggested, to determine why students lacked understanding. Wadsworth (1998) asserts that the continual interaction between action and reflection forces the solution to surface. Eisenstat, Spector and Beer (1990, p.1) define reflection "as a process of entering dialogue based on the data collected and guided by a systemic framework to discover the root causes of the problem." Reflection is taking time to think, which is what critical thinking is all about. Craig (2009) concurs, addressing the following questions. What did I expect to happen? What happened? I realised that rarely is an outcome what was initially envisioned. In many instances, the problem deteriorated rather than improved. Since reflection is such a crucial part of action research, a reflective journal was used to record key aspects that emerged from this study.

Reflective journal

Cohen, Manion and Morrison (2007, p.310) contends that "reflection is three-fold. It is reflection-in-action, reflection on-action, and critical reflection". Reflection occurs at every stage of action research. Reflection analysed whether knowledge was constructed as initially intended (Koshy, Koshy & Waterman, 2011; Cohen, Manion & Morrison, 2007). Both research questions were probed by analysing the generated data to determine if the research problem was satisfactorily addressed. Creswell and Creswell (2018) argue that the original plan should be revised or modified and re-actioned if the action was unsuccessful or partially successful. Once again, the data should be analysed and reflectively considered. This cyclical helix should continue until initial goals are accomplished.

O'Connell and Dyment (2011, p.47) argue that a reflective journal is a written document created when you "think about various concepts, events, or interactions over a period of time for the purposes of gaining insights into self-awareness and learning." Its educational use is to record teaching and learning experiences, reflections from observations, situational responses and exploration of cognitive reasoning. Dreyer (2015) concurs that a reflective journal helps identify crucial teaching and learning events in your professional development. Most researchers have resolved that a reflective journal is a construct of effective pedagogy. (Dreyer, 2015; Dunlap, 2006; O'Connell & Dyment, 2011; Agustin, 2019; Hubbs & Brand, 2005).

The reflective journal documented my feelings, speculations, personal thoughts, prejudices, ideas and impressions. (O'Connell & Dyment, 2011; Creswell 2014). I acted as a semi-participant-observer giving advice when asked. My observations began during the theory component. It was evident that students could draw the schematics easily without actually comprehending what was drawn. The participants were engaged in the activity of 'learning to draw rather than drawing to learn.' Students were also observed as they conducted the practical tasks, and these observations were noted in my reflective journal.

Dunlap (2006) contends that teachers using reflective journals offer formative and summative feedback to their students while gaining formative and summative feedback on their curriculum, teaching and performance. As Cohen, Manion and Morrison (2007) argued, I used this feedback to fine-tune my teaching and learning and address student needs. The use of a reflective journal improved my professional development and administrative tasks, enhanced my writing and reflection on career direction (O'Connell & Dyment, 2011; Dunlap, 2006). Teachers should be trained and workshopped on using a journal effectively (O'Connell & Dyment, 2011; Dunlap, 2006), for they struggle with how or where to commence writing. Many researchers keep a journal, not as a reflective practice but rather to fulfil their thesis requirements. O'Connell and Dyment (2011) argue that they write with the reader in mind. This raises ethical issues about whether the researcher feels coerced to write what their audience wants to hear rather than personal disclosure.

Step Five: Capturing the learning

Step Five addressed how the learning was captured and shared to complete the process. Schrueder (1997) argues that in many organisations, information is not easily cascaded to everyone. This knowledge ends up lost when selected individuals leave or when the team disbands. Schuiling and Vermaak (2017) contend that this can be prevented when information is captured and institutionalised. Failing to capture learning is why many problems re-appear. Data was generated, captured and appropriately recorded to evaluate the assessments and outcomes, track progress, and report the findings accurately and timeously. The cycle (problem, design, action, reflection, and capture of learning) must be repeated as many times as it takes to solve the problem (Koshy, 2005; Kemmis, 2006; Jugoo, 2014). Action research has dual objectives; the first is problem-solving. However, if you only focus on solving the problem, then the learning aspect could be lost.

3.5.3 Strengths of action research

Coghlan and Brannick (2010) argue that action research allows the researcher to obtain a comprehensive knowledge relating to the problem through their quest for improvement and change from their actioned plans. Cohen, Manion and Morrison (2007) contend that action research aids in professionalising teaching systematically and reflectively collecting data on pedagogy to promote improvement and continuous growth. Creswell (2014) maintains that lessons are investigated empirically through the action research design, with each day's findings informing the following lesson. Reflective practitioners improve their practice through action research, helping students accomplish learning objectives (Coghlan & Brannick, 2010; Bertram & Christiansen, 2014; Altrichter, Posch & Somekh, 1993).

According to Cohen, Manion and Morrison (2007), action research contributes to building a culture of professionalism. One of the primary faculty goals, contends Bakaeen (2012), is to develop a well-educated student. However, teachers may differ on aspects of the shared vision on how to accomplish this goal. Dunn, Lyman and Marx (2003) concur that teachers can engage in independent research agendas, share research findings with colleagues of all specialities, and transform themselves into learning communities. When classroom issues teachers face are dialogued, wiser professional decisions are made (Koshy, Koshy & Waterman, 2011; Fay et al., 2010; Craig, 2009). All teachers within the division should study their practice collaboratively to promote programme development to achieve institutional excellence. When faculty and teachers choose an issue to action research, progress on crucial learning programme improvements and team building will undoubtedly become an achieved shared goal (Craig, 2009; Elliott, 1991; Ferrance, 2000).

Creswell (2014) argues that action research promotes a systemised form of professional practice enhancing teacher motivation and efficacy. This research design helps teachers identify the problem reflectively, design a plan, action the plan, reflect on the actioned component and capture the learning (Kemmis, 2006; Jugoo, 2014). The demands of teaching have grown exponentially, with teachers required to do more with less. For Cohen, Manion and Morrison (2007), action research offers the teacher the opportunity to evaluate their practice in a structured manner, eliminating a single style and integrating multiple teaching styles for all teaching practice. It investigates how effective teaching and learning are conducted amongst students, teachers and the institution. Koshy, Koshy and Waterman (2011) concur that it provides evidence of the difference teachers make when integrating data into their work. For teachers, compelling data on effective practice becomes a significant energising influence. Self-efficacy equilibrium was balanced and evaluated against student understanding of knowledge and teacher knowledge of instructional strategies (Ledwith, 2007; Macintyre, 2000; McKernan, 1991).

McKernan (1991) contends that action research investigated teacher practice and promoted knowledge construction by implementing new teaching methods to replace traditional ones. Craig (2009) concurs that students' active participation in knowledge construction through an alternative teaching strategy empowers the teacher. Mor et al. (2014) contend that when students develop a holistic approach to any given situation and learn to see the whole (complete) rather than in part, their ability to comprehend the inter-related design becomes beneficial. Barnett and Ceci (2002) suggest that cognitive skills progress from knowledge acquisition and understanding to application, analysis and evaluation.

3.5.4 Weaknesses of action research

Williams, May and Wiggins (1996) allege that many critics assert that action research is not a widely recognised scientific study method within the mainstream research traditions. Hakim (2012) argues that action research could be construed as unreliable since it cannot be generalised to other settings. People in different contexts will have diverse issues. However, it is a valid form of research representing the researcher’s context of the fundamental changes made on what they wanted to do and how they did it. Ledwith (2007) critiques that action research focuses narrowly on specific fields of study, therefore, has a poor research design.

These criticisms are countered for the following reasons. Firstly, well-published studies supporting its use in education are available (Kemmis, 2006; Creswell, 2014; Koshy, Koshy & Waterman, 2011; McAteer, 2013; Schuiling & Vermaak, 2017). Wadsworth (1998) concurs that action research explores a teacher's effort to reflect and improve their practice. According to Koshy (2005, p.3), "Research is about generating new knowledge. Action research creates new knowledge based on enquiries conducted within specific and often practical contexts." Through action research, the teacher evaluates the results of the planned changes in their practice.

3.6 Research questions

The following research questions guided this study:

1. How does introducing a drawing to learn teaching strategy using patterns improve teaching and learning in NCV Electrical Level 2?
2. To what extent does drawing to learn using patterns address student misconceptions of electrical circuits?

3.7 Research setting

This research study was located at a TVET College in Pietermaritzburg. The College provides programs up to diploma level and engineering and general studies programs on the National Qualifications Framework (NQF) Levels 2 to 4. The programs delivered were (as regulated by the FET Act 16 of 2006 and amended in 2012) part-time, distance learning and full-time classes. TVET colleges are vital for providing post-school training and education and are strategically crucial in South Africa's developmental plans. Nundkumar (2016) asserts that this form of education, although primarily focused on students who had completed their secondary school education, catering for those who wanted to achieve grade 12 through a vocational route. Through the Department of Higher Education and Training, colleges delivered skills and expertise to commerce, industry and the country, as elucidated in the White Paper for Post-School Education and Training (2013).

Up to 2002, South Africa had 152 Technical Colleges. The 152 Technical Colleges amalgamated to form 50 large multi-disciplinary institutions, retitled Further Education and Training Colleges. In 2014, they were renamed Technical and Vocational Education and Training Colleges. The new name described the institutions' character succinctly. The TVET construct encompassed 50 colleges with 260 campuses for training and education. As stated in the Further Education and Training Colleges Amendment Act (No. 16 of 2006), TVET Colleges are the responsibility of DHET. The White Paper for Post-School Education and Training (2013, p.x11) states that the minister of DHET is obligated "to develop a skilled and capable workforce to support an inclusive growth path."

3.8 Sampling strategies

Creswell and Creswell (2014) contend that sampling describes the strategy when the researcher selects an individual or group to participate in the study. Welman, Kruger and Mitchell (2008, as cited in Nundkumar, 2016, p.15) contend that "the target population is the complete collection of cases from which a sample is extracted." Convenience sampling was utilised to select the NCV Level 2 electrical students. Cohen, Manion and Morrison (2007) describe convenience sampling as non-probable. In this study, the target population of participants comprised 18 NCV Level 2 students who were easily accessible, available, willing, and administratively and conveniently situated within the research study. Creswell (2014) argues that the convenient sample is not an accurate representation of the population. Although the data was accessible and easily collectable, due to the excellent rapport I had with my students, I was mindful that it could be biased and jeopardise the participants and the researcher (Creswell, 2014; Dunn, Lyman & Marx, 2003). Cohen, Manion and Morrison (2007) concur that bias must be acknowledged, and generalisations cannot be made. Multiple approaches to data collection for triangulation and validation were selected.

NCV Level 2 students were purposively chosen rather than Level 3 or Level 4 students. The Level 2 students were selected to monitor the impact of these new teaching and learning strategies. I also wanted to evaluate student's ability to apply this learning strategy at higher levels where they would need to engage with more complex electrical schematics. According to Creswell and Creswell (2014), purposive sampling does not require a specific number of participants. Cohen, Manion and Morrison (2007) concur that the researcher chooses non-random participants who are available and willing to provide the necessary information for qualitative research. Purposive sampling aims to obtain thorough insight related to the research questions. Mertens (2007) contends that purposive sampling is compatible with the critical paradigm, given that the researcher endeavours to glean in-depth perspectives from the participants for emancipation.

The purposive sample chosen comprised 18 students from my NCV Electrical Level 2 class. The respondents' mean age was 19 years. Most of these students were categorised as lower or middle class in our present social stratification, where the vast majority lived in townships. Ngubane (2013, p.8) asserts that "Township is a South African term that usually refers to the often-underdeveloped urban living areas that, from the late 19th century until the end of apartheid, were reserved for non-whites (Africans, Coloureds and Indians)." Nongxa (2010) argued that most children living in townships study at deprived impoverished institutions.

Two-thirds of high schools had no sports or recreational facilities, with approximately 50% of schools in townships suffering from a lack of classrooms. Zungu (2015) argues that these socio-economic challenges wreak havoc, devastating students' academic achievements. Students also travelled long distances to the institution, leaving home very early and returning very late. Attendance was also compromised when they did not have money for travelling. Ramnarain and Ramaila (2012) contend that the medium of instruction, English, was not the home language for most students. Many of these students are from quintile one and quintile two schools and had been disadvantaged by not having access to quality education. Educational disparity, claims Ngubane (2013), continues, with the middle class served by high levy schools yielding better academic results than those serving the poor. This research is located against this backdrop.

3.9 Data collection instruments

Data collection is imperative to secure quality evidence or information from the research questions posed to make conclusive findings, informed decisions, and inferences from the facts. (Creswell, & Creswell, 2018; Akinyode, 2018). The research methodology chapter argues Koshy, Koshy and Waterman (2011) must include the methods used for data collection during the research. These data-gathering techniques include interviews, questionnaires, focus group discussions, surveys, observations, cohorts, and control trials on testing the hypothesis to explain a phenomenon (Dunn, Lyman & Marx, 2003; Garg, 2016). Qualitative research methods always ask who, what, how, when and why. Creswell (2014) argues that this is to understand the quality or nature of the phenomenon. However, quantitative research considers the issue of magnitude (how much) of an occurrence or association. This study used data collection instruments that generated both quantitative and qualitative data.

Three data generation tools were utilised in this study. These were focus group discussions, a likert scale questionnaire and structured observations. The likert scale questionnaire comprised close-ended, reflective questions, which generated quantitative data and corroborated the focus group discussions and structured observations. All three data generation instruments reinforced data triangulation. From this information, as alluded to by Koshy, Koshy and Waterman (2011), the examined themes were conceptualised from the different collection instruments.

3.9.1 Focus-group discussions

> Focus groups are contrived settings, bringing together a specifically chosen sector of the population to discuss a particular theme or topic, where the interaction with the group leads to data and outcomes. Their contrived nature is both their strength and their weakness: they are unnatural settings, yet they are very focused on a particular issue and, therefore, will yield insights that might not otherwise have been available in a candid interview (Cohen, Manion & Morrison, 2007, p.376).

Bertram and Christiansen (2014) state that focus group discussions produce considerable amounts of non-quantifiable data in a small amount of time. However, this data is less than what is presented from interviews. For the focus group discussions, alleges Creswell (2014), the researcher selects participants and facilitates small groups to dialogue crucial aspects of the research. The 18 NCV Level 2 students were divided into two groups of five and two groups of four and participated in the focus group discussions. As noted by Cohen, Manion and Morrison (2007), the discussions were an invaluable exploratory method, providing a range of feelings, emotions, and views through the interaction that would have been omitted in an interview. Cohen, Manion and Morrison (2007, p.376) contend that focus group discussions are a form of group interviews that rely on the "interaction within the group who discuss a topic supplied by the researcher, yielding a collective rather than an individual view." The opinions, perceptions and experiences that the focus group discussions divulged were noted. These dialogues revealed detailed knowledge, information and insight. Participants abandoned their inhibitions and spoke freely. The 13 questions (Refer to Appendix 3) were open-ended, apprehending richness, sincerity, honesty, authenticity, and depth, yet allowing for diverse responses (Mertens, 2010; Newsome, 2016). Focus group discussions were very productive because those who responded stimulated the quieter students to participate.

The challenges encountered were also noted. Due to the global Covid-19 pandemic, the students' responses were not recorded as each student had to wear a face mask and a face shield to prevent the spread of the virus. Participants were seated 1,5m apart to ensure social distancing. The face masks, shields and distance muffled the responses, preventing clear audible recordings. To resolve this setback, students wrote down their responses to the focus group questions in English. A translator was not used as all seven subject examinations for this engineering course are written in English. The duration of the focus group discussions was approximately forty minutes. Oxley et al. (2017) argue that English is not the first language of most participants; however, through participation in the discussions, this was, addressed, when those who could articulate their thoughts prompted others by sharing expressive verbs . Data analyses were strengthened by using participants own words.

Consequently, this data cannot be easily generalised. The overt participants influenced key aspects discussed, while several students spoke very little, probably due to their personality; however, they did write constructive responses. Creswell (2014) cautions that the researcher could also unwittingly give cues and influence participant responses when explaining the questions. Pseudonyms were created to ensure participant anonymity and confidentiality. Evaluations, feedback, questions and replies were documented in the reflective journal. The focus group discussions addressed both research questions. Focus groups were cost-effective and easily facilitated (Creswell & Creswell, 2018; Mertens, 2010) producing qualitative data. The interaction permitted the participants to be probed for clarity.

3.9.2 Questionnaires

A questionnaire is a group data collection instrument comprised of a string of questions or prompts requiring a response (Bakker, van der Voordt, Vink & de Boon, 2014; Creswell & Creswell, 2018).According to Cohen, Manion and Morrison (2007, p.317):

> The questionnaire is a widely used and useful instrument for collecting information, providing structured, numerical data, being able to be administered without the presence of the researcher, and often being comparatively straightforward to analyse.

This research study used questionnaires to gather quantitative data. Closed questionnaires were uncomplicated and straightforward and did not require explanations (Bakker et al., 2014; Mertens, 2010). Participants found them easy to answer, and they were easy to interpret, evaluate and code for statistical analysis. However, Pell (2005) contends that open-ended questions were a source of greater depth and divulged participant thinking and required considerably more effort from respondents to formulate their replies.

3.9.2.1 Likert questionnaires.

Cohen, Manion and Morrison (2007) outline that Rensis Likert devised a scale that provided a range of responses to a given statement or question. Jamieson (2004, p.1217) contends that "likert scales are commonly used to measure attitude, providing a range of responses to a given question or statement". This instrument is widely used and is very attractive in research due to the subtlety of response constructed into the scale. The likert Scale for this study (Refer to Appendix 4) applied a linear presumption, measuring from strongly agree to strongly disagree (McLeod, 2019; Pell, 2005). Each response was assigned a numeric value used to gauge the investigated viewpoint. For Jamieson (2004), the advantage of likert scales is that they probed past the minimal yes or no answers and provided a degree of opinionated perspective. Anonymity was maintained by giving respondents the option of filling in personal details on the questionnaire. However, Paulhus (1984) identified that respondents who did write their names and personal information were prone to divulge greater detail and effort to their responses. Pseudonyms were given to all participants who filled in personal details. McLeod (2019) contends that likert scales also reduces social bias, preventing specific findings from becoming salient and other vital aspects merging into the background. For this research study, the likert scale questionnaire consisted of ten questions (Refer to Appendix 4), generating quantitative data.

Questionnaires provided anonymity and were cost-effective, allowing for significant data collection from the questions asked (Bakker et al., 2014). The questionnaires were objective, verifying the discussed focus group questions. They were easily collected and categorised into patterns and themes. However, there was limited flexibility in participant explanations. Although students answered all the questions, some questions could be omitted, notably when the researcher is not present. This data collection tool can be viewed as an imposition, argues Bertram and Christiansen (2014), concerning the time taken to complete them. The sensitivity of the questions can also be perceived as an intrusion.

3.9.3 Structured Observations

What students say, exclaims Cohen, Manion and Morrison (2007), may differ from what they do. Observation schedules could help to clarify the difference. Kálmán (2017) contends that observations also permit a researcher to examine assumed practical behavioural patterns that might not be noticed. Cohen, Manion and Morrison (2007, p.397) contend that observations are beneficial for “recording non-verbal behaviour” and disclose overlooked aspects that participants did not freely communicate. Research observations are qualitative practices where participant behaviour is observed in natural settings (Creswell, 2014; Cohen, Manion & Morrison, 2007; Akinyode, 2018). Cohen, Manion and Morrison (2007, p.397) concur that “What counts as evidence depends on when, where and for how long we look”. The observations were indirect and participatory. Students drew the circuit diagram and generated a parts list from it. They identified the correct components and used them to connect the circuit as per the schematic drawn at the designated workstations. A summative assessment based on a structured observation schedule was used to evaluate competence (Refer to Appendix 5). Cohen, Manion and Morrison (2007, p.397) assert that “A structured observation will already have its hypotheses decided and will use the observational data to confirm or refute these hypotheses”.

The structured summative observation schedule (Refer to Appendix 5) was used in conjunction with an observation journal that detailed qualitative aspects observed during the practical task. Participants were required to draw the electrical schematic, connect the circuit using the diagram, and compile a parts list to demonstrate understanding. Abrahams, Reiss and Sharpe (2013) concur that observations help to assess competence. These observations also helped me identify incorrect workshop practices or misconceptions of electrical diagrams which were not allocated on the assessment sheet. Observations generated quantitative and qualitative data for both research questions and assisted in the triangulation of data. Johnson and Christensen (2014) argue that data triangulation corroborates the results from different data collection methods.

3.10 Data collection

One cycle of action research was utilised in this study. This was due to the Covid-19 lockdown restrictions which influenced timetabling and curriculum delivery at the TVET College. This meant that the contact teaching time that I had with my Level 2 Electrical Engineering students was significantly reduced which made planning a second cycle of action research unfeasible. A well-prepared action research project requires flexibility in its approach, continuous reflection and careful planning from the researcher (Newsome, 2016; Bates, 2015; Phillips & Carr, 2014). I identified the topic, set a context for the study and clearly defined the learning expectations. The problem I identified was that students' rote learnt electrical schematics but could not interpret the drawing. The NCV syllabus addressed the importance of various electrical schematics; however, it neglected including any structured pedagogy on reading and interpreting electrical drawings overlooking provision for this critical aspect of teaching and learning (Chisholm & Leyendecker, 2008; Abrahams, Reiss & Sharpe, 2013). Delamare Le Deist and Winterton (2005) contend that reading and interpreting electrical schematics is crucial for electrical competence. This action research study endeavoured to address this problem.

Reflecting on these challenges, as alluded by Nolen and Putten (2007), I recorded my thoughts as I embarked on this study in my reflective journal. Every electrical drawing had a wealth of information that gave the reader clarity on structure and design. The watershed moment occurred when I realised that I could conceptually improve teaching and learning using a drawing. Instead of students learning to draw, they could draw to learn, enhance cognition, and improve their grasp of complicated theory. Another problem identified was component and design misconceptions of students. This became the reconnaissance stage from which ensued a design strategy.

An action plan was designed to improve my practice (McKernan, 1991; Elliott, 1991). My goal was to introduce drawing to learn as an alternative conceptual teaching strategy.

Pattern learning was structured into the lesson to assist students grasp the concepts, structure and design. The formulated pattern could be applied to any electrical drawing, whether simple or complex. The pattern format would also address the misconceptions students encountered. The misconceptions addressed were component identification, component connections, component wiring and component placement. I planned to use WhatsApp as the social media platform to introduce my students to a blended learning platform (Bates, 2015; Han & Ellis, 2019).

3.10.1 WhatsApp social media platform

The social media platform used in this study was WhatsApp. Bates (2015, p.119) argues that this text-based chat allows for “threaded connections”, permitting specific participant responses to chosen comments rather than comments displayed chronologically. Thomas, Johnson, and Fishman (2018) clarified that it allowed for vibrant, dynamic sub-topics to be expanded and developed. The platform permitted multiple responses from a single thread within the discussion. Aspects of the practical planning were clearly explained in class and were also communicated via the WhatsApp social media platform. Students who needed clarity on the lesson were encouraged to ask questions via WhatsApp chat. The students were given a rating scale of five questions (Refer to Appendix 6). The rating scale focused on student’s perceptions of blended learning (Banci & Soren, 2008; Huang, Ma & Zhuang, 2008).

A rating scale questionnaire helped me as the action research to reflect on and to assess how successful the blended learning approach (Refer to Appendix 6) was implemented. It was also used to determine the efficacy of utilising WhatsApp as an event planner. The drawing to learn lesson was introduced via this online platform and was part of the blended approach to this lesson due to Covid-19 level 5 lockdown measures. Students were given the rating scale questionnaire to complete after the summative assessment. However, this was not used as a data generation tool addressing either research question.

The action plan was then implemented. The global Covid-19 pandemic had forced South Africa to go to a level 5 lockdown in March 2020. All TVET colleges shut down in March

2020 and gradually reopened in July 2020. The college set up the Covid-19 Learner Support Programme that was aired on DSTV channel 265. My lesson was recorded and aired on this channel in May and June 2020. The pandemic highlighted how vital blended learning had become to ensure sustainable, viable teaching and learning in and out of the classroom.

The pattern learning lesson plan was designed using Microsoft PowerPoint and was recorded as a video lesson. I posted the video to my students via WhatsApp. Using the following link (https://www.youtube.com/watch?v=89dJlhL6Q6c), students could access the video on YouTube. For those students who could not access the lesson on YouTube, the video lesson was edited and subdivided into four parts to post on WhatsApp. However, these were big files. Each part was posted on the student WhatsApp group chat, with students watching the lesson and giving feedback via WhatsApp. The challenges encountered were diarised in my reflective journal. I paused and reflected on the study process. From student responses, many challenges surfaced. Student issues encountered were diverse and conspicuous. Some could not download the video, while others had network problems. Students did not have enough device memory, and several could not afford to buy data; others did not have smartphones. However, the biggest challenge was the size of the video (475MB). Although I had split the video into four parts, these video files were still too large. With this realisation, the initial plan was revised.

3.10.2 The revised plan

This study would be impeded if student issues encountered were not addressed. I sourced a video editing app and created a voice-over PowerPoint video. The reduction in the video size was considerable. I then uploaded a 40MB lesson onto the group chat as a single file. Students were informed that they would receive their NSFAS grants in June 2020, enabling those who were cash strapped to purchase data. Those who did not have smartphones were encouraged to use compatible devices that their parents, siblings, neighbours or friends owned, thus discouraging purchasing new devices. Network issues were overcome by changing mobile service providers. The challenges were resolved in four weeks. The lesson was downloaded, and the new teaching and learning strategy was explained. The teaching process was deliberately slow-paced to ensure participant comprehension and understanding of the objectives. The week-long lesson clarified the summative practical task students would complete in the workshop. This concluded the online part of the lesson successfully.

Participants attended the class lesson, and all ethical aspects were revisited and explained in detail. Before the lesson commenced, the study's key objective and purpose were discussed with the students. The students were informed about all data generation tools. For this study, the lesson was taught using drawing to learn as a teaching strategy. Pattern learning was used to simplify the electrical connections. Students identified the components and correctly connected the wiring diagram using the pattern numbered format and were required to compile a parts list from the drawing to assess understanding of the schematics. Each student was allocated a simulation panel and given conductors to connect the various components undertaking the task successfully. The practical task and the schematic completed by students were observed and analysed. I aimed to assess whether students could assign meaning to lines drawn on a page.

The Hawthorne effect insignificantly impacted this study, with no drastic change in student behaviour noticed. Students were assigned to four groups, with peer teaching and learning encouraged. The practical task challenged several participants despite understanding the theory and successfully drawing the schematic. Certain groups promptly completed the task. Unusually, more males found the practical task challenging. However, there were more females in the class. Most students welcomed and enjoyed the opportunity of undertaking the practical task and were curious and keen to attempt connecting more challenging electrical schematics. The observations demonstrated improved student comprehension and understanding of electrical schematics on completion of the practical tasks. This also applied to students who initially struggled with the task. Each student was assessed using a structured summative assessment observation schedule to determine competence.

After the task, students participated in a focus group discussion, reflecting on the completed task. The focus group discussions could not be recorded successfully due to social distancing, face masks and face shields. Students also completed a questionnaire. All aspects of the process were diarised in my reflective journal.

3.11 Data analysis

Analysis occurs when the whole is divided into its separate components and individually examined. Data analysis involves processing raw data, converting it into useful information to test hypotheses, disprove theories, or answering research questions (Braun & Clarke, 2006; Medelyan, 2020). Cohen, Manion and Morrison (2007, p.461) assert that "data analysis involves organising, accounting for and explaining the data; in short, making sense of data in terms of the participants' definitions of the situation, noting patterns, themes, categories and regularities."

It was imperative to first determine what type of data analyses I would conduct. The data was systematically and procedurally organised, permitting the analysis to be precise and accurate (Newsome, 2016; Braun & Clarke, 2006). Both quantitative and qualitative analysis using an inductive approach was used in this study. The structured quantitative data were grouped and tabulated. The qualitative data were grouped and organised into categories. Both data sets were then cleaned, eliminating duplications and incorrect tabulations (Creswell, 2014; Garg, 2016). A variety of techniques were utilised to begin interpreting and making sense of the data or information collected. The process of selecting, focusing, simplifying, abstracting and transforming the data from my data collection instruments commenced (Newsome, 2016; Creswell, 2014). I familiarised myself with the data. The qualitative data contained wordy descriptive responses, which I read several times, looking for basic patterns, themes and regularities in the process of transcription. I constantly revisited the research questions, searching for patterns while discarding irrelevant data. A framework emerged from the wide-ranging ideas, impressions, and phrases, which developed into codes. Coding helped to structure and label the data. The generated codes helped to identify emerging patterns that formulated the themes. These themes addressed the research questions and also areas to be further explored. Creswell and Creswell (2018, p.248) suggest the following steps in analysing data:

> Organise and prepare the data for analysis. Read or look at all the data. Start coding all of the data. Use the coding process to generate a description of the setting or people as well as categories or themes for analysis. Advance how the description and themes will be represented in the qualitative narrative. A final step in qualitative data analysis involves interpreting the findings or results.

3.11.1 Thematic analysis

Holton formulated and developed thematic analysis in the 1970s (Merton, 1975; Lorelli et al., 2017). Data analysed qualitatively argues Cohen, Manion and Morrison (2007) entails explaining, accounting and organising, yet coherently identifying regularities, themes, patterns and categories from the participants. Braun and Clark (2006, p.79) contend that "thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data. It minimally organises and describes your data set in (rich) detail." This type of analysis depicting a repetitive method transitions jumbled data to organised patterns and themes. Thematic analysis, argue Lorelli et al. (2017, p.2), is a suitable research approach that evaluates participant's opinions, knowledge, experiences, values and views "qualitatively or quantitatively." Caulfield (2019) contends that thematic analysis permits flexibility during data interpretation by allowing substantial data sets to be sorted into broad themes. However, he cautions that since this type of analysis is subjective, nuances may be missed in the data. The researcher, argues Lorelli et al. (2017), must reflect cautiously on their interpretations and choices and closely monitor the data to prevent discarding information or acquiring codes that are not there.

Thematic analysis, contends Braun and Clark (2006), has two distinct approaches. The first is an inductive approach. Caulfield (2019) argued that this approach allows the data to determine and define the themes. However, he argues that a deductive approach engages the data with anticipated preconceived themes that you are interested in analysing. Medelyan (2020) concurs, stating that this could originate from literature, theory, a conceptual framework or the research questions. Although deductive analysis saves time and ensures that your research questions are addressed and coded, argues Lorelli et al. (2017), bias can be encountered. Predefined codes can develop a predisposition to expected answers. One of the consequences of this is confirmation bias.

Confirmation bias was addressed. Marsh and Hanlon (2007) clarify that confirmation bias, also called expectation bias or confirmatory bias, permits you to see what you want to see. Wickens and Hollands (2000, as cited in Lehner et al., 2008, p.584) define confirmation bias "as a tendency for people to seek information and cues that confirm the tentatively held hypothesis or belief, and not seek (or discount) those that support an opposite conclusion or belief". This bias, argues Lee et al. (2013), influences how information is gathered, interpreted and recalled. Confirmation bias, contends Calikli and Bener (2015) can cause a researcher to lose objectivity by selectively analysing and interpreting data. When information is only analysed in a manner that corroborates their expected findings, researchers confirm their prejudicial hypothesis, resulting in important contradictions or other significant themes being overlooked. Cherry (2020) concurs that when researchers accept and realise that confirmation bias is an inherent trait that all humans have, it becomes easier to recognise opposing perspectives or contradictory data. This study employed a thematic inductive approach, utilising Braun and Clarke's (2006) six analysis steps.

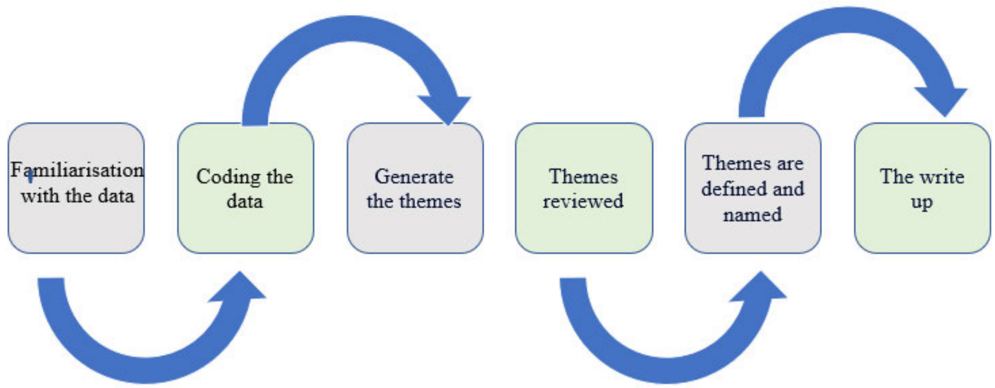


Figure 3.4: Flow chart of Braun and Clarke's (2006) six steps of analysis.

3.11.1.1 Braun and Clarke’s (2006) six steps of analysis

Familiarisation: Bates (2015) argues that a well-prepared action research project requires flexibility in its approach, continuous reflection and careful planning from the researcher. Initially, I became acquainted with the essence of the information by perusing and making notes multiple times after transcription.

Coding the data: Medelyan (2020, p.1) defines coding as “the process of labelling and organising your data to identify different themes and the relationships between them.” During coding, sentences and phrases were highlighted and penned as condensed labels or codes. The generated codes described key points, feelings or ideas expressed by the participants. I thoroughly considered potential aspects of interest. All sentences and phrases matching the codes were highlighted. By reading and re-reading the data, new codes were constantly added. From the main recurring data points, the condensed codes were grouped and analysed.

Generating themes: An extensive list of different codes was developed at this stage, focusing on an overall theme level. Themes were generated from a subset of codes, with some forming main or sub-themes, while other codes that were vague and not relevant were discarded. The main themes were more distinct and were derived from a combination of several codes. At the end of this stage, a collection of themes and sub-themes were classified. For the deductive approach, the potential themes had to speak to the research questions.

Themes are reviewed: This is to ensure that they were an accurate and authentic representation of the data. This step comprised of two parts; the first was the review of the coded data. Data extracts were re-read to ensure that they formed a coherent pattern that fitted into each theme. Codes were then analysed and rearranged to determine if they tailored into each theme coherently. The second step entailed the review of the themes. Each theme was considered relative to the data's corpus to determine if the entire data's essence is reflected totally or partially. For this study, problematic themes were split or combined, and missing aspects tweaked to make them accurately applicable.

Themes are defined and titled: They capture the essence of what each theme conveyed. Each theme was analysed to determine if it contained sub-themes. At this stage, themes that had working labels were purposefully named and titled. Names and titles created were punchy and concise to convey the theme's essence to the reader promptly. At the end of step 5, the defined and titled themes were succinctly formulated to express the data's exact meaning.

The write up: Every effort was made to ensure the write up was logical, coherent, non-repetitive, concise, and a noteworthy account of the reported data. The write up provided sufficient evidence of each theme using vivid examples from the participant responses.

3.12 Trustworthiness

Creswell and Miller (as cited in Creswell, 2014, p.251) assert that "Validity is one of the strengths of qualitative research and is based on determining whether the findings are accurate from the standpoint of the researcher, the participant, or the readers". Garg (2016) maintains that the aspects that speak to validity are credibility, authenticity, trustworthiness, and replicability. In quantitative studies, trustworthiness is described in terms of reliability and validity. However, in qualitative studies, the findings are dependable, confirmable, credible and transferable. Helvi et al. (2014, p.2) contend that "the aim of trustworthiness in a qualitative inquiry is to support the argument that the inquiry's findings are worth paying attention to."

Dependability refers to replicability. This research had to ensure adequate information to allow for the study to be replicated with consistent findings (Cohen, Manion & Morrison, 2007; Creswell, 2014). Inquiry audits can be used to establish dependability. For this study, member checking alluded to by Kálmán (2017), allowed students to respond to the generated data in the follow-up participant consultation. This was done to correct errors, clarify and discuss their interpretations. All students concurred that their data and responses were recorded accurately as none of the students requested any changes.

Confirmability addresses bias. Lee, Sugimoto, Zhang and Cronin (2013) contend that researcher bias should not distort the interpretation of participant responses to fit a narrative. Marsh and Hanlon (2007) contend that the researcher must maintain neutrality without interference. This study established confirmability by maintaining a systemised approach that documented every step of the analysis, providing a rationale for the findings. Confirmability established that the research study's findings participant responses accurately.

Credibility aims to determine the truth about the findings of the research. It questions the accuracy and truthfulness of the study. One of the ways to accomplish this is through triangulation. Triangulation entails gathering multiple data sources to construct coherent validated themes (Creswell & Creswell, 2018; Cohen, Manion & Morrison, 2007). This study used questionnaires, focus group discussions, a structured observation schedule and a reflective journal to ensure trustworthiness.

Transferability refers to other contexts. The researcher determines how the study findings in similar situations, similar phenomena or populations are applicable. Qualitative studies use rich descriptions to illustrate how the study findings apply to other contexts.

Creswell and Creswell (2018, p.251) highlight specific validity strategies. These are: "triangulation; member checking; using rich, thick descriptions; clarifying bias, the researcher brings to the study; also presenting negative or discrepant information that runs counter to the themes."

As a researcher, I needed to ensure that this action research study was trustworthy. I presented my positionality as a researcher to the participants to prevent confusion over my position as teacher and researcher. I used rich detailed descriptions, as alluded to by Creswell (2014). I endeavoured to identify any bias through self-reflection identified by Garg (2016) that could have influenced my interpretation of the study, such as my socio-economic context, culture, gender and history. As alluded to by Cohen, Manion and Morrison (2007), I presented contradictory data, validating the study's accuracy and representation, which was evident in the analysis. This study was examined to determine if it was dependable, credible, confirmable and transferable (Creswell, 2014). Cohen, Manion and Morrison (2007) concur, adding repeatability, reliability and data validity. If the same questions were asked three months later, would they generate the same results (repeatability)? If a different person asked the same questions would they get the same replies (reliability)? (Bertram & Christiansen, 2014).

This study used a reflective journal to allow other researchers to follow the train of thought behind the findings, ensuring trustworthiness. Using pseudonyms maintained participant anonymity and confidentiality without revealing their identities, contributing to this study's reliability. Acknowledging the limitations of this action research project also added to the study's trustworthiness.

3.13 Ethical considerations

Creswell (2014) argues that ethics in research such as authenticity, personal disclosure, the credibility of the research report, the researcher's role in cross-cultural contexts and issues of personal privacy must be addressed. Before conducting research, ethical clearance must be obtained. Creswell and Creswell (2018, p.132) states, "Seek university approval on campus through an institutional review board (IRB)." Ethical clearance was applied for and obtained from the University of KwaZulu-Natal for this research project (Refer to Appendix 7). The permission to conduct research was submitted to the DHET (Refer to Appendix 1), and the declaration of consent documents was also presented to the campus manager and departmental head (Refer to Appendix 8).

A participant declaration of consent form (Refer to Appendix 2) was submitted to all participants (Bertram & Christiansen, 2014; Creswell, 2014; Garg, 2016). As alluded to by Bertram and Christiansen (2014), students were informed about the ethical issues about the research, such as voluntary participation, anonymity and confidentiality. The participants' right to withdraw at any given time if they no longer felt comfortable taking part in the research were explained. Written consent to voluntarily participate in the research study was collected from each participant. The research participant's identities were protected, and the study, as noted by Creswell (2014), benefited (beneficence) students involved and did not cause any harm to the participants (non-maleficience). This study was cognisant of other ethical issues such as authenticity, personal disclosure, the credibility of the research report; cross-cultural concerns; and personal privacy issues (Singh, 2012; Bertram & Christiansen, 2014). Trust was established, contends Garg (2016), to uphold the integrity of the research, preventing transgressions and offences that could negatively reflect on the institution. As alluded to by Creswell and Creswell (2018), this study highlights the four instances when ethics were considered. They were before the research was conducted; secondly, at the commencement of the study; thirdly, throughout the collection and analysis of the data; concluding with the verification, sharing, storing, and reporting the data.

Participant and institution anonymity were considered for this project (Hays & Singh, 2012; Bertram & Christiansen, 2014; Garg, 2016). The campus name and participants' identities were not disclosed. For protection, pseudonyms were used, and any identifiable participant features were also changed. I was mindful of any vulnerable participants while conducting a needs assessment. I ensured all participants received the same treatment. Another important ethical issue in research is confidentiality. (Creswell, 2014; Cohen, Manion & Morrison, 2007). The participant information was protected by non-disclosure practices ensuring crucial compromising information was not disclosed. Confidentiality was maintained by safely storing data in my supervisor's university office for five years and subsequently destroyed (Bevan, 2007; Creswell, 2014). Respecting participants and also being honest and sympathetic is essential when doing research. I avoided any form of deception, took cognisance of power imbalances, and prevented collecting harmful information. I refrained from using leading questions and reported on contradictory findings.

3.14 Limitations of the study

Creswell (2014) contends that the researcher's peculiar abilities profoundly impact the quality of research. Garg (2016) argues that this is influenced by researcher bias. Johnson and Christensen (2014) concur that researcher techniques of data collection combined with their unique perspective can subtly alter the generated data. In qualitative research, Cohen, Manion and Morrison (2007) argue that rigour is much more arduous to demonstrate, assess, and maintain. The following limitations were identified in this action research study. Analysis and interpretation were time-consuming due to the volume of data. This study necessitated meticulous planning to ensure the generated data was accurate. Although the researcher's presence could have exacerbated the Hawthorne effect, this was not an issue. The study employed new teaching strategies. For educators to adopt and practice them, additional resources, time and effort were required. Therefore, the findings of this study might not be easily adopted by teachers. The main challenge experienced during this study was the global Covid-19 pandemic. Hirooka (2020) and Sismondo (2020) state that the Western world had shut down after the virus first appeared in the far-east. Shingler-Nace (2020, p.202) highlight the "anxiety and fear" that had gripped every nation. In South Africa, the country experienced a level 5 lockdown from March 2020. Conventional teaching and learning abruptly ended with face-to-face learning resuming in July 2020 at the TVET College. Data collection was restricted (Wyse et al., 2020). The focus group discussion was not audio recorded since students had to wear face masks and shields. To overcome this challenge, students wrote down their responses. Peer collaboration was restricted due to social distancing. Sierpina (2020, p.1) highlights some of the global challenges experienced; "All interviews this year are likely to be online, Zoom, Skype, or some other platform rather than in-person to reduce travel, disease exposure, and to expedite a shortened interview season." This also impacted the number of action research cycles that could have been done under normal circumstances.

3.15 Conclusion

This chapter outlined the information necessary to replicate this study, explained how the design structured the research, addressed the research questions, and clarified its fit for purpose. The chapter commenced with the purpose of this study and a brief explanation of the methodology. The chapter explained the suitability of the critical research paradigm for this study. A detailed discourse justifying the use of action research ensued, clarifying its strengths and weaknesses for this study. This was followed by the research setting and sample chosen. The three data collection instruments, namely; focus group discussions, a likert scale questionnaire, and a structured observation were explained, followed by data collection and analysis. The chapter concluded with a discussion of issues of trustworthiness, ethical considerations and limitations of the study. Methodology and research design choices were justified and substantiated by relevant literature. The following chapter discusses the presentation and analysis of data.

CHAPTER FOUR: PRESENTATION AND ANALYSIS OF DATA

4.1 Introduction

The previous chapter discussed the methodological approach and research design that were used to address the research questions. In this chapter, the data is presented, analysed and clustered into patterns, codes and themes, as alluded to by Creswell (2014). Two conceptual frameworks were used as the lens to analyse and interpret the data. Excerpts from the participants are included to give credibility to the research findings and accurately illuminate participants' views.

This chapter focuses on the presentation of generated data and analysis using both conceptual frameworks and relevant literature. Data was gathered from 18 participants from my NCV Level 2 class at a TVET college. Firstly, in this chapter, data are presented and analysed according to the research questions, using the following research instruments: focus group discussions, a likert Scale questionnaire and a structured observation schedule generated from each participant. My reflective journal entries supplements and supports the codes and themes, triangulating the data to ensure accuracy in the analysis. Both research questions are addressed using Shulman's (1986) pedagogical content knowledge (PCK) and Lave and Wenger's (1991) situated learning Theory. Finally, ideas and themes that emerged after an inductive analysis are presented in a table. All 18 participants were assigned pseudonyms to protect their anonymity and allowed them to communicate freely and honestly. Participants' responses in their own words are included to enhance credibility and are represented in italics.

4.2 Profile of participants

This study generated data from 18 NCV Level 2 participants, comprising eleven female and seven male students. The respondents' mean age was 19.The Report 191 curriculum had worked effectively in the previous (apartheid) dispensation because it was structured into the old apprenticeship program. In the apprenticeship program, industry was required to identify suitable candidates, orientate the incumbents. After a vocational training period, they were sent to technical colleges to receive their theory training. With the change in our democratic dispensation and the new NCV program's introduction, the old arrangement fell away (Nundkumar, 2016; Chisholm & Leyendecker, 2008). School leavers enrol at the TVET colleges, and the theory component becomes the initial part of their tutorials rather than the latter. Almost all the students in my NCV Level 2 class had left or finished school and had limited electrical skills. Mutemeri and Chetty (2011) argue that English is not their mother tongue. Most of my students live in townships which Ngubane (2013, p.8) described as "underdeveloped urban living areas that, from the late 19th century until the end of apartheid, were reserved for non-whites (Africans, Coloureds and Indians)." Most of these township students, argues Nongxa (2010), studied at deprived impoverished institutions. Huchzermeyer (2011) contends that many of these students are keen to learn but have not received the proper foundational training to embark on an engineering career path. These students who have poorly developed critical thinking and problem-solving skills struggle to assimilate knowledge.

May (2011, as cited in Nundkumar, 2016, p.111) contends that "research is more than a reflection on our opinions and prejudices: it substantiates, refutes, organises or generates our thinking and produces evidence that may challenge not only our own beliefs but those of groups and societies in general." Data analysis is "the most complex phase of qualitative research and one that receives the least thoughtful discussion in the literature," argues Nowell et al., (2017, p.1). Johnson and Christensen (2014) contend that once the data is collected, the analysis must commence. In this study, as alluded to by Strauss and Corbin (1998), various methods were employed to designate and clarify collected data to illustrate an inductive approach to the research. As intimated by Shamoo and Resnik (2003), data was generated, collected, examined and analysed to formulate the findings, results and conclusions. In this study, data analysis was a progressive process, analysed concurrently during the collection. Cohen, Manion and Morrison (2007) concur that researchers analyse data during the total data collection period. The data was repeatedly studied and analysed to grasp and gain clarity of its essence. As alluded to by Akinyode (2018), the preliminary data was then labelled, dated and filed. The process of disaggregating the data into reduced subpopulations followed. The raw data was classified and categorised into organised ideas and concepts. The primary data were coded and compared within and across categories, constructing principal themes. Coherence amongst the diverse data sources was examined to find patterns of significance and clarify and explain the emerging themes and explicit phenomena

(Creswell, 2014; Sobh & Perry, 2006). These reduced themes linked to the conceptual framework and relevant literature.

The following research questions steered this research study:

1. How does introducing a drawing to learn teaching strategy using patterns improve teaching and learning in NCV Electrical Level 2?
2. To what extent does drawing to learn using patterns address student misconceptions of electrical circuits?

4.3 Thematic analysis

Thematic analysis, contends Braun and Clark (2006), has two distinct approaches. The first is an inductive approach. Caulfield (2019) argued that this approach allows the data to determine and define the themes. However, he argues that a deductive approach engages the data with anticipated preconceived themes that you are interested in analysing. Medelyan (2020) concurs, stating that this could originate from literature, theory, a conceptual framework or the research questions. The correct choice of analysis saves time and ensures that your research questions are addressed and coded, argues Lorelli et al. (2017). However, bias can be encountered and predefined codes can develop a predisposition to expected answers. One of the consequences of this is confirmation bias.

Marsh and Hanlon (2007) clarify that confirmation bias, also called expectation bias or confirmatory bias, permits you to see what you want to see. Wickens and Hollands (2000, as cited in Lehner et al. , 2008, p.584) define confirmation bias "as a tendency for people to seek information and cues that confirm the tentatively held hypothesis or belief, and not seek (or discount) those that support an opposite conclusion or belief." This bias, argues Lee et al. (2013), influences how information is gathered, interpreted and recalled. Confirmation bias contends Calikli and Bener (2015) can cause a researcher to lose objectivity by selectively analysing and interpreting data. When information is only analysed in a manner that corroborates their expected findings, researchers confirm their prejudicial hypothesis, resulting in important contradictions or other significant themes being overlooked. Cherry (2020) concurs that when researchers accept and realise that confirmation bias is an inherent trait that all humans have, it becomes easier to recognise opposing perspectives or contradictory data. This study employed a thematic inductive approach, utilising Braun and Clarke's (2006) six steps of analysis.

Thematic analysis identified patterns from the entire dataset addressing the research questions. Patterns were identified through familiarisation, coding, generating themes, reviewing, defining and naming themes, followed by the write up (Braun & Clarke, 2006). The data generated were represented by figures, charts, tables and a histogram, which were developed into an organised, compressed assembly of information as alluded to by Cohen, Manion and Morrison (2007) that permitted me to draw conclusions and take actions. Koshy, Koshy and Waterman (2011) contend that what students say and how it is interpreted is vital for action research. Creswell (2014) argues that the researcher should report the complete range of findings, including contradictory data (Putnam & Borko 2000; Newsome, 2016).

Coherence amongst the diverse data sources were examined to find patterns of significance to clarify emerging themes, explain patterns and explicate phenomena (Creswell, 2014; Koshy, Koshy & Waterman, 2011). These themes were analysed to identify the key findings. The themes also linked to the conceptual framework and literature. The findings were subjective interpretations and affirmations of assertions made in the literature, yet I was mindful that there could be a confirmation or divergence from the assertions made, as alluded to by Garg (2016).

Table 4.1 Progression of the generated data

Research Questions	**Participant**	**Data Generation**	**Analysis**	**Research Type**
1. How does introducing a drawing to learn teaching strategy using pattern learning improve teaching and learning in NCV Electrical Level 2?	Student	Questionnaire	Quantitative	Inductive
	Student	Focus group discussion	Qualitative	
	Student/ Researcher	Structured observation schedule	Quantitative Qualitative	
	Researcher	Personal diary	Qualitative	
2. To what extent does drawing to learn using patterns address student misconceptions of electrical circuits?	Student	Questionnaire	Quantitative	Inductive
	Student	Focus group discussion	Qualitative	
	Student/ Researcher	Structured observation schedule	Quantitative Qualitative	
	Researcher	Personal diary	Qualitative	

4.4 Analysis of data and emerging themes

The data was prepared, transcribed, and organised for analysis. A catalogue of visual information, observations, reflections and arrangements into diverse evidence as alluded to by Braun and Clarke (2006) was formulated. Participant files were created to store all the data received from each student. Table 4.2 that follows outlines the label codes used to represent the different data generation instruments. All three instruments generated data for both research questions.

Table 4.2: Label codes used in data analysis

INSTRUMENTS	LABEL CODES
Questionnaires	Q
Focus group discussions	FG
Structured observation schedule	OS

Researcher journal entries included as data were represented by the label code (JE)

This research aimed to determine if teaching and learning would improve by introducing an alternative teaching strategy. Pedagogical content knowledge (PCK) was the first conceptual framework steering the analysis addressing the first research question. Park and Oliver (2008, p.264) contend that (PCK) "is teachers' understanding and enactment of how to help a group of students understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment." I introduced a drawing to learn teaching strategy "transforming content into a teachable form," as alluded to by Rollnick et al., (2008, p.1365). Shulman (1986, p.9) concurs stating when PCK is used, complex subject matter knowledge (SMK) could be made "comprehensible to others." Lave and Wenger's (1991) situated learning Theory was the second conceptual framework used. For this study, situated learning was analysed primarily through Contu and Willmott's conceptualisation framework, as indicated in Table 4.3 below.

Table 4.3 Situated conceptualisations compared. Contu and Willmott (2003, p.294)

Conceptualisation		Established	Situated
1.	Learning	Cognitive/ passive/ selective.	Interactive/participative and pervasive
2.	Form of knowledge	Canonical/ codified/ theoretical distilled in texts and manuals	Tacit/ embedded/ Practical embedded in community and identity
3.	Understanding developed	Abstract/ universal	Embodied/ context sensitive.
4.	Outcome of Learning	Acquisition of information or skill.	Transformation of identity.
5.	Transmission	Vertical/ instruction by authorities.	Horizontal /collaboration with peers

4.5 Research question 1:

How does introducing a drawing to learn teaching strategy using patterns improve teaching and learning in NCV Electrical Level 2?

In figure 4.1 below, the process of the analysis is illustrated. Data was generated from the three main tools: focus group discussions, the questionnaire, and the structured observation schedule. Data were supplemented from the researcher's journal reflecting on each instrument. The inductive data commences addressing the first research question.

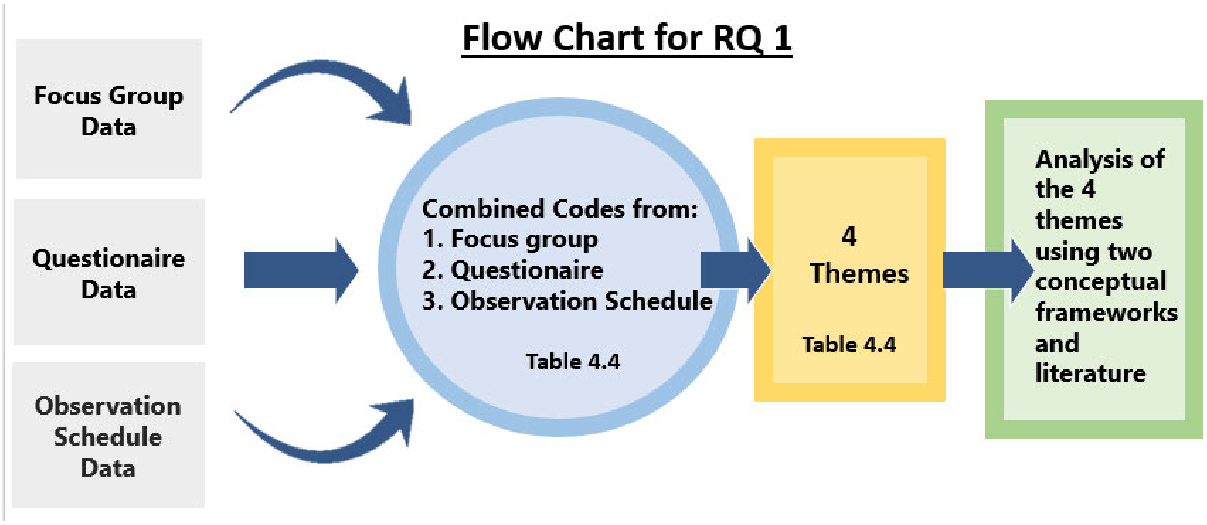


Figure 4.1 Flow chart of the first research question

Table 4.4 below indicates the process of finalisation of the four main themes for the research question. The table shows how the themes were derived from the principal codes of each data generation instrument. PCK using primarily Windschitl's categories of knowledge (2004) was the first conceptual framework used. Situated learning using the conceptualisations of learning from Lave and Wenger (1994) Contu and Willmott (2003) was the second conceptual framework used. Both conceptual frameworks that established the analysis are indicated in the last column. In the analysis of the research question via the main themes, it was evident that some codes overlapped. This commonality and overlap illustrates how robustly each theme synergised with the other.

CODES/PHRASES Focus group	**CODES/PHRASES** Questionnaire	**CODES/PHRASES** Observation	**THEMES RQ1**	**CONCEPTUAL FRAMEWORKS**
DTL improves knowledge construction, recognition, comprehension and understanding	DTL helps students extract knowledgeable information from the circuit diagram to accurately connect schematics.	Observations from the summative assessment allowed both the researcher and the participant to evaluate knowledge construction.	***Encourages active participation in knowledge construction.***	***PCK: Knowledge of student conceptions*** *(Shulman, 1986)* ***Situated learning: Learning through active participation*** *(Contu & Willmott, 2003)*
DTL Improves thinking, reasoning, recognition and understanding.	Patterns create a perception of order in what appears chaotic and assists foster and develop vital logic and critical thinking skills	Drawing to learn promoted understanding and critical thinking permitting each student to competently complete the task.	***Improves cognitive processes.***	***PCK: promotes cognitive activation*** *(Burge, Lenkeit & Sizmur, 2015)*
Pattern learning simplified complex electrical drawings.	DTL simplifies complicated explanations and assisted in the development of predictions from observations.	Students inserted the numbered pattern into their circuit diagrams, which allowed them to accurately identify the components for connection.	***Simplifies complex explanations.***	***PCK: Promotes unambiguous conceptions of target ideas.*** *(Windschitl, 2004)* ***Situated learning: Learning is contextualised*** *(Contu & Willmott, 2003)*
DTL became a strategic teaching and learning tool as	Identifying patterns in the drawing improved confidence to attempt more complicated	Self -efficacy of the participants positively contributed to them	***Improved teacher's and students' self-***	***PCK: combines forms of instruction with others for an improved teaching and learning experience***

students familiarised themselves with pattern learning.	tasks.	competently completing the task using patterned learning.	***efficacy.***	*(Windschitl, 2004)* ***Situated learning: Learning is collaborative*** *(Contu & Willmott, 2003)*

Table 4.4: Combined codes and amalgamated themes for research question 1

4.5.1 Analysis of research question 1:

How does introducing a drawing to learn teaching strategy using patterns improve teaching and learning in NCV Electrical Level 2?

4.5.1.1 Encourages active participation in knowledge construction

Drawing to learn as a new teaching strategy was implemented and elicited varied responses from the participants. Initially, some students seemed confused with drawing to learn and learning to draw. They assumed it was the same. As the lesson unravelled and the concept became clear, student understanding of this new strategy improved. One of the principal codes emanating from the focus group discussions was that drawing to learn helped participants extract knowledgeable information from the circuit diagram to connect schematics accurately.

"It is more important to draw to learn because when I look at the electrical drawing it gives me with information that will allow me to connect the electrical correctly"(Student F).

> *Initially drawing to learn and learning to draw seemed to convey the same meaning, however when explained, participants identified the difference and grasped the significance of drawing to learn. The circuit diagram was addressed using a drawing to learn teaching strategy before completing the practical task. This strategy allowed the students to complete the task competently* (JE).

Figure 4.2 follows analysing the response from the likert scale questionnaire.

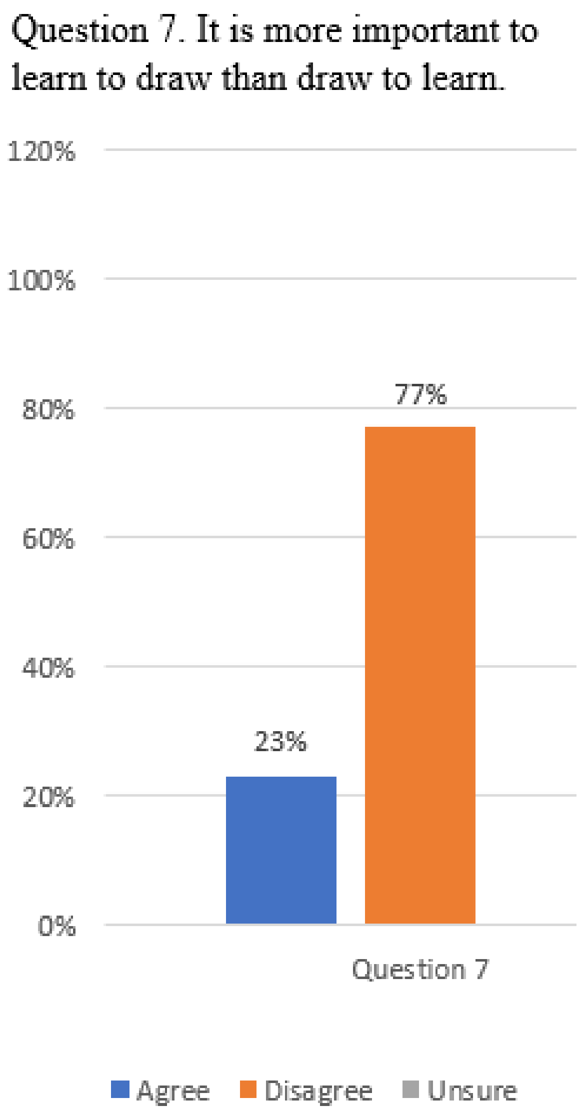


Figure 4.2 Analysis of question seven from the questionnaire

In Figure 4.2, Question Seven from the questionnaire was analysed. Data contradiction was evident because 23% of the students agreed that learning to draw was more important. However, when the students were asked the same question in the focus group discussions, all participants agreed that drawing to learn was more important than learning to draw. The contradiction emerged from individual students' misunderstanding the questionnaire, but they corrected their responses when clarified in the focus group discussions. Do you think it's more important to learn to draw or draw to learn? *"It is more important to draw to learn because when I observe the circuit diagram it provides me with knowledge that allows me to wire the schematic properly"* Student B.

> *As students started to engage with this alternate teaching and learning style, they recognised the learning benefits of drawing to learn. Students transitioned from rote learning to knowledge construction* (JE). *Pattern learning initially did challenge certain students, however once grasped, was easily assimilated into new learning practices that promoted improved schematic comprehension* (JE).

Ainsworth, Prain and Tytler (2011) contend that visual modes play a critical role in knowledge construction in addition to talking, reading, and writing. They identified that student's perceptions were expanded and deepened, especially when working with graphs. Drawing to learn helped to unravel "learning demands inherent in the subject matter" (Bucat, 2005, p.11) as the lesson evolved into a synergistic tryst of subject knowledge, pedagogical knowledge and curricular knowledge. Students identified symbols representing components; thus, they could construct a parts list if they pictured what the drawing entailed. Van Meter (2001) advocates this concept of mental models created from thought recall instead of lower-order learning, where students engage in recognition by memorisation. Tempelman and Pilot (2011, p.262) explain that these models synthesise theory and practice, helping students utilise "facts, theories and insights into their design projects."

The participants found that theory is better learnt and understood when applied in practice. Baldwin and Crawford (2010, as cited in Quillin & Thomas, 2015) argue that practical tasks promote instinctive curiosity. Through personal endeavours, exploring phenomena is natural and progressive, rather than coercive, and it assists in memorisation. To determine competence, participants engaged in a practical task. "*Both the educator and the student evaluated knowledge construction through the practical task"* (OS). Students chose components to undertake the practical task at a workstation based on a generated parts list. Knowledge construction and competence were evaluated through the summative task. Clancey (1995, p.49) emphasises that "knowledge is dynamically constructed" when activities are conceptualised in a given environment through situated activities. However, when students are placed in learning environments that replicate real work situations, they actively immerse themselves in activities while utilising critical thinking skills. (Stein, 1998; Clancey, 1995) The participants in this study learnt by actively participating in the learning experience.

Kind (2009, p.174), adapting Shulman's theories, states "that PCK comprises two components: instructional strategies and learning difficulties."

Drawing to learn encouraged active participation in knowledge construction and addressed both issues and improved "understanding of experiments; problem-solving, processing of data and related concepts into a complete picture aiding in learning content knowledge." (Quillin & Thomas, 2015, p.5). Participants engaged in active learning and knowledge construction through interactions and participation in the learning process instead of passively imbibing knowledge. Knowledge construction evolved from knowledge creation, the highest order of learning (Barnett & Ceci, 2002; Bruehler, 2018).

4.5.1.2. Improves cognitive processes

Another significant observation made from the data generated was ***drawing to learn improved cognitive processes such as critical thinking, awareness, and reasoning.*** Visual literacy occurred when students transitioned from learning to draw to drawing to learn. Students attached meaning to schematic components, thus transferring knowledge from the pictorial to the physical application. Quillin and Thomas (2015, p.2) contend that "visual literacy" is the ability and aptitude of students to explain ideas presented by educators, likewise to craft, construct and create "visual representations" by themselves. The learning structure became implicit in the experience rather than in the subject matter only (Contu &Willmott, 2003).

PARTS LIST	
ITEM	QUANTITY
Circuit breaker	1
Two-way switch	2
Light bulb	1
Conductors	6

Student B

"Students prepared a parts list [Student B] *from the circuit diagram using intellectual intuition (to think, reason, recognise and understand)"* (JE).

> *"Students started to identify components from the schematic correctly. Students generated a component list which was one of the requirements of the practical task. To do this, they had to identify and attach meaning to the components accurately"* (JE).

Students created meaning from these actual activities (Lave &Wenger, 1991; Stein & Clearinghouse, 1998). Clancey (1995, p.49) concurs that situated learning activities are conceptualised in a given environment while "knowledge is dynamically constructed." However, one of the vital aspects of this research was determining if this teaching strategy improved understanding. Understanding and comprehension is a cognitive process in learning and, when attained, should permanently change behaviour (Bruehler, 2018; Burge, Lenkeit &Sizmur, 2015). The research observations were focused on determining if this teaching strategy produced behavioural change. Fan (2015) concurs that the most rudimentary visualisation skill, drawing, assimilates with cognitive functions fundamental to scientific rationale. When participants read and understood the schematic, visual literacy occurred.

Visual literacy assisted students in cognitive activation. Ergönenç, Neuman and Fischer (2014) argue that PCK promotes cognitive activation and similarly drawing to learn improved mental processes such as critical thinking, awareness and reasoning. Burge, Lenkeit and Sizmur (2015, p.2) contend that:

> Cognitive activation encourages pupils to think more deeply in order to find solutions and to focus on the method they use to reach the answer rather than simply focusing on the answer itself. Making connections between… facts, procedures and ideas, will result in enhanced learning and a deeper understanding of the concepts.

Burge, Lenkeit and Sizmur (2015, p.2) argue that cognitive activation positively correlates to "self-efficacy". Cognitive activation resulting in visual literacy was accomplished through pattern learning. As alluded to by Dehaene et al., (2015), patterns created a perception of order in what appeared chaotic, which fostered and developed vital logic and critical thinking. Jones, Stewart, and Power (1999, p.2) state that "patterns are a way of recording the knowledge of experienced practitioners, best practice and lessons learned". Students were observed identifying patterns that enhanced comprehension.

Now that you have used the pattern learning can you identify patterns on your own while learning? *"Certainly, at the start it was tricky. As I applied it became straightforward*" (Student C).

Understanding and utilising pattern learning ***improved cognitive processes such as critical thinking, awareness and reasoning.***

Now that you have learnt the skill of interpreting drawings, do you think drawing to learn has improved your ability to think and reason?

"*Definitely it has upgraded our reasoning. I recognise parts effortlessly. It has assisted me to understand the whole circuit"* (Student I).

Konovalov and Krajbich (2018) contend that in comprehending patterns, students grasp scientific relationships using graphs, charts, tables and drawings during the process of analysing data and solving complex scientific problems. Warburton and Winters (2014) argued that the capacity to distinguish, create and recognise patterns assists in the fabrication of predictions from observations.

The data indicated that participants' recognised electrical schematics as not simply lines on a page, but each line conveyed ideas or represented components.

By looking at an electrical schematic can you picture what the connected project would look like?

"Yes, I now have a better knowledge of how the circuit works. I also know how the circuit connects" (Student J).

Clancey (1995, p.49) contends that "situated learning is the study of how human knowledge develops in the course of activity, and especially how people create and interpret descriptions". Larkin and Simon (1987) argue that drawings facilitate cognition that relieves the working memory load by absolving it to keep track of the different factors relating to the problem.

In Figure 4.3 below, questions three and four from the questionnaire were analysed. These questions delve into aspects of pattern learning. The correlation between these similar answers triangulated the findings. The codes revealed that 94% of students would choose to use pattern learning in other subjects. Students using this teaching strategy enhanced cognitive ability, finding it easily applicable to other learning areas. Cognitive abilities progressed from knowledge acquisition and understanding to evaluation and application. (Hanna, 2007; Bruehler, 2018).

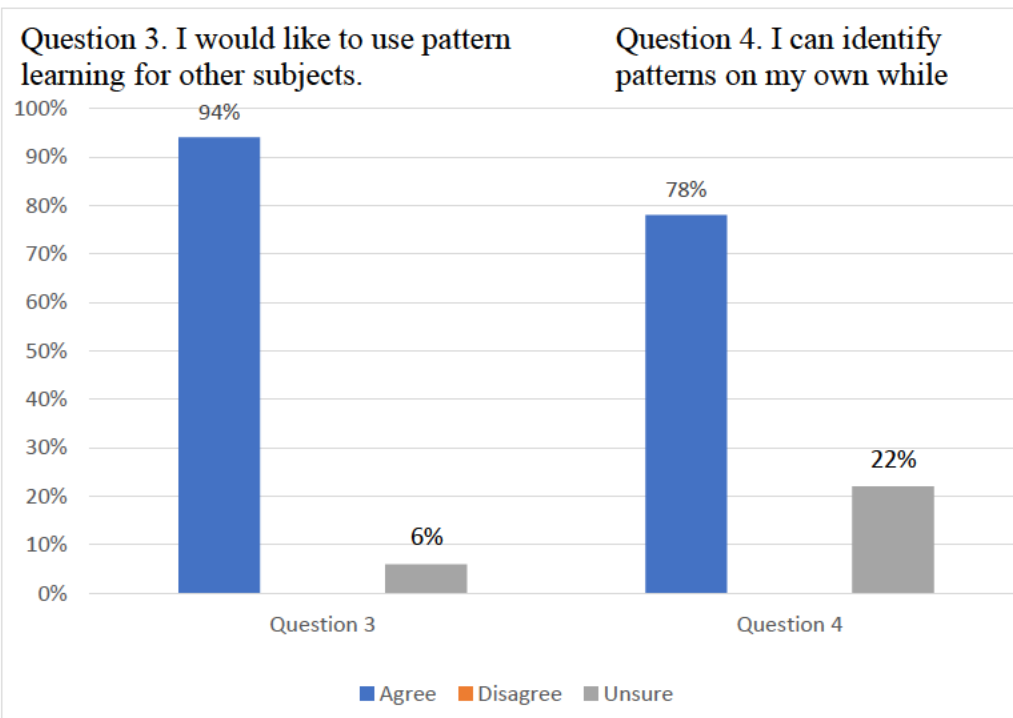


Figure 4.3 Analyses of questions three and four from the questionnaire.

Do you think patterns should be used in other subjects?

"Definitely I recognise that this method of learning makes difficult questions easy" (Student M).

Reflectively it was noted that, *"this method of teaching and learning developed student's mental pictures. Students predicted schematic outcomes better once they identified pattern"* (JE).

"Participants, through patterned learning, could formulate knowledgeable, educated deductions while learning" (JE).

"Electrical drawings are complicated and complex. However, as students identified patterns, they could see a logical order in what appeared chaotic. This promoted crucial logic and critical thinking skills" (JE).

"The complexity of certain problems diminished when students identified patterns during the lessons" (JE).

"Although pattern learning was used to unravel the complications of circuit diagrams, it could be applied to teaching and learning in all subjects" (JE).

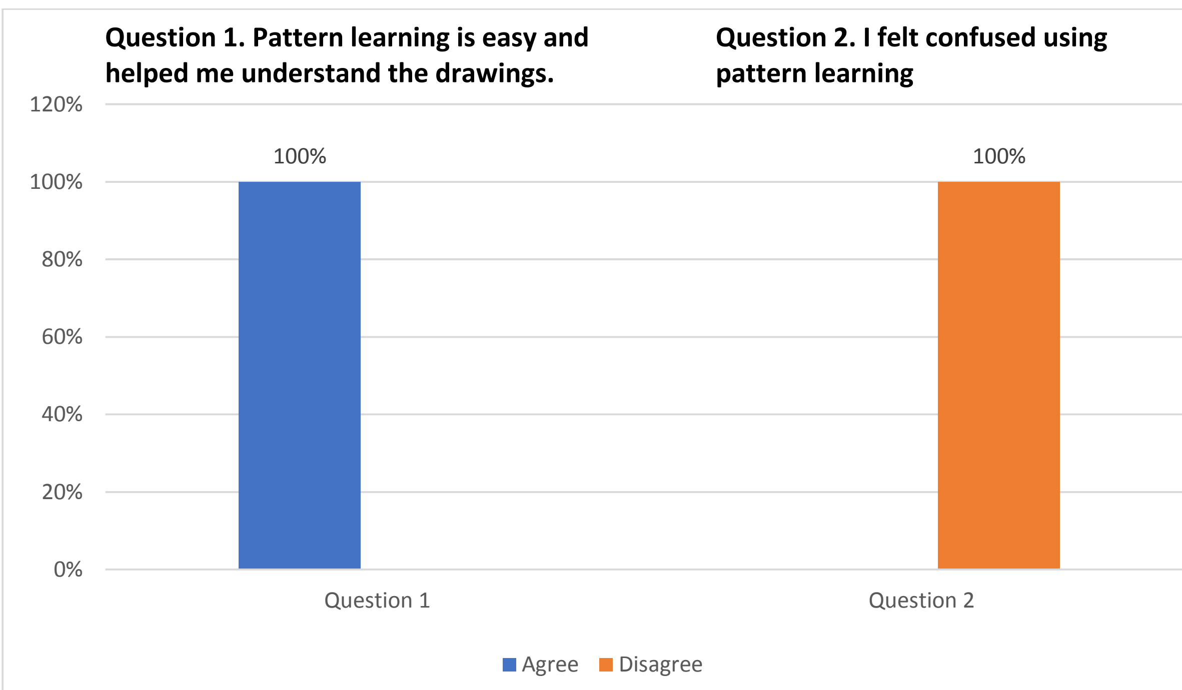


Figure 4.4 Analysis of questions one and two from the questionnaire.

Figure 4.4 displays the enthusiastic embrace of pattern learning. Pattern learning simplified complex electrical drawings, helped develop predictions from observations, and created a perception of order in what appeared chaotic. It assisted in fostering and developing logical and critical thinking skills, integrating focal ideas with ideas from other domains, as alluded to by Windschitl (2004).

Drawing to learn enhanced cognitive development by improving critical thinking, problem-solving and understanding scientific relationships as students explored learning through a new teaching strategy.

4.5.1.3. Simplifies complex explanations

"When students identified patterns, they grasped complex concepts easily" (JE). ***Drawing to learn simplified complex explanations*** and provoked students' participation in active knowledge construction.

Do you find it easier to draw than to explain an idea with words?

"Definitely I find it easier to draw. Electrical drawings do not require complicated details but they can convey my ideas clearly" (Student I).

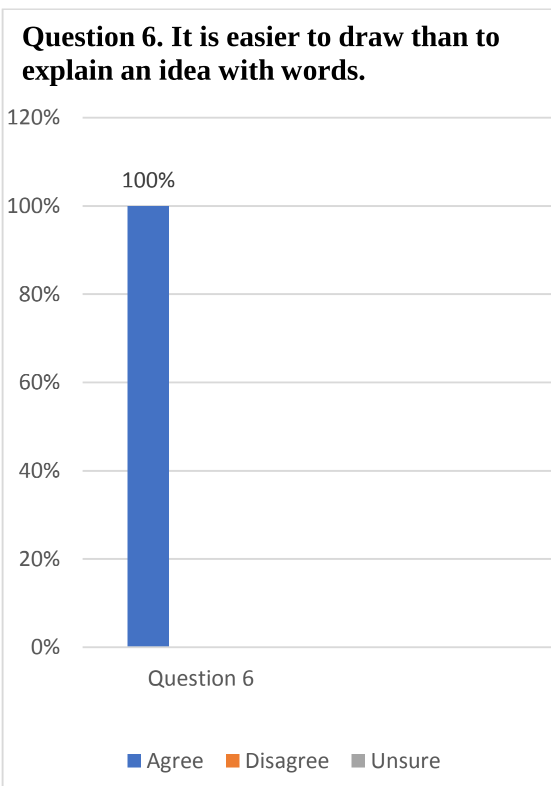


Figure 4.5 Analysis of question six from the questionnaire

In Figure 4.5, the coding revealed that all students (100%) believed that it was easier to express ideas and thoughts through drawings than through words. Reflectively, it was noted that:

> [*t*]*he medium of instruction at our institution is English, which is not the mother tongue for most students. This major communication barrier students' encounter was overcome using drawings to communicate ideas and thoughts* (JE).

"For students, an electrical drawing can simplify complicated explanations. Drawing circuit diagrams assisted students in translating complex scientific terms into a simple perceptual task" (JE).

"It has become an acceptable norm to mark students drawings correct as an alternative to a written answer in engineering examinations" (JE).

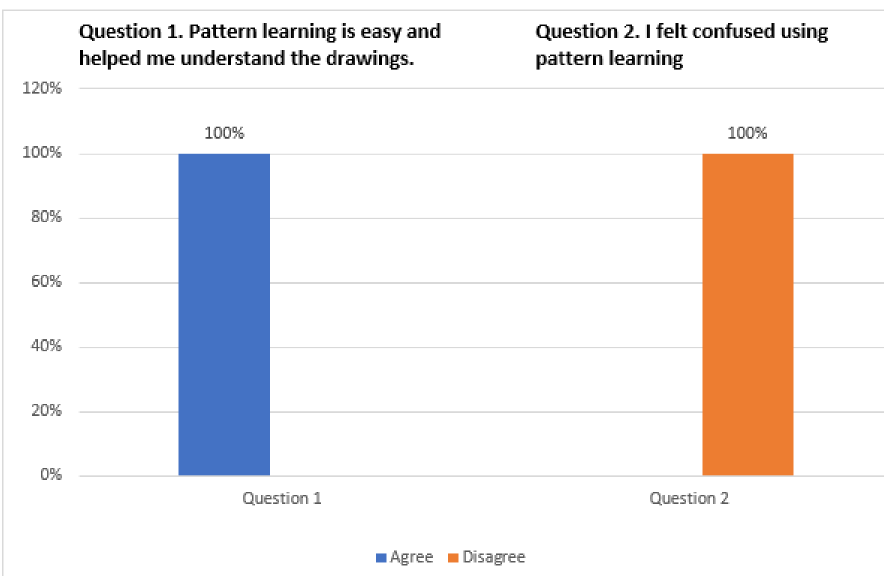


Figure 4.4 Analyses of questions one and two from the questionnaire

Question one and two were analysed the second time as indicated in Figure 4.4 . All participants agreed that pattern learning helped them understand the drawing. The same question was reframed and asked in the second question. The answers to the second question corroborated and triangulated the responses from the first question. The

following reflective journal notes indicated that, *“pattern learning initially challenged certain students, however once grasped, it was easily assimilated into new learning practices that promoted improved schematic comprehension”* (JE).
“When students identified patterns, they grasped complex concepts easily” (JE).

Pattern learning simplified complex electrical drawings and assisted develop predictions from observations. Students were shown that drawings could be used alternatively to complicated theory. On the other hand, schematics contain immense information, which is easier to recall than to write up a theory explanation. A circuit diagram contains large amounts of implicit knowledge; extracting or explaining that information from memory recall is easier than rote learning large amounts of theory. Thus, drawing to learn simplifies complex explanations.

Larkin and Simon (1987) corroborated that diagrams enable reasoning by translating gruelling computational techniques into simple perceptual tasks. Quillin and Thomas (2015, p.2) concur that “there is a vast difference between knowing about [schematics] (content knowledge) and knowledge about the teaching and learning of [understanding schematics] (PCK)”. Adams (2017) contends that teachers need to support students to master the skills required on their own.

Maries and Singh (2018) describe the cognitive load theory and advocate that students who draw and understand diagrams are better problem solvers. Conversely, Serra and Dunlosky (2010, p.699) referred to “metacognitive judgments” as one of the types of information sources people require to determine their ability to perform a task. *“Electrical drawings simplify complicated explanations. Drawing circuit diagrams assisted students translate difficult scientific terms into simple perceptual tasks”* (JE).

Adams (2017) asserts that drawing was both a process and a product, and students’ capabilities were evaluated through performance, corroborated by their achievements. Contu and Willmott (2003) describe this as contextualised learning. Empirical studies have confirmed that the accuracy and quality of drawings link and correlate with successful performance tests on reasoning about what was just learned. (Bhatt, 2011; Wammes, Meade & Fernandes, 2016; Larkin & Simon, 1987; Uesaka, Manalo & Ichikawa, 2007). PCK argues Windschitl (2004) promoted unambiguous conceptions of target ideas through the teacher's sequence of activities to promote a clear understanding of focal ideas.

Drawing to learn simplified complex explanations translating gruelling computational techniques into simple perceptual tasks promoting predictions from observations. Students who draw and understand diagrams are better problem solvers who could contextualise learning.

4.5.1.4. Improved teacher and student self-efficacy

Cognitive activation distinctly correlates to "self-efficacy." ***Drawing to learn using a patterned learning approach improved teachers' and students' self-efficacy, which positively contributed to their performance.*** Burge, Lenkeit and Sizmur (2015, p.2) assert that cognitive activation is:

> [a]bout teaching pupils strategies, such as summarising, questioning and predicting, which they can call upon when solving maths problems. Such strategies encourage pupils to think more deeply in order to find solutions and to focus on the method they use to reach the answer rather than simply focusing on the answer itself.

Fortsch et al. (2017) contend that cognitive activation provides content instruction that stimulates deep thinking and conceptual understanding while learning a concept resulting in visual literacy. Visual literacy was accomplished through pattern learning. As alluded to by Dehaene et al. (2015), patterns created a perception of order in what appeared chaotic, which fostered and developed vital logic and critical thinking.

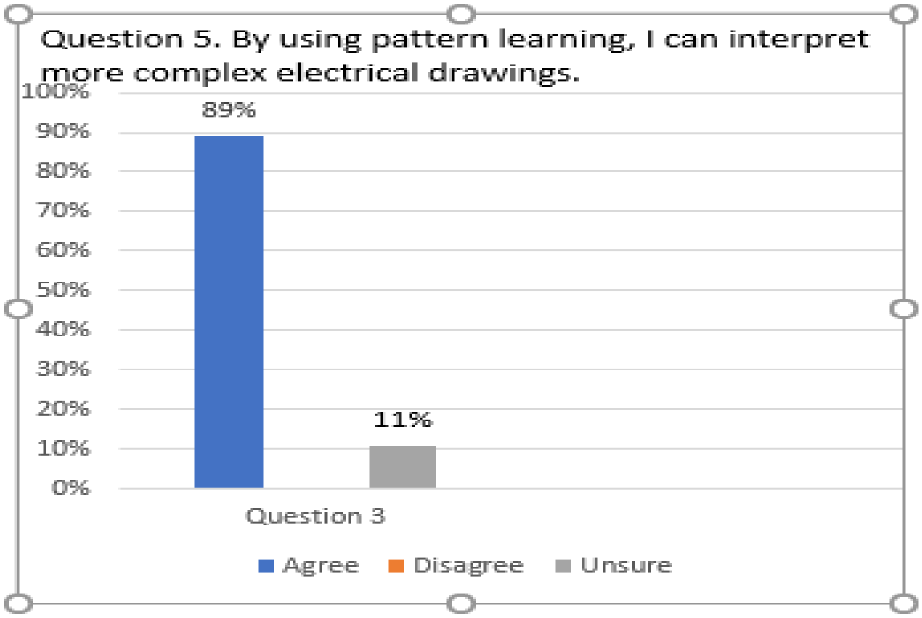


Figure 4.6 Analysis of question five from the questionnaire

In the analysis of Question Five from Figure 4.6, all participants agreed, there was a measure of uncertainty emanating from the codes. Participants justified this hesitancy in their focus group responses stating they would be capable of interpreting more complex schematics provided they did so under a skilled person's supervision.

Now that you have used pattern learning can you identify patterns on your own while learning?

"Certainly, at the start it was tricky as I applied it became straightforward" (Student D).

Do you think that by using pattern learning you could interpret more complex electrical drawings?

"Definitely, pattern learning permitted me a sturdy understanding. I know that we will be capable to interpret difficult schematics by the help of a skilled teacher" (Student P).

The coding displayed that (89%) participants were confident to use their acquired knowledge to interpret more challenging electrical schematics. The following reflective notes explained that *"some participants identified patterns immediately in the drawings;*

however, pattern recognition improved gradually in others. By recognising patterns, participants could identify inaccurate diagram connections" (JE).

> *By identifying patterns in the drawing to learn teaching strategy, students became more confident about reading the circuit diagram and undertaking the practical task. When shown more complicated schematics, some were keen to attempt connecting them. However, they will need assistance as they navigate through more complex circuit diagrams.* (JE).

The ability to identify wrong or inaccurate drawings helped students in knowledge construction. Identifying patterns in the drawing improved confidence to attempt more complicated tasks.

"Drawing to learn assisted students to read and interpret the circuit diagram to connect the schematic accurately." (OS). *"Every participant successfully undertook the practical task, with all scoring above 95%"* (OS).

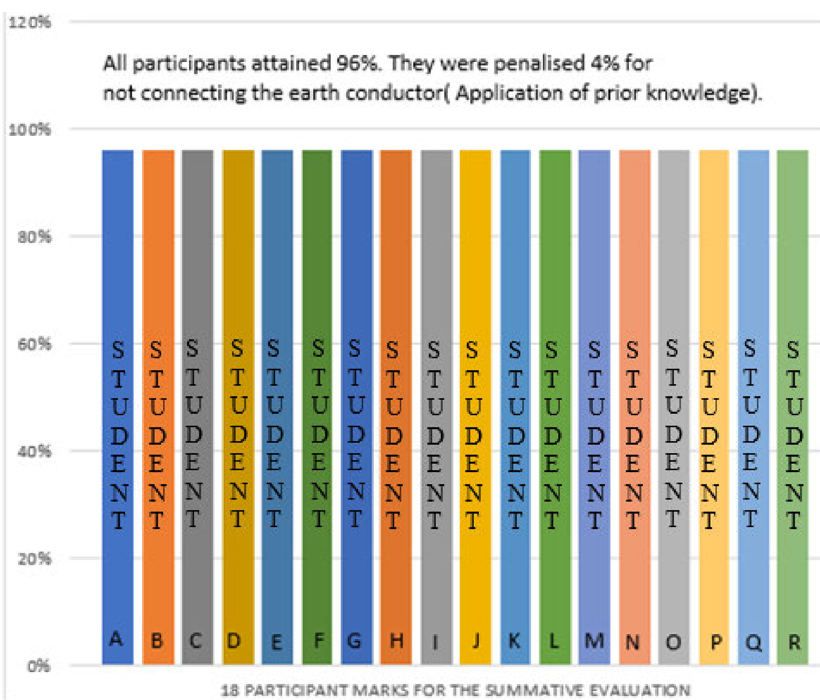
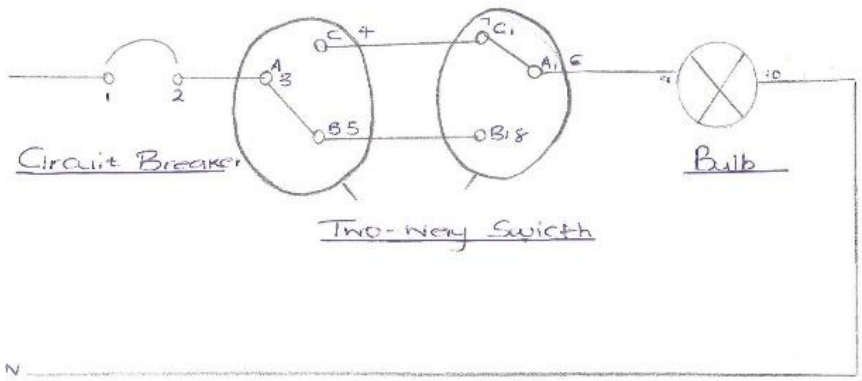


Figure 4.7 Histogram of summative assessment results

Students were taught how to insert numbers into the drawing. This was the first pattern application.



Pattern 1 (Student N)

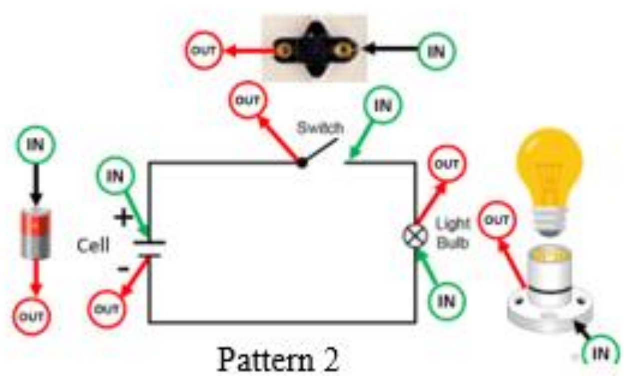


Figure 4.8 Pattern 2 (from the lesson)

Students were then tutored on how components are connected in a circuit. The second pattern was introduced where students added in or out to each component, as indicated in Figure 4.8.

The initial student engagement included implementing a patterned numbering system that progressed numerically from left to right on each component terminal starting from the circuit breaker to the first two-way switch and then the second two-way switch followed by the bulb and concluding with the neutral connection. Although this looked simplistic, its success hinged on student cognition. Inserting numbers was designed to aid metacognition and the ability of students to systemise knowledge. Systemised knowledge was effectively transferred by creating a logical and functional path that students could follow. The utilisation of drawing to learn as a conceptual tool aided knowledge construction. Drawing to learn as a cognitive teaching strategy using pattern learning aided students to learn intricate and complex numbering concepts. The electrical schematic enhanced visual awareness and simplified the perceptual task. Self-efficacy was evaluated against student understanding of knowledge and teacher knowledge of instructional strategies. The schematic scaffolded the practical task and enhanced knowledge construction.

From my observations certain student grasped the concepts easily. However, others were slower. Students were encouraged to engage collaborative peer learning and ask their peers to explain concepts. This promoted self-efficacy as visual literacy became evident.

When students realised how simple it was (Figure 4.9) to apply pattern learning to the schematic, their confidence improved, as outlined in my journal entry and participants' likert scale responses: *"Patterned teaching aided students learn intricate, complex number concepts. Electrical drawings utilise intricate numbering formats intimidating trainees"* (JE).

Tick the appropriate block	% Strongly agree	% Agree	% Not Sure	% Disagree	% Strongly disagree
1. Pattern learning is easy and helped me understand the drawings.	83%	17%			

Figure 4.9 Pattern learning analysis

Any negative perceptions towards drawings, especially schematics, diminished as self-efficacy improved. Drawing to learn enabled students to extract knowledgeable information from the circuit diagram to connect the schematic accurately. The summative practical task confirmed, verified, and corroborated participant responses from the other data generation tools. All the participants (Figure 4.10) agreed that communicating ideas and thoughts through graphical and symbolic representations was simplified by engaging drawings.

Tick the appropriate block	% Strongly agree	% Agree	% Not Sure	% Disagree	% Strongly disagree
6. It is easier to draw than to explain an idea with words.	94%	6%			

Figure 4.10 Visual explanations are easier than theory

Larkin and Simon (1987) describe how visual explanations were more significant than writing a paragraph under certain circumstances. Bhatt (2011) concurs that better integration of verbal, graphical and symbolic representations in engineering curricula can help students understand various ways of communicating given concepts, thus leveraging their understanding to problem solve. Larkin and Simon (1987) compared the verbal description of solving physics and maths problems against the benefits of referring to a diagram. They found an adequately constructed diagram assisted processability by restricting flawed, inaccurate perceptions such as in Venn diagrams. Clancey (1995, p.49) contends that "situated learning [through] activity…[helps] create and interpret descriptions". Through drawings, argues Quillin and Thomas (2015), students could think more explicitly and expressly. This improved their ability to communicate, clarify and exchange concepts or ideas among their peers:

> *I also noted that the visual component of communication was part of verbal, written, graphical and symbolic illustrations. A student must excel in all four ways of communication to navigate engineering concepts successfully.* (JE)

Pedagogical patterns were vital to improving student's ability to read and understand schematics. ***Drawing to learn using a patterned learning approach improved teachers' and students' self-efficacy, which positively contributed to their performance.*** Identifying patterns in the circuit diagram assisted in comprehending the drawings.

Jones, Stewart, and Power (1999, p.2) assert that "patterns are a way of recording the knowledge of experienced practitioners, best practice and lessons learned". It was observed that when students identified patterns, it enhanced comprehension. *"Certainly, pattern learning gave me a good grasp. I believe that I will be skilled to understand tricky circuit diagrams with the assistance of a qualified electrician" (Student C).*

Researchers argue that when students learn and explore patterns, they construct significant memory retention foundations (Alexander et al., 1977; Mor et al., 2014). The capacity to distinguish, create and recognise patterns, argues Mor et al., (2014), assists in the fabrication of predictions from observations. *"Pattern learning initially did challenge certain students, however once grasped was easily assimilated into new learning practices that promoted improved schematic comprehension"* (JE). Fernández (1998) concurs that patterns are used to aid children in learning intricate, complex numbering concepts and mathematical theories in kindergarten.

Lockyer et al. (2009) surmise that patterns correlate and identify regularities and allow students to perceive relationships helping them develop generalisations. *"When students identified patterns, they grasped complex concepts easily"* (JE). Empirical studies have concluded that identifying and understanding recurring patterns allows students to formulate knowledgeable, educated deductions, hypothesis assumptions and guesses. (Dehaene et al., 2015; Quillin & Thomas 2015; Mor et al., 2014).

PCK, argues Park and Oliver (2008, p.271), is fostered "through enhanced teacher efficacy" if the teaching experience was successfully undertaken. Windschitl (2004) asserts that PCK combines multiple instruction forms for an improved teaching and learning experience.

In implementing a drawing to learn teaching and learning strategy, teaching efficacy improved. One way of measuring teacher efficacy was to determine how new and existing knowledge was organised and integrated. Quillin and Thomas (2015) describe drawing as an effective learning strategy that assists students in surmounting limitations in curricula, effectively managing their knowledge, and successfully integrating existing knowledge. Guskey (1987) verifies that improved teacher efficacy promotes instituting commendable professional objectives with teachers displaying an inclination to attempt different teaching strategies in their teaching practice. This was true for this study when students were observed grasping the concepts being taught. Drawing to learn using a patterned collaborative learning approach improved teacher and student self-efficacy, which positively contributed to teacher and student performance. A collaborative approach developed (Contu & Willmott, 2003) not between student and student but between student and teacher in a situated learning context:

> *By identifying patterns in the drawing to learn teaching strategy, students became more confident about reading the circuit diagram and undertaking the practical task. This additional teaching strategy has increased my teaching repertoire and will be included in my pedagogy. When shown more complicated schematics, some were keen to attempt connecting them. However, they will need assistance as they navigate through more complex circuit diagrams.* (JE)

Self-efficacy improved significantly, and this was confirmed by the enthusiasm participants displayed in attempting to engage with more complicated circuit diagrams. Wood and Bandura (1989) contend that self-efficacy is the conviction of an individual to meet the expected behaviour, thus successfully achieving their goals. However, self-efficacy argues Eny (2015, p.391) "mediates between the teachers' knowledge of instructional strategies of science teaching and students' understanding of science knowledge. The relationship between self-efficacy and cognitive knowledge of PCK shows the relationship is mutually beneficial". The development of cognitive knowledge through the practical application of PCK through drawing to learn improved student and teacher self-efficacy.

Drawing to learn using a patterned learning approach improved teachers' and students' self-efficacy, which positively contributed to their performance. Cognitive activation is distinctly correlated to self-efficacy by providing content instruction that stimulates deep thinking and conceptual understanding while learning a concept. Identifying wrong or inaccurate drawings helped students in knowledge construction and identifying patterns in the drawing improved their confidence to attempt more complicated tasks. An adequately constructed diagram assisted processability, and self-efficacy, by restricting flawed, inaccurate perceptions. When students identified and explored patterns, they enhanced comprehension and constructed significant memory retention foundations promoting self-efficacy.

4.6 Research question 2:

To what extent does drawing to learn using patterns address student misconceptions of electrical circuits?

In Figure 4.11 below, the process of the analysis is illustrated. Data was generated from the three main tools: focus group discussions, the questionnaire, and the structured observation schedule. Data were supplemented from the researcher's journal reflecting on each instrument.

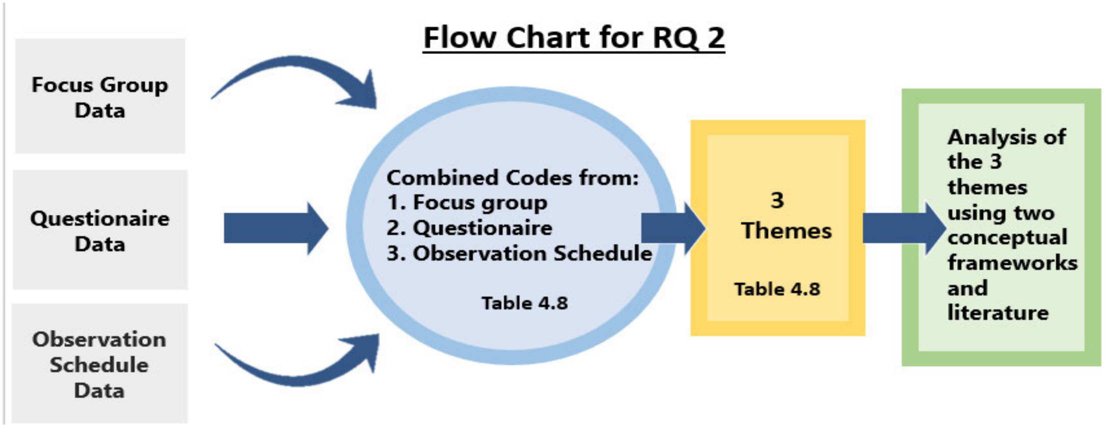


Figure 4.11 Flow chart for research question two.

Table 4.5 below indicates the process of finalisation of the three main themes for the second research question. The table shows how the themes were derived from the principal codes of each data generation instrument. PCK using primarily Windschitl's categories of knowledge (2004), was the first conceptual framework used. Situated learning using the conceptualisations of learning from Lave and Wenger (1994) and Contu and Willmott (2003) was the second conceptual framework used. Both conceptual frameworks that established the analysis are indicated in the last column. In the analysis of the research question via the main themes, it was evident that some codes overlapped. This commonality and overlap illustrates how robustly each theme synergised with the other.

CODES/PHRASES Focus group	**CODES/PHRASES** Questionnaire	**CODES/PHRASES** Observation	**THEMES** **RQ2**	**CONCEPTUAL** **FRAMEWORKS**
Students can attach meaning to schematics components to transfer this knowledge from the pictorial to the physical application.	Electrical misconceptions originate from mistaken beliefs, lacking understanding, incorrect thinking and inaccurate views.	The practical task evaluated whether knowledge was transferred correctly or erroneously.	***Promotes knowledge transfer***	***PCK scaffolds reasoning.*** *(Windschitl, 2004).* ***Situated learning: Learning is transformative*** *(Contu & Willmott, 2003)*
Electrical misconceptions originate from mistaken beliefs, poor understanding, incorrect thinking and inaccurate views.	Drawing to learn exposed and addressed underlying misconceptions.	The practical task evaluated whether identified misconceptions were eliminated.	***Improves students' awareness of preconceived misconceptions.***	***PCK elicit students' existing conceptions*** *(Windschitl, 2004).* ***Situated learning Develops through the construction of identities.*** (Lave and Wenger 1991)
Drawing to learn has helped students identify critical gaps in their knowledge and the need to recognise and be aware of other underlying misconceptions.	Drawing to learn has helped students identify critical gaps in their knowledge and the need to recognise and be aware of other misconceptions.	Students identified and eliminated knowledge gaps through intellectual intuition.	***Helped students identify critical gaps in their knowledge.***	***PCK identifies shortcomings in thinking and reasoning.*** *(Windschitl, 2004).* ***Situated learning iss tacit*** *(Contu & Willmott, 2003)*

Table 4.5: Combined codes and amalgamated themes for research question 2

4.6.1 Analysis of research question 2

To what extent does drawing to learn using patterns address student misconceptions of electrical circuits?

4.6.1.1 Promotes knowledge transfer

The first theme analysed was '*drawing to learn promotes knowledge transfer which corrects erroneous and improper thinking'. "Knowledge transfer through the use of a practical task occurred correctly and effortlessly and not erroneously"* (OS). Students could attach meaning to schematic components and transferred this knowledge from the pictorial to the physical application.

Do you think lines in a schematic have meaning?

"Definitely every line is a conductor that is attached to a part" (Student O).

"Drawing to learn assisted students to read and interpret the circuit diagram to connect the schematic accurately" (OS). Thus, drawing to learn enabled students to extract knowledgeable information from the circuit diagram to connect the schematic accurately.

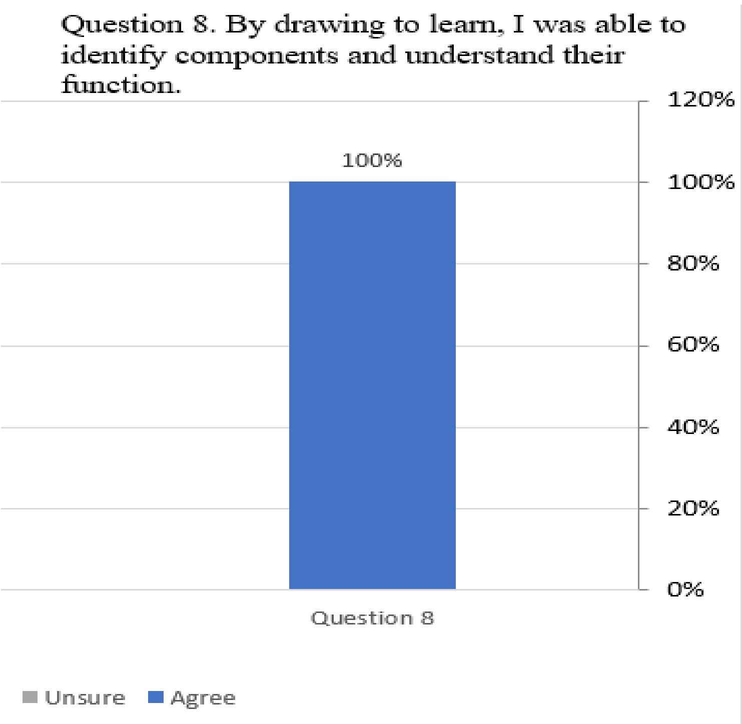
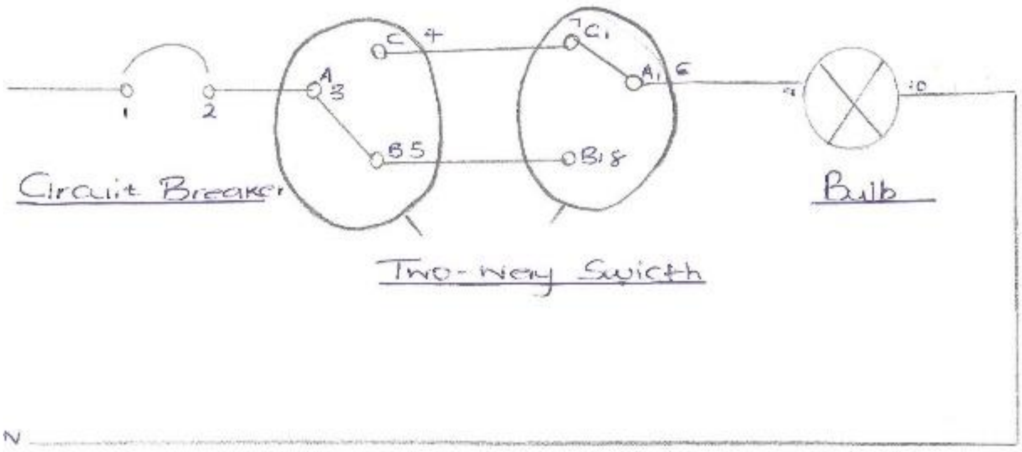


Figure 4.12, Analysis of question eight from the questionnaire

By looking at an electrical schematic can you picture what the connected project would look like?

"Definitely I have acquired a better understanding of how the circuit operates. I also recognise how the parts match (Student N).

For knowledge to be transferred correctly, knowledge needed to be systemised, giving students a potential advantage. *"I organised and arranged knowledge by creating a logical path that students could follow"* (JE). Students commenced drawing the schematic and then inserting the pattern, generating a parts list and then connecting the components in a practical task.



Student N

"Students started to identify components from the schematic correctly. This information was transferred to a generated parts list. To do this, they had to identify and understand the function of the components" (JE). The generated parts list was one of the summative assessment sub-tasks and was used as a measuring tool to determine competence. Students knowledgeably transferred information systematically from the schematic to the parts list. ***Drawing to learn promoted knowledge transfer.***

COMPILED PARTS LIST	
ITEMS	QUANTITY
Circuit breaker	1
Two-way switch	2
Light bulb	1
Conductors	6

Student B

Barnett and Ceci (2002) contend that knowledge transfer occurs cognitively when a student masters an assignment in one context and can apply that knowledge in several other settings. Manfredi et al. (2019. p.1336) assert that knowledge transfer was not only about replication of it but “rather, it involves the modification of some existing knowledge to a different context. What is transferred is (usually) not the underlying knowledge but rather applications of this knowledge in the form of solutions to specific problems”. Manfredi et al. (2019, p.1336) argue that “Tacit knowledge in arts and crafts organisations is hard to articulate and requires observation, demonstration, and experience for its transfer.”

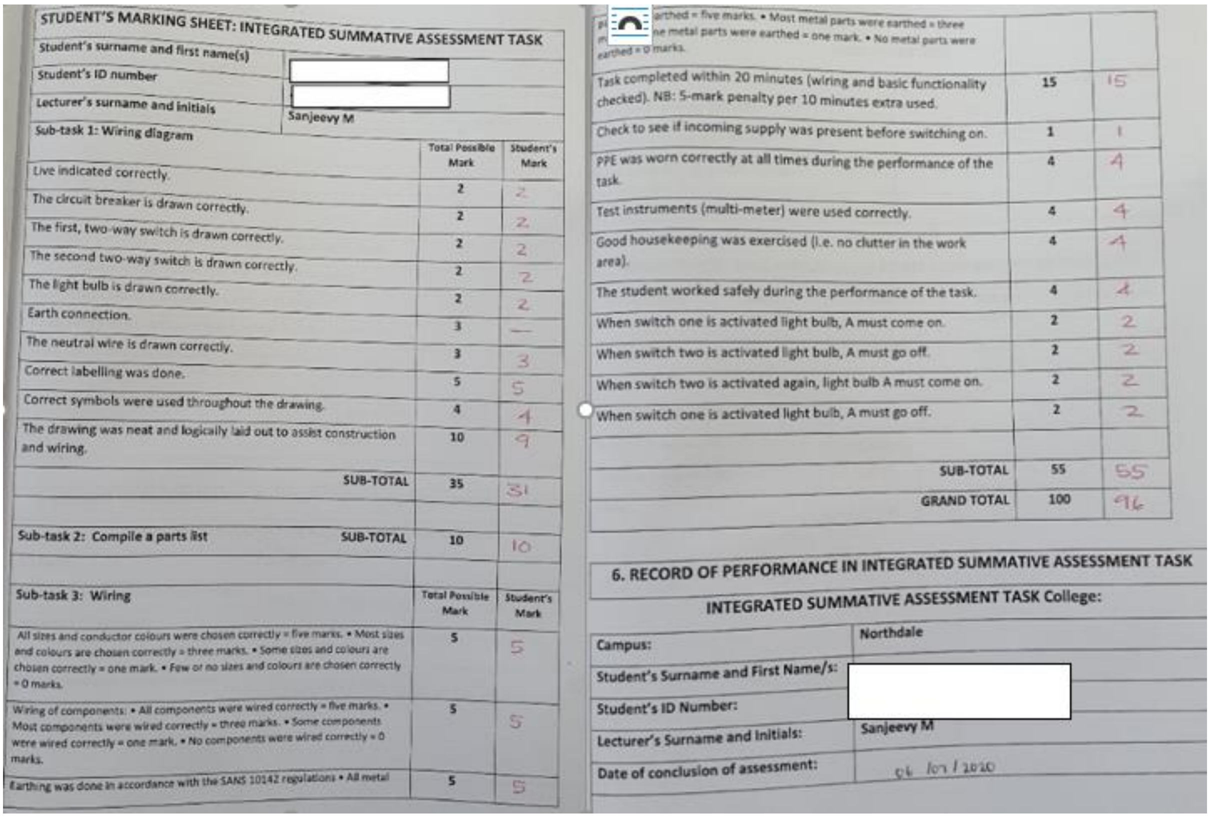
Do you think patterns should be used in other subjects?
“Definitely, I recognise that this method of learning makes difficult questions easy” (Student M).

The transfer of knowledge outside original learning environments has often been deemed a hallmark of authentic learning. (Barnett & Ceci, 2002; Manfredi et al., 2019).

I noted that the visual component of communication was part of verbal, written, graphical and symbolic illustrations. A student must excel in all four communication methods to successfully navigate and transfer engineering concepts (JE).

Teaching with a solid conceptual framework instead of memorising notes and facts allows students to arrange knowledge functionally. For this study, I engaged a conceptual approach to learning that forced students to practice their skills.
The practical task stimulated thought-provoking curiosity and enjoyment and encouraged rigorous thinking for test preparations (OS).

Practical tasks, argue Ainsworth, Prain, and Tytler (2011), also teach skills and enhance scientific intelligence acquisition, which teachers can promote through assessments and class activities. However, Hofstein and Kind (2012, as cited in Abrahams, Reiss & Sharpe, 2013, p.2), argue that “there is a need to acquire appropriate and meaningful guidance for practical work”. The summative assessment of student R indicates how the evaluation to test competence was undertaken.



STUDENT'S MARKING SHEET: INTEGRATED SUMMATIVE ASSESSMENT TASK

Student's surname and first name(s)	
Student's ID number	
Lecturer's surname and initials	Sanjeevy M

Sub-task 1: Wiring diagram	Total Possible Mark	Student's Mark
Live indicated correctly.	2	2
The circuit breaker is drawn correctly.	2	2
The first, two-way switch is drawn correctly.	2	2
The second two-way switch is drawn correctly.	2	2
The light bulb is drawn correctly.	2	2
Earth connection.	3	—
The neutral wire is drawn correctly.	3	3
Correct labelling was done.	5	5
Correct symbols were used throughout the drawing.	4	4
The drawing was neat and logically laid out to assist construction and wiring.	10	9
SUB-TOTAL	35	31
Sub-task 2: Compile a parts list SUB-TOTAL	10	10

Sub-task 3: Wiring	Total Possible Mark	Student's Mark
All sizes and conductor colours were chosen correctly = five marks. • Most sizes and colours are chosen correctly = three marks. • Some sizes and colours are chosen correctly = one mark. • Few or no sizes and colours are chosen correctly = 0 marks.	5	5
Wiring of components: • All components were wired correctly = five marks. • Most components were wired correctly = three marks. • Some components were wired correctly = one mark. • No components were wired correctly = 0 marks.	5	5
Earthing was done in accordance with the SANS 10142 regulations • All metal parts were earthed = five marks. • Most metal parts were earthed = three marks. • Some metal parts were earthed = one mark. • No metal parts were earthed = 0 marks.	5	5
Task completed within 20 minutes (wiring and basic functionality checked). NB: 5-mark penalty per 10 minutes extra used.	15	15
Check to see if incoming supply was present before switching on.	1	1
PPE was worn correctly at all times during the performance of the task.	4	4
Test instruments (multi-meter) were used correctly.	4	4
Good housekeeping was exercised (i.e. no clutter in the work area).	4	4
The student worked safely during the performance of the task.	4	4
When switch one is activated light bulb, A must come on.	2	2
When switch two is activated light bulb, A must go off.	2	2
When switch two is activated again, light bulb A must come on.	2	2
When switch one is activated light bulb, A must go off.	2	2
SUB-TOTAL	55	55
GRAND TOTAL	100	96

6. RECORD OF PERFORMANCE IN INTEGRATED SUMMATIVE ASSESSMENT TASK

INTEGRATED SUMMATIVE ASSESSMENT TASK College:

Campus:	Northdale
Student's Surname and First Name/s:	
Student's ID Number:	
Lecturer's Surname and Initials:	Sanjeevy M
Date of conclusion of assessment:	06 /07 / 2020

Student R

Another observation made from the lesson was the initial apprehension of reading electrical schematics.

When the drawing to learn lesson was introduced, a complicated electrical schematic used in industry was also shown to students, which seemed to intimidate students (OS).

This was done to show the progressive nature of the learning and how it could scaffold students to read and interpret industrial schematics. Uesaka, Manalo, and Ichikawa (2007) highlight inaccurate student perceptions that drawing models are challenging even though they were more likely to get the correct answer when utilised.

The practical task evaluated whether knowledge was transferred successfully using one of Stein and Clearinghouse's (1998, p.1) guiding activities of situated learning that "learning is the result of a social process encompassing ways of thinking, perceiving, problem-solving, and interacting." Contu and Wilmot (2003) concur that situated learning is transformative. Clancey (1995, p.49) elaborates how through situated learning, "knowledge is dynamically constructed," as activities are conceptualised in a given environment.

In introducing drawing to learn as an innovative teaching and learning strategy, I endeavoured to reignite a proactive approach to learning from students (Grossman, 1990; Magnusson, Krajcik & Borko, 1999). Ainsworth, Prain, and Tytler (2011, p.1096) argue that, “Many students lost interest in science because they were forced to adopt passive roles”. This was a result of traditional teaching methods, rote learning and poor transfer of knowledge. Progressive teachers promote enquiry and more interactive learning. Manfredi et al. (2019, p. 1336) argue that “Tacit knowledge in arts and crafts organisations is hard to articulate and requires observation, demonstration, and experience for its transfer.” However, PCK argues Windschitl (2004) scaffolded the reasoning process assisting students in transferring accurate scientific ideas and concepts.

Electrical drawings are complicated and complex. However, as students identified patterns, they could see a logical order in what appears chaotic. This promoted crucial logic and critical thinking skills to transfer knowledge (JE).

Drawing to learn promoted knowledge transfer which corrected erroneous and improper thinking. Knowledge transfer occurred cognitively when a student masters an assignment in one context and can apply that knowledge in several other settings. The transfer of knowledge outside original learning environments has often been deemed a hallmark of authentic learning. For knowledge to be transferred correctly, knowledge needed to be systemised, giving students a potential advantage.

4.6.1.2 Improves students’ awareness of preconceived misconceptions

Drawing to learn exposed underlying misconceptions.
Unmasking electrical misconceptions by correctly drawing, reading and interpreting electrical schematics was not easy initially, however when recognised, it completely changed student perceptions (JE).

Electrical misconceptions originate from mistaken beliefs, lacking understanding, incorrect thinking and inaccurate views. Factors that influenced misconceptions were a lack of knowledge, curriculum design, culture, background, gender, language, and cognitive perspectives. (Sencar & Eryilmaz, 2004; Rollnick et al., 2008).

Misconception is a complicated term that needed to be thoroughly addressed and explained. Students realised and identified their misconceptions (mistaken beliefs; incorrect thinking; and inaccurate views) when engaging in the drawing to learn lesson (JE).

What are electrical misconceptions?
"Mistaken beliefs; bad understanding; incorrect thinking" (Student M).
"An incorrect opinion; an incorrect view; incorrect thinking" (Student B).

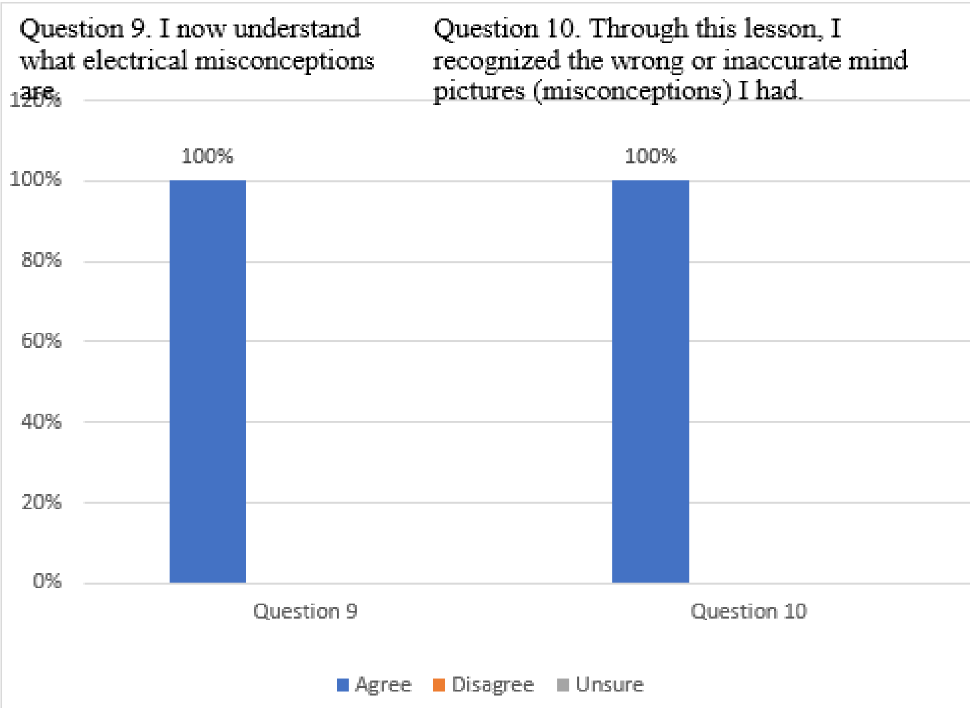


Figure 4.13, Analysis of questions nine and ten from the questionnaire.

In Figure 4.13, questions nine and ten were analysed. The coding displayed a correlation that all students (100%) identified that incorrect opinions or views created by flawed understanding or thinking resulted in misconceptions.

Misconception is a complicated term that needed to be thoroughly addressed and explained. Students realised and identified certain electrical misconceptions (mistaken beliefs; incorrect thinking; and inaccurate views) when engaging in the drawing to learn lesson (JE).
I also recognised that a well-constructed diagram limited incorrect thinking (JE).

Larkin and Simon (1987) compared the verbal description of solving physics and maths problems against the benefits of referring to a diagram. They found a diagram that was adequately constructed assisted processability by restricting flawed, inaccurate perceptions, as in Venn diagrams. Sketches and drawings also help unmask certain preconceptions. Fan (2015, p.174) elaborates that “drawings, unlike our private perceptual images, were observable to all. Drawings could be shared; therefore, they could be utilised effectively to facilitate scientific thinking.”

Drawing to learn exposed underlying misconceptions by identifying critical gaps in their knowledge and the need to recognise and be aware of other misconceptions. Taylor (2017) acknowledges that misconceptions occur in how students organise scientific knowledge and their comprehension of scientific methods.

“Students were challenged to explain how the related scientific concept correlated to what was drawn” (OS).

Students were encouraged to discuss their understanding of electrical concepts to ascertain whether their conceptions were correct or amiss. It was important to note that rote learning had to be dismantled. This allowed me, the teacher, to address any identified misconceptions.

Teacher efficacy played a critical role in addressing this. Tytler (2002) defines preconceptions that conflict with scientific opinions as misconceptions. Students’ misconceptions exposed cognitive dissonance, which Corradi, Clarebout and Elen (2015, p.693) describes “as the sense of conflict between external facts and internal thinking processes.” When student’s inaccurate beliefs were challenged, a behavioural change occurred, reducing or eliminating dissonance. When the teacher possesses compelling pedagogical and subject knowledge, the student engages in questioning, makes connections, draws inferences, and validates knowledge from early learning. Systematic organisation of knowledge, argues Chabrak and Craig (2013), aided in consonance. This promoted the teacher from not only understanding students’ common misconceptions but developing correct conceptions. Drawing to learn improved students’ awareness of preconceived misconceptions.

Knowledge deficiency also contributed to inaccurate perceptions or misconceptions. When knowledge is systematically constructed, it is correctly transferred, eliminating misconceptions.

Knowledge was organised and arranged to create a logical path that students could follow. (JE).

Windschitl (2004) contends that PCK probes how to elicit student's conceptions by questioning aspects of student's prior knowledge.

Students identified crucial deficiencies in their learning during the drawing to learn lesson when they identified their misconceptions (JE).

Chang, Liu and Chen (1998) explain that throughout the learning process, students may perform poorly due to deficiencies in knowledge. Drawing to learn improved students' awareness of preconceived misconception which originated from mistaken beliefs, deficient understanding, erroneous thinking and inaccurate views. An adequately constructed diagram restricting flawed, inaccurate perceptions. Students' misconceptions exposed cognitive dissonance which is the conflict about what is factual and inaccurate thinking.

4.6.1.3 Helped students identify critical gaps in their knowledge

The first knowledge gap identified was in the curriculum design. Students were taught how to draw electrical schematics, but there was no clearly defined pedagogical approach to reading and interpreting complex schematics. Instituting a pattern learning approach addressed this shortfall, as seen in the focus group responses from student F.

> *By finding the patterns what was difficult became simple*. Student F. *Yes, pattern learning allowed me a strong foundation. I am sure that I will be able to read more electrical under the guidance of an experienced person* (Student F).

Drawing to learn using patterned learning encouraged higher-order thought. Participants progressed from gaining knowledge to understanding and then applying it. Drawing to learn scaffolded learning to foster analysis and evaluation. Ultimately, it creatively resolved a historical gap in the curriculum design, where students were taught how to draw electrical schematics but not how to interpret them.

Now that you have learnt the skill of interpreting drawings do you think drawing to learn has improved your ability to think and reason?
"Yes, it has improved my thinking. I understand components easily. It has helped me to see the complete circuit" (Student O).

As students started to see the whole (complete) rather than in part, their ability to comprehend the inter-related electrical design would become highly beneficial, especially to fault find, repair and design circuits. Cognitive abilities progressed from knowledge acquisition and understanding to application, analysis and evaluation. (Hanna, 2007; Bruehler, 2018). Addressing misconceptions helped students identify critical gaps in their knowledge.

During the drawing to learn lesson, one of the key misconceptions identified was current flow (JE).

Knowing how to connect an AC circuit was crucial; this enabled students to affix the switch on the live and not the neutral conductor for the practical task.

I also recognised that a diagram that was constructed knowledgeably restricted flawed understanding and incorrect and inaccurate perceptions (JE).

Within the circuit diagrams, the layout also revealed important information of where components would be fixed. If this was not systemised and laid out correctly, students developed inaccurate mind pictures. Did you have challenges with electrical misconceptions before this lesson?
"*Yes I wrongly identified some of the components at home*" (Student E).

Once students understood and recognised electrical misconceptions, their knowledge gaps became pronounced. Inaccurately identified electrical components were corrected, and these knowledge gaps were addressed. Park and Oliver (2008, p.270) argue that PCK enabled teachers "to confront students' misconceptions and stimulate conceptual changes". However, Windschitl (2004) also identified shortcomings in thinking and reasoning by recognising students' limitations of thought processes about concepts and skills.

This study also revealed that drawings aided cognitive reflection. Students realised that they had addressed misconceptions but concluded that there could be many other misconceptions that exist.

Do you have challenges with electrical misconceptions after the lesson?

"*No, I understand what misconceptions are. However, I know that there are other misconceptions that are there"* (Student E).

Helping students develop a reflective approach to their learning enables them to evaluate what they have learnt. Reflection is an essential tool that addresses knowledge gaps. Chang, Liu and Chen (1998) argue that complicated theory is grasped easily when students understand learning fundamentals. PCK is not viewed as knowledge of one single entity in teaching, as alluded to by Moodley and Gaigher (2019), but rather as a sound understanding of all types of knowledge related to how a subject was taught.

The use of the workshop also contributed to addressing knowledge gaps. Students do not easily understand complex concepts due to their tacit nature. Lave and Wenger (1991) reiterate that situated learning is tacit by nature and difficult to transfer through written or verbal means. Tacit knowledge became easily shared when students watched and then undertook the practical task. Knowledge gaps also became pronounced when students shared ideas or thoughts on social media platforms. This study used a WhatsApp chat group to introduce the drawing to learn lesson. Wiggins and McTighe (2006) explain that when students created and openly shared their ideas on a public platform, they also enhanced personal development when what was posted was critiqued against presentation, coherence, content, and clarity. The platform allowed for misconceptions to be addressed.

"As a teacher, this researcher realised how valuable these online portals into student thinking for formative, summative and diagnostic assessments were to address misconceptions" (JE). Fan (2015, p.174) concurred that "drawings, unlike our private perceptual images, were observable to all. Drawings could be shared; therefore, they could be utilised effectively to facilitate scientific thinking."

Drawing to learn helped students identify critical gaps in their knowledge and using patterned learning promoted higher-order thought. Participants progressed from gaining knowledge to understanding and then applying it scaffolding learning to foster analysis and evaluation. It resolved a historical gap in the curriculum design, where students were taught how to draw electrical schematics but not how to interpret them. Drawing to learn helped students develop a reflective approach to their learning and enabled them to evaluate what they had learnt.

4.7 Reflections

In this section, I discuss three key issues that emerged from my reflections as the researcher. The first key reflection was ***ease of mastery***. Kálmán (2017) contends that observations also permit a researcher to examine assumed practical behavioural patterns that might not be noticed. The structured observations disclosed overlooked aspects that the participants did not freely communicate in the focus group discussions or questionnaires. I implemented a new teaching strategy; however, students adopted and adapted new learning strategies. Some students promptly mastered the numbered format technique, whilst others took a little longer, competently completing the task. *"Certain participants quickly mastered the ability to use the numbered pattern within the schematic and complete the practical task; however, others took extra time to complete the task"* (JE).

The second key reflection was ***an effective blended learning platform contributed to enhanced teaching and learning and augmented understanding of the electrical drawings***. Before the implementation of the amended plan, students had encountered many challenges. The teaching plan was revised and implemented. Park and Oliver (2008, p.268) contend that PCK is "knowledge-on-action; that is knowledge elaborated and enacted through reflection-on-action undertaken after the teaching practice is completed." The teacher, through reflection-on-action, modifies, reorganises, or expands their PCK to teach the topic differently after evaluating existing practice. The online component of this study was revised to accommodate challenges encountered by students.

Wiggins and McTighe (2006, p.12) assert that the efficient use of drawings in education and the effective measure of drawings as a tool depends "on the alignment between desired outcomes, assessment, and activities." Teachers need to employ support that will assist students to master the skills required on their own.

Device issues were varied, ranging from old devices, insufficient memory, faulty or *damaged units. These devices were incompatible with a blended learning lesson. Some students also had network issues. Poor reception prevented them from accessing the video lesson. Other students had difficulties acquiring data* (JE).

Roth, Mavin and Dekker (2014, p.522) contend that preference is given to “knowing-of-practice rather than knowing-in-practice in many institutions”. Their research endeavoured to determine how teaching and training are evaluated and enacted, encompassing theory into practice through the relevant experiences.

PCK has both characteristics of “knowledge-in-action and knowledge-on-action.” These two features did not conflict but guided each other through reflection. Action research is founded on reflection in every cycle of its process. Shulman (1986) also points to three distinct ways teaching PCK is influenced by students through knowledge domains, which are significant components of PCK. One of the three ways relevant to this study was implementing instructional strategies based on the students' online challenges and learning difficulties. These changes were addressed by integrating curriculum knowledge, students’ learning difficulties, and assessment strategies. As alluded to by Rollnick et al. (2008, p.1380), my “knowledge of practice” was accomplished by creatively introducing pattern learning. Bucat (2005) contends that PCK is not viewed as knowledge of one single entity in teaching but rather a sound understanding of all types of knowledge related to how a subject is taught.

The blended learning platform contributed to enhancing teaching and learning and augmented understanding of the electrical drawings. Blended learning was preferred instead of only using face to face teaching. Students overwhelmingly approved and were satisfied using the online platform. Student motivation improved in the process of constructing their knowledge. However, most students deemed face to face interaction as vital for teaching and learning, not only with educators but also with their peers (JE).

Table 4.6: The rating scale questionnaire tabulated as percentages

Please tick the appropriate block	% YES	% SOMEWHAT	% UNDECIDED	% NOT REALLY	% NO
Has blended learning enhanced your understanding of the drawing?	100%				
Do you prefer using WhatsApp as an event planner for your lessons?	94%	6%			
Did your chats via WhatsApp help you complete the practical task?	94%	6%			
Do you prefer working cooperatively in a class only without using WhatsApp?		6%			94%
Do you prefer working cooperatively in and out of the class using WhatsApp?	94%		6%		

Banci and Soren (2008) argue that the focus of blended learning has progressed beyond technology to create an effective learning environment. Blended learning was a preferred learning method instead of only using face to face teaching. Said (2008) highlighted the following about blended learning: students overwhelmingly approved and were satisfied using the online platform, student motivation improved in the process of constructing their knowledge and most students deemed face-to-face interaction vital for teaching and learning, not only with teachers but also with their peers.

The third key reflection was ***curriculum saliency***. As the teacher/researcher, schematics in the curriculum and the workplace became crucial for teaching and learning. Although its significance was not acknowledged in the curriculum, my subject matter knowledge (SMK) allowed me to determine its importance in my pedagogy. Rollnick et al. (2008, p.1367) explain that curriculum saliency impacts "decisions to leave out certain aspects of the topic, and in teachers' awareness of how a topic fits into the curriculum".

> *These students are commencing their journey to becoming qualified artisans. Experience is one of the best tutors. Ensuring that this part of the curriculum is more pronounced and magnified will assist them in the world of work. Students must be*

realistic in their expectations to read complicated schematics as their knowledge will increase in time (JE).

4.8 Conclusion

This chapter analysed the data presented, which was clustered into patterns codes and themes. The analysis was undertaken through two conceptual frameworks. Excerpts from the participants were included to give credibility to the research findings and accurately illuminate participants' views.

Data was presented and analysed according to research questions using the following instruments: focus group discussions, a likert scale questionnaire and a structured observation schedule generated from each participant. My reflective journal entries relating to each of these data-generating instruments supplemented and supported the codes and themes, triangulating the data to ensure accuracy in the analysis. Both research questions were analysed using Shulman’s (1986) pedagogical content knowledge (PCK) and Lave and Wenger’s (1991) situated learning theory. Themes that emerged after an inductive analysis for the first research question is that drawing to learn encourages active participation in knowledge construction; improves cognitive processes, simplifies complex explanations and improved teacher and student self-efficacy. Themes that were identified from the second research question is drawing to learn promotes knowledge transfer; improves students’ awareness of preconceived misconceptions and helped students identify critical gaps in their knowledge. Chapter Five that follows discusses the findings, recommendations and conclusion.

CHAPTER FIVE: DISCUSSION, RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

The purpose of this study was to explore the use of drawing to learn as a teaching strategy to improve teaching and learning in NCV Electrical Level 2. In addition, this study examined the extent to which drawing to learn enhances student's interpretation and understanding of electrical schematics. This study also explored how students' misconceptions of electrical circuits contributed to their struggle to interpret and understand electrical drawings. In this chapter, the data presented in Chapter Four is discussed by addressing the research questions of the study and elaborating how the data is analysed, interpreted and connected to the conceptual frameworks and the related literature. A summary of the key findings is then presented, followed by the limitations of the study and the recommendations for further research. The chapter is then concluded with the researcher's final reflection.

This study aimed to address the following research questions:

1. How does introducing a drawing to learn teaching strategy using patterns improve teaching and learning in NCV Electrical Level 2?
2. To what extent does drawing to learn using patterns address student misconceptions of electrical circuits?

The research utilised two conceptual frameworks namely, pedagogical content knowledge and situated learning to analyse both research questions.

5.2 Discussion

The discussion that follows outlines the key findings of the study in relation to the two research questions.

5.2.1 Analysis of research question 1:

How does introducing a drawing to learn teaching strategy using patterns improve teaching and learning in NCV Electrical Level 2?

Drawing to learn encouraged ***active participation in knowledge construction***. This new teaching strategy was implemented and elicited various responses from the participants. Initially, some students seemed confused with drawing to learn and learning to draw. They assumed it was the same. As the lesson unravelled and the concept became clear, student understanding of this new strategy improved. One of the principal codes emanating from the focus group discussions was that drawing to learn helped participants extract knowledgeable information from the circuit diagram to connect schematics accurately.

As students started to engage with this alternate teaching and learning style, they recognised the learning benefits of drawing to learn. Students transitioned from rote learning to knowledge construction. Students utilised conceptual thinking, developing an understanding of why they were undertaking the task. Ainsworth, Prain and Tytler (2011) contend that visual modes play a critical role in knowledge construction in addition to talking, reading, and writing. They identified that student's perceptions were expanded and deepened, especially when working with graphs. Bucat (2005, p.11) argues that drawing to learn helped unravel "learning demands inherent in the subject matter" as the lesson evolved into a synergistic tryst of subject knowledge, pedagogical knowledge and curricular knowledge. Students identified symbols that represented components; thus, applying insight, they started to think abstractly, constructing a parts list from the picture of what the drawing entailed. Van Meter (2001) advocates this concept of mental models created from thought recall instead of lower-order learning, where students engage in recognition by memorisation. Tempelman and Pilot (2011, p.262) explain that these models synthesise theory and practice, helping students utilise "facts, theories and insights into their design projects".

The participants found that theory is better learnt and understood when applied in practice. Baldwin and Crawford (2010, as cited in Quillin & Thomas, 2015) argue that practical tasks promote instinctive curiosity. Through personal endeavours, exploring phenomena became natural and progressive, rather than coercive, and assisted in memorisation. To determine competence, participants engaged in a practical task. Both the teacher and the student evaluated knowledge construction through the summative assessment task. Students chose components to undertake the practical task at a workstation based on a generated parts list (Huth et al., 2017). As knowledge and understanding grew, conceptual knowledge developed. Knowledge construction and competence were evaluated through this summative task. Clancey (1995, p.49) emphasises that "knowledge is dynamically constructed" when activities are conceptualised in a given environment through situated learning. Kind (2009, p.174), adapting Shulman's theories, contends "that PCK comprises two components: instructional strategies and learning difficulties". Drawing to learn encouraged active participation in knowledge construction and addressed both issues and improved "understanding of experiments; problem-solving, processing of data and related concepts into a complete picture aiding in learning content knowledge”. (Quillin& Thomas, 2015, p.5). **When electrical schematics are taught using proper conceptual tools, participatory knowledge construction becomes pronounced.**

Another significant observation made from the data generated was ***drawing to learn improved cognitive processes*** such as critical thinking, awareness, and reasoning. Visual literacy occurred when students transitioned from learning to draw to drawing to learn. Students attached meaning to schematic components, thus transferring knowledge from the pictorial to the physical application. Quillin and Thomas (2015, p.2) contend that “visual literacy” is the ability and aptitude of students to explain ideas presented by teachers, likewise to craft, construct and create “visual representations” by themselves. The learning structure became implicit in the experience rather than in the subject matter only (Contu &Willmott, 2003).

Students prepared a parts list from the circuit diagram using intellectual intuition (to think, reason, recognise and understand). Students started to identify components from the schematic correctly. To do this, they had to recognise and attach meaning to the components accurately (Lave &Wenger, 1991; Stein & Clearinghouse, 1998). One of the vital aspects of this research was determining if this teaching strategy improved understanding. Understanding and comprehension is a cognitive process in learning and, when attained, should permanently change behaviour (Johnson-Laird, 1983; Jong, 2010). Fan (2015) concurs and states that the most rudimentary visualisation skill, drawing, assimilates with cognitive functions fundamental to scientific rationale. When participants read and understood the schematic, visual literacy occurred. Visual literacy assisted students in cognitive activation. Ergönenç, Neuman and Fischer (2014) argue that PCK promotes cognitive activation and similarly drawing to learn improved mental process such as critical thinking, awareness and reasoning. Burge, Lenkeit and Sizmur (2015, p.2) contend that:

> Cognitive activation encourages pupils to think more deeply to find solutions and focus on the method they use to reach the answer rather than simply focusing on the answer itself. Making connections between… facts, procedures and ideas, will result in enhanced learning and a deeper understanding of the concepts.

As alluded to by Dehaene et al. (2015), patterns created a perception of order in what appeared chaotic, which fostered and developed vital logic and critical thinking.

Konovalov and Krajbich (2018) contend that in comprehending patterns, students grasp scientific relationships using graphs, charts, tables and drawings during the process of analysing data and solving complex scientific problems. Mor et al. (2014) argue that the capacity to distinguish, create and recognise patterns assists in the fabrication of predictions from observations.

Larkin and Simon (1987) argue that drawings facilitate cognition that relieves the working memory load by absolving it to keep track of the different factors relating to the problem. Cognitive abilities progressed from knowledge acquisition, understanding and application to analyses, evaluation and creation (Hanna, 2007; Bruehler, 2018). This method of teaching and learning developed student's mental pictures. Students predicted schematic outcomes better once they identified patterns. Participants, through patterned learning, could formulate knowledgeable, educated deductions while learning. Electrical drawings are complicated and complex. Pattern learning was used to unravel the complications of circuit diagrams. It can be applied to teaching and learning in all subjects. It assists by fostering vital logic and critical thinking skills, integrating focal ideas with ideas from other domains, alludes Windschitl (2004). This teaching strategy using pattern learning improved student's **cognitive processes** and helped them learn intricate, complex numbering concepts through the implementation of **drawing to learn.**

Drawing to learn ***simplifies complex explanations***. When students identified patterns, they grasped complex concepts effortlessly. Drawing to learn simplified complex explanations and provoked students' participation in active knowledge construction. Students were presented with the basic idea first. Detailed complex information was progressively disclosed. The ability to build from the simple to the complex developed schemas and mental models in student's minds. When mind pictures were fully developed, it became easier to express ideas and thoughts through drawings than through words. The medium of instruction at our institution is English, which is not the mother tongue for most students. This communication barrier students encountered was overcome using drawings to communicate ideas and thoughts. For students, understanding electrical drawings created mind maps that simplified complicated explanations. Drawing circuit diagrams assisted students to translate complex scientific terms into simple perceptual tasks. It has become an acceptable norm to mark students' drawings as an alternative to a written answer in engineering examinations.

When students identified patterns, they grasped complex concepts quickly. Pattern learning simplified complex electrical drawings and assisted to develop predictions from observations. Students were shown that diagrams could be used alternatively to complicated theory. On the other hand, schematics contained immense information, which is easier to recall than writing up a theory explanation. A circuit diagram contains large amounts of implicit knowledge and extracting or explaining that information from memory recall is easier than rote learning large amounts of theory. Thus, drawing to learn simplifies complex explanations.

Larkin and Simon (1987) corroborated that diagrams enable reasoning by translating gruelling computational techniques into simple perceptual tasks. Quillin and Thomas (2015, p.2) concur that "there is a vast difference between knowing about [schematics] (content knowledge) and knowledge about the teaching and learning of [understanding schematics] (PCK)."
The ability to see the whole rather than in part contextualised learning (Contu & Willmott, 2003). When knowledge was constructed from the simple to the complex, complicated explanations were simplified. Students cognitively developed mind pictures and drawing circuit diagrams assisted students to translate complex scientific terms into simple perceptual tasks. Adams (2017) asserts that drawing was both a process and a product, and students' capabilities were evaluated through performance, corroborated by their achievements. **Drawing to learn enhanced visual perception, simplifying complex perceptual tasks.**

Drawing to learn ***improved teacher's and students' self-efficacy***. When students realised how simple it was to apply pattern learning to the schematic, their confidence improved dramatically. The simplicity of the teaching style enabled rapid learning application. Burge, Lenkeit and Sizmur (2015) called this cognitive activation. Cognitive activation distinctly correlates to self-efficacy. Burge, Lenkeit and Sizmur (2015, p.2) state that cognitive activation is:

> [a]bout teaching pupils strategies, such as summarising, questioning and predicting, which they can call upon when solving maths problems. Such strategies encourage pupils to think more deeply, find solutions, and focus on the method they use to reach the answer rather than simply focusing on the answer itself.

When the focus was changed from what to why perceptions changed, drawing to learn using a patterned learning approach improved teachers' and students' self-efficacy, which positively contributed to their performance. Any negative perceptions toward drawings, especially schematics, diminished as self-efficacy improved. Drawing to learn enabled students to extract knowledgeable information from the circuit diagram to connect the schematic accurately. Quillin and Thomas (2015) argue that through drawings, students could think more explicitly and expressly. This improved their ability to communicate, clarify and exchange concepts or ideas among their peers. I also noted that the visual component of communication was part of verbal, written, graphic and symbolic illustrations. A student must excel in all four forms of communication to navigate engineering concepts successfully. Identifying patterns in the circuit diagram assisted in comprehending the drawings. Jones, Stewart, and Power (1999, p.2) contend that “patterns are a way of recording the knowledge of experienced practitioners, best practice and lessons learned.” It was observed that when students identified patterns, it enhanced comprehension.

Park and Oliver (2008, p.271) argue that PCK is fostered “through enhanced teacher efficacy” if the teaching experience was successfully undertaken. Windschitl (2004) asserts that PCK combines multiple instruction forms for an improved teaching and learning experience. In implementing a drawing to learn teaching and learning strategy, teaching efficacy improved. One way of measuring teacher efficacy was to determine how new and existing knowledge was organised and integrated.

By identifying patterns in the drawing to learn teaching strategy, students became more confident to read the circuit diagram and undertake the practical task. This additional teaching strategy has increased my teaching repertoire and will be included in my pedagogy. When shown more complicated schematics, some students were keen to attempt connecting them. However, they will need assistance as they navigate through more complex circuit diagrams. Self-efficacy improved significantly, and this was confirmed by the enthusiasm participants displayed in attempting to engage with more complicated circuit diagrams. Bandura (1988) contends that self-efficacy is the conviction of an individual to meet the expected behaviour, thus successfully achieving their goals. However, Eny (2015, p.391) argues that self-efficacy “mediates between the teachers’ knowledge of instructional strategies of science teaching and students’ understanding of scientific knowledge. The relationship between self-efficacy and cognitive knowledge of PCK shows the relationship is mutually beneficial.” The development of cognitive knowledge through the practical application of PCK through drawing to learn improved student and teacher self-efficacy. **Self-efficacy equilibrium was balanced and evaluated against student understanding of knowledge and teacher knowledge of instructional strategies**.

5.2.2 Analysis of research question 2:

To what extent does drawing to learn using patterns address student misconceptions of electrical circuits?

Drawing to learn ***promoted knowledge transfer*** correcting erroneous and improper thinking. Knowledge transfer through the use of a practical task occurred correctly, effortlessly and not erroneously. Students attached meaning to schematic symbols and transferred pictorial knowledge to the physical application. Students read and interpreted the circuit diagram and connected the schematic accurately; thus, drawing to learn enabled students to extract information to undertake the task accurately and knowledgeably. For knowledge to be transferred correctly, knowledge needed to be systemised. I organised and arranged knowledge by creating a logical path that students could follow. Students commenced drawing the schematic and then inserted the pattern, generated a parts list and then connected the components in a practical task. Barnett and Ceci (2002) contend that knowledge transfer occurs cognitively when a student masters an assignment in one context and can apply that knowledge in several other settings. Manfredi et al. (2019. p.1336) assert that knowledge transfer was not only about replication of it but "rather, it involves the modification of some existing knowledge to a different context and "what is transferred is (usually) not the underlying knowledge but rather applications of this knowledge in the form of solutions to specific problems". The transfer of knowledge outside original learning environments has often been deemed a hallmark of authentic learning (Barnett & Ceci, 2002; Manfredi et al., 2019).

For this study, I engaged a conceptual approach to learning that encouraged students to practice skills. The practical task stimulated thought-provoking curiosity and enjoyment and encouraged rigorous thinking for test preparations. Practical activities, argue Ainsworth, Prain, and Tytler (2011), also teach skills and enhance scientific intelligence acquisition, which teachers can promote through assessments and class activities. However, Hofstein and Kind (2012, as cited in Abrahams, Reiss & Sharpe, 2013, p.2), argue that "there is a need to acquire appropriate and meaningful guidance for practical work". Contu and Wilmot (2003) concur that situated learning is transformative. Clancey (1995, p.49) elaborate how through situated learning, "knowledge is dynamically constructed," as activities are conceptualised in a given environment.

In introducing drawing to learn as an innovative teaching and learning strategy, I endeavoured to reignite a proactive approach to learning from students (Grossman, 1990; Magnusson, Krajcik & Borko, 1999). Ainsworth, Prain, and Tytler (2011, p.1096) argue that “Many students lost interest in science because they were forced to adopt passive roles”. This was a result of traditional teaching methods, rote learning and poor transfer of knowledge. Progressive teachers promote enquiry and more interactive based learning. Manfredi et al. (2019, p.1336) argue that “Tacit knowledge in arts and crafts organisations is hard to articulate and requires observation, demonstration, and experience for its transfer.” However, Windschitl (2004) argues that PCK scaffolded the reasoning process assisting students in transferring accurate scientific ideas and concepts. Electrical drawings are complicated and complex; however, as students identified patterns, they could see a logical order in what appears chaotic. This promoted important logic and critical thinking skills to transfer knowledge. Drawing to learn facilitated knowledge transfer which corrected erroneous and improper thinking. **When knowledge is systemised by organising, arranging and creating a logical yet functional path that students can follow, knowledge is effectively transferred.**

Drawing to learn ***improved students' awareness of preconceived misconceptions***. Drawing to learn exposed underlying misconceptions. Unmasking electrical misconceptions by correctly drawing, reading and interpreting electrical schematics was not easy initially; however, when recognised, it completely changed student perceptions. Electrical misconceptions originate from mistaken beliefs, lacking understanding, incorrect thinking and inaccurate views. Factors that influenced misconceptions were lack of knowledge, curriculum design, culture, background, gender, language, and cognitive perspectives. (Sencar & Eryilmaz, 2004; Rollnick, Bennett et al., 2008). Misconception was a complicated term that needed to be thoroughly addressed and explained. Students realised and identified their misconceptions (mistaken beliefs, incorrect thinking, and inaccurate views) when engaging in the drawing to learn lesson. I also recognised that a well-constructed diagram limited incorrect thinking. Sketches and drawings also help unmask certain preconceptions.

Students' misconceptions exposed cognitive dissonance, which Corradi, Clarebout and Elen (2015, p.693) describes “as the sense of conflict between external facts and internal thinking processes.” When student's inaccurate beliefs were challenged, a behavioural change occurred, reducing or eliminating dissonance. Systematic organisation of knowledge argues Chabrak and Craig (2013), aided in consonance. Taylor (2017) acknowledges that misconceptions occur in how students organise scientific knowledge and their comprehension of scientific methods. Students were challenged to explain how the related scientific concept correlated to what was drawn. Students were encouraged to discuss their understanding of electrical concepts to comprehend whether their conceptions were correct or amiss. It was important to note that rote learning had to be dismantled. Teacher efficacy played a critical role in addressing this. When a teacher possesses compelling pedagogical and subject knowledge, the student engages in questioning, makes connections, draws inferences, and validates knowledge from early learning. This promoted the teacher from not only understanding students' common misconceptions but developing correct conceptions. Knowledge was organised and arranged to create a logical path that students could follow. Windschitl (2004) contends that PCK probes how to elicit student's conceptions by questioning aspects of students' prior knowledge. Students identified crucial deficiencies in their learning during the drawing to learn lesson when they recognised their misconceptions. **The drawing to learn teaching strategy developed into a problem-solving tool that simplified complicated processes and unmasked electrical misconceptions by addressing dissonance.**

Drawing to learn helped ***students identify critical gaps in their knowledge***. Instituting a pattern learning approach addressed the critical gap in the curriculum design. Students were taught how to draw electrical schematics, but there was no clearly defined pedagogical approach to reading and interpreting complex schematics. Drawing to learn using patterned learning encouraged higher-order thought. Participants progressed from gaining knowledge to understanding and then applying it. Drawing to learn scaffolded learning to foster analysis and evaluation. As students started to see the whole (complete) rather than in part, their ability to comprehend the inter-related electrical design would become highly beneficial, especially to fault find, repair and design circuits. Cognitive abilities progressed from knowledge acquisition and understanding to application, analysis and evaluation. (Hanna, 2007; Bruehler, 2018). Addressing misconceptions helped students identify critical gaps in their knowledge.

During the drawing to learn lesson, one of the main misconceptions identified was current flow. Knowing how to connect an AC circuit was crucial; this enabled students to affix the switch on the live and not the neutral conductor for the practical task. I also recognised that a diagram that was constructed knowledgeably restricted flawed understanding and incorrect and inaccurate perceptions. Within the circuit diagrams, the layout also revealed important information of where components would be fixed. If this was not systemised and laid out correctly, students developed inaccurate mind pictures.

Once students understood and recognised electrical misconceptions, their knowledge gaps became pronounced. Inaccurately identified electrical components were corrected, and these knowledge gaps addressed. Park and Oliver (2008, p.270) argue that PCK enabled teachers "to confront students' misconceptions and stimulate conceptual changes." However, Windschitl (2004) also identified shortcomings in thinking and reasoning by recognising students' limitations of thought processes about concepts and skills. This study also revealed that drawings aided cognitive reflection. Students realised that they had addressed misconceptions but concluded that there could be many other misconceptions that exist. Helping students develop a reflective approach to their learning enables them to evaluate what they had learnt. Reflection is an essential tool that addressed knowledge gaps. Chang, Liu and Chen (1998) argue that complicated theory is grasped easily when students understand learning fundamentals. PCK is not viewed as knowledge of one single entity in teaching, as alluded to by Moodley and Gaigher (2019), but rather a sound understanding of all types of knowledge related to how a subject was taught.

The use of a practical task also contributed to addressing knowledge gaps. Students do not easily understand complex concepts due to their tacit nature; however, they grasped the theory component of the lesson effortlessly by participating in a practical activity, eliminating knowledge gaps. Lave and Wenger (1991) reiterate that situated learning is tacit by nature and difficult to transfer through written or verbal means. Knowledge gaps also became pronounced when students shared ideas or thoughts on social media platforms. This study used a WhatsApp chat group to introduce the drawing to learn lesson. The platform allowed for misconceptions to be addressed. As a teacher/researcher, I realised how valuable these online portals were to student thinking for formative, summative, and diagnostic assessments to address misconceptions. **Lecturers' PCK must include structures that promote knowledge acquisition, reflection, evaluation, application and creation, addressing misconceptions thus reducing knowledge gaps.**

5.3 Methodological contributions of action research

Newsome (2016) argues that the research design significantly impacts the study's findings forming a stable foundation for the complete study. This action research study examined how drawing to learn as an alternative teaching strategy enhanced the interpretation and understanding of electrical drawings. These are the contributions and the value of action research as highlighted in this study.

As suggested by Coghlan and Brannick (2010), action research persuaded me as the researcher to comprehensively explore all aspects of the problem. This research study prompted a detailed analysis of electrical schematics in the NCV electrical syllabus. The syllabus contained numerous electrical drawings with additional schematics to undertake practical assignments, evaluated as summative tasks. The students' final practical examination at level three and four are based on complicated electrical schematics. The curriculum includes simple to complex circuit diagrams, which students need to know for their final examination. However, the NCV curriculum does not conceptualise this essential aspect of teaching and learning. Shulman (1987) contends that there is no clearly defined pedagogical transfer of this knowledge. Teachers must identify teaching strategies to transmit this knowledge to students (Smith et al., 2007; Stein & Clearinghouse, 1998). Reading and understanding circuit diagrams is a vital component of any good electrician's repertoire. Many students rote learnt schematics for exam purposes without understanding what they had drawn (Tempelman & Pilot, 2011; Thulasiraman, 2003). This study addresses this pedagogical gap.

This action research study examined how students engaged in this new teaching strategy and whether it improved their cognition. It also examined how student's misconceptions of electrical circuits contributed to their struggle to interpret and understand electrical drawings. This action research study offered an alternative teaching method to improve students' conceptual learning practices significantly. The effectiveness of this alternate drawing to learn teaching strategy has been empirically tested for the first time in a TVET college in South Africa, highlighting the significance of this study. This action research study contributed to best practices, improving professionalism, and other teachers can use the findings to improve teaching and learning in vocational education.

Action research aided in professionalising teaching, and this study compelled me to systematically and reflectively collect data on my pedagogy to promote improvement and continuous growth. My lessons were investigated empirically, and each day's findings informed the following lesson; thus, mastery of teaching developed exponentially (Creswell, 2014; Koshy, Koshy & Waterman, 2011). My strengths as a reflective practitioner improved by researching my practice, which helped students accomplish learning objectives (Dreyer, 2015; Ergönenç et al., 2014). In this study, as alluded by Hanna (2007), PCK included structures that promoted knowledge acquisition, reflection, evaluation, application and creation. Practical tasks in conjunction with an alternative teaching strategy addressed misconceptions, thus reducing knowledge gaps.

Action research, argues Creswell (2014), contributed to building a culture of professionalism. This action research study created awareness of collaboration. For the campus to develop into an institution of excellence, all lecturers within the division should study their practice collaboratively to promote programme development. If faculty and teachers choose an issue to action research, progress on important learning programme improvements and team building will undoubtedly become an achieved shared goal (Craig, 2009; Elliott, 1991; Ferrance, 2000). One of the primary faculty goals, contends Bakaeen (2012), is to develop a well-educated student. However, teachers may differ on aspects of the shared vision on how to accomplish this goal. Dunn, Lyman and Marx concur (2003) that teachers can engage in independent research agendas, share research findings with colleagues of all specialities, and transform themselves into learning communities. When classroom issues teachers face are dialogued, wiser professional decisions are made (Koshy, Koshy & Waterman, 2011; Fay et al., 2010; Craig, 2009).

Action research, asserts Creswell (2014), promotes a systemised form of professional practice enhancing teacher motivation and efficacy. Action research helped identify the problem reflectively, design a plan, action the plan, reflect on the actioned component and capture the learning (Kemmis, 2006; Jugoo, 2014). The demands of teaching have grown exponentially, with teachers required to do more with less. Cohen, Manion and Morrison (2007) contend that action research offers the teacher the opportunity to evaluate their practice in a structured manner. It investigates how effective teaching and learning are conducted amongst students, teachers and the institution. Koshy, Koshy and Waterman (2011) concur that it positively contributes to improved teaching and learning when teachers integrate data into their work. For teachers, compelling data on effective practice becomes a significant energising influence. Self-efficacy equilibrium was balanced and evaluated against student understanding of knowledge and teacher knowledge of instructional strategies (Ledwith, 2007; Macintyre, 2000; McKernan, 1991).

McKernan (1991) contends that action research investigated teacher practice and promoted knowledge construction by implementing new teaching methods to replace traditional ones. Craig (2009) argues that good teaching practice aids in knowledge construction. Huth et al.

(2017) concur that students transitioned from rote to conceptualised learning through this teaching strategy. Participants constructed knowledge through comprehension, application, analysis, evaluation and creation (Jong, 2010; Johnson-Laird, 1983). Electrical schematics were taught using proper conceptual tools; consequently, participatory knowledge construction became pronounced. Kind (2009) contends that this cognitive teaching strategy using pattern learning helped students learn intricate, complex numbering concepts by implementing drawing to learn. Electrical drawings contend Larkin and Simon (1987), enhanced visual perception and simplified complex perceptual tasks. Using a practical task in conjunction with an alternative teaching strategy addressed misconceptions, reduced knowledge gaps and promoted conceptualisation through situated learning (Lave & Wenger, 1991; Contu & Willmott, 2003).

Action research fostered a deeper understanding of student challenges and methods to overcome them. Patterns became the 'hook' that drew participants into the challenging concept taught. When students identified patterns, argue Dehaene et al. (2015), they grasped complex concepts quickly. The ability to build from the simple to the complex contends Fan (2015), developed schemas and mental models in students' minds. Electrical misconceptions that originated from mistaken beliefs lacking understanding, incorrect thinking and inaccurate views were addressed through this study. Through action research, argues Elliott (1991), factors that influenced misconceptions were identified and addressed. For knowledge to be transferred correctly, knowledge needed to be systemised. In this study, knowledge was organised and arranged by creating a logical path that students could follow (Manfredi et al., 2019; Millar, 2004). Knowledge transfer, contends Mohler (2007), occurred cognitively when students mastered an assignment in one context and then applied that knowledge in several other settings.

Action research empowered both teachers and students. Student's active participation in knowledge construction through an alternative teaching strategy empowered the teacher (Mor et al., 2014; Muijs, 2006). Cognitive abilities, argue Tempelman and Pilot (2011), progressed from knowledge acquisition and understanding to application, analysis and evaluation. Chabrak and Craig (2013) contend that when students' inaccurate beliefs were challenged, behavioural change occurred, reducing or eliminating dissonance and emancipating their thinking.

5.4 Summary of key findings

When electrical schematics are taught using proper conceptual tools, participatory knowledge construction becomes pronounced. This cognitive teaching strategy using pattern learning aided students to learn intricate, complex numbering concepts through the implementation of drawing to learn. Electrical drawings enhanced visual perception, simplifying complex perceptual tasks. Self-efficacy was evaluated against student understanding of knowledge and teacher knowledge of instructional strategies. When knowledge is systemised by organising, arranging and creating a logical yet functional path that students can follow, knowledge is effectively transferred. The drawing to learn teaching strategy developed into a problem-solving tool that simplified complicated processes and unmasked electrical misconceptions by addressing dissonance. Effective PCK promotes knowledge acquisition, reflection, evaluation, application and creation, addressing misconceptions, thus reducing knowledge gaps.

The researcher highlighted the following three key reflections. The first was the ease of mastery which was noticed among several students as they engaged in this new teaching strategy. As students adopted and adapted to this new strategy, some students promptly mastered the numbered format technique, whilst others took a little longer still competently completing the task. Also, emanating from this study was that an effective blended learning platform contributed to enhanced teaching and learning and augmented understanding of the electrical drawings. Curriculum saliency, the third key reflection, related to the teacher's awareness of how vital a topic is to the curriculum. Reading and understanding electrical schematics is crucial for a competent electrician. Although its significance was not clearly acknowledged in the curriculum, my subject matter knowledge (SMK) allowed me to determine its importance in my pedagogy.

5.5 Limitations of the study

The study involved a small sample of 18 students that were conveniently selected from an NCV Electrical Level 2 class from one of fifty-two colleges and were not representative of all students participating in this programme nationally. The calibre of the participants was unique to this class and could have consisted of bright, intuitive students with no significant learning challenges or deficiencies. These issues of internal validity could have been different with another group of participants.

The originality value of using pattern learning to improve reading, understanding and interpretation of electrical schematics cognitively must be stressed as no other similar empirical studies were found within TVET. Most empirical studies on drawings and schematics focused on schools and not vocational education, warranting more research. This study was dependable, credible, confirmable and transferable only to other similar contexts, and the findings cannot be generalised. Although minimised, the Hawthorne effect cannot be ignored since it was a class of my students. As the teacher /researcher, I did participate in the lesson and it is possible that influenced this study as my role was not neutral.

5.6 Conclusions of the Study

Most students can draw; however, they rote learn circuit diagrams for examination purposes because they were inadequately trained to read and interpret schematics. Drawing to learn as a teaching strategy improved teaching and learning at a Technical Vocational Education and Training College. Drawing to learn rather than learning to draw enhanced students' interpretation and understanding of electrical schematics using a patterned learning format. Drawing to learn addressed electrical misconceptions, the focus was on drawing as a product of the learning process. Proper conceptual tools aided knowledge construction and a cognitive teaching strategy using pattern learning helped students learn intricate and complex numbering concepts by implementing drawing to learn. Electrical drawings enhanced visual awareness and simplifying perceptual tasks. Self-efficacy was evaluated against student understanding of knowledge and teacher knowledge of instructional strategies. Systemised knowledge is effectively transferred by creating a logical and functional path that students can follow. The drawing to learn teaching strategy simplified complicated processes and unmasked electrical misconceptions by addressing dissonance.

5.7 Recommendations for further research

There is a dearth of empirical studies using pattern learning within a drawing to learn teaching strategy in Electrical Engineering at TVET colleges, and therefore, more research is warranted in this area of study. The whole idea of action research is to improve and critically evaluate your practice. As an action researcher, I reflected on the single cycle engaged, and although the research conclusively found the implementation of this alternate teaching strategy successful, I encountered challenges and problems. The implementation of the blended learning platform was problematic. Many of the implementation issues detailed in Chapter Three can be addressed. DHET has commenced issuing TVET students with laptops. Due to the restrictions of Covid-19, this could not be implemented. Further research using a pattern format in other subjects like physical science or mathematics should be explored. Most empirical studies on drawings and schematics focused on schools and not vocational education, suggesting that more research in this field is needed.Electrical schematics must be taught using proper conceptual tools and implementing new and innovative teaching strategies like drawing to learn using pattern learning will develop students' cognitive abilities. Practical activities should be conceptualised and contextualised to enhance knowledge construction. The curriculum needs to be revised to address the gap in teaching students to read and interpret electrical schematics. Visual literacy must be evaluated and assessed by teachers with these assessments mandated through the revised curriculum. Teachers must systemise knowledge by organising, arranging and creating a logical yet functional path that students can follow.

5.8 Conclusion

The purpose of this study was to explore the use of drawing to learn as a teaching strategy to improve teaching and learning in NCV Electrical Level 2. In addition, the study examined the extent to which drawing to learn enhances student's interpretation and understanding of electrical schematics. Many TVET students were prone to learn how to draw electrical schematics for examination purposes; unfortunately, they could not interpret what they drew. Drawing to learn using a patterned format was introduced and helped to anchor complex abstract knowledge into student's long-term memory, promoting meaningful conceptual understanding.

As I laboured to navigate my way through this thesis what commenced as a labour of pain slowly transformed into a "labour of love," as described by Grant and Osanloo (2014, p.12), demanding "much work, sweat, and tears". I challenged myself that this will not be just an exercise to attain a qualification but rather the unfolding of an imperceptible yet conspicuous moment in my life. I endeavoured to "write something worth reading or do something worth writing," as alluded to by Franklin (1737).

Most STEM teachers are not aware that "drawing is a science process skill," as stated by Quillin and Thomas (2015, p.13).This study has shown that when electrical schematics are taught using proper conceptual tools, knowledge is constructed, and aided in learning intricate, complex numbering concepts. Electrical drawings enhanced visual perception, simplifying complex perceptual tasks. Self-efficacy was evaluated against student understanding of knowledge and teacher knowledge of instructional strategies. Systemised teaching unmasked misconceptions and simply created a path to effectively transfer knowledge. Effective PCK promotes knowledge acquisition, reflection, evaluation, application and creation, addressing misconceptions, thus reducing knowledge gaps. Solid conceptual teaching strategies can dismantle outdated methodologies and assist students to improve cognition and grasp tacit knowledge effectively.

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APPENDICES:

Appendix 1 Letter to the campus manager

Appendix 1A: Letter to the Campus Manageress

20 Larkspur Rd
Northdale
Pietermaritzburg
3201
1 June 2019

Dear Ms., Selepe

My name is Mark Sanjeevy (Student No. 213569811) a Masters in Education (MEd) student in the School of Education at the University of KwaZulu-Natal (Pietermaritzburg campus). As part of the requirement for this degree, I am required to conduct a research project. The title of my research study is: **Using drawing to learn as an alternate teaching strategy to enhance interpretation and understanding of electrical drawings in my NCV electrical class.**

The aim and purpose of this research study is to examine ways to improve interpretation of electrical schematics. This study is expected to use 21 participants who are learners in NCV Level 2 and will involve the following procedures. As participants, students will be observed during a practical lesson. Learners will be required to complete Likert scale questionnaires and participate in focus group discussions. These discussions are expected to last between 20 to 30 minutes and will not disrupt teaching and learning. Follow-up discussions may be conducted if necessary. All focus group discussions will be voice-recorded. The duration of the research will be 2-4 weeks. Data will be generated through focus group discussions, a Likert scale questionnaire, observations and WhatsApp as a social media platform.

This study will not involve any risks and/or discomfort to the institution and participants. Also, the study will not provide direct benefits to the institution or participants. I will be implementing a new teaching strategy as an intervention which could enhance teaching and learning.

In the event of any problems, concerns or questions you may contact me, my supervisor or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

My contact details

Email: marksanjeevy@gmail.com Cell: 0834640856

Supervisor

Dr J. Naidoo

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Participation in this research study is voluntary and learners may withdraw participation at any point. In the event of refusal/withdrawal of participation learners will not be penalised. There are no consequences for learners if they withdraw from the study.
No costs will be incurred by learners as a result of participation in the study and there are no incentives or reimbursements for participation in the study.
All names of institutions and participants will be changed, and pseudonyms will be used so that participants remain anonymous. Information provided by learners will remain confidential and will not be shared with anyone else. Data generated through lesson observations, questionnaires and focused group discussions will be stored in my supervisor's office, at the School of Education, Pietermaritzburg campus for five years, and thereafter destroyed.
Yours in Education

Mark Sanjeevy

DECLARATION OF CONSENT

I Olpha N. Selepe (Full names of the campus manageress) have been informed about the study entitled: **Using drawing to learn as an alternate teaching strategy to enhance interpretation and understanding of electrical drawings in my NCV electrical class. Undertaken by Mark Sanjeevy.**

I understand the purpose and procedures of the study.

[redacted] MANAGERESS

01/06/2019
DATE

Appendix 2: Letter to Participant.

20 Larkspur Rd
Northdale
Pietermaritzburg
3201
1 May 2019

Dear Participant

REQUEST FOR PARTICIPATION IN RESEARCH PROJECT

My name is Mark Sanjeevy (Student No. 213569811) a Master's in Education (MEd) student in the School of Education at the University of KwaZulu-Natal (Pietermaritzburg campus). As part of the requirement for this degree, I am required to conducting a research project. I request your assistance in this research project by being a participant in this research study. The title of my research is: **Using drawing to learn as an alternate teaching strategy to enhance interpretation and understanding of electrical drawings in my NCV electrical class.**

The aim and purpose of this research study are to examine ways to improve the interpretation of electrical schematics. This study is expected to use 21 participants who are students in NCV Level 3 and will involve the following procedures. As participants, students will be observed during lessons as a data generation method. Students will be required to complete likert scale questionnaires or participate in focus group discussions, that is expected to last between 20 to 40 minutes at a time suitable to them which will not disturb teaching and learning. Follow-up discussions may be conducted if necessary. All focus group discussions will be voice-recorded. The duration of their participation, if they choose to participate and remain in the study, is expected to be 4-6 weeks. Data will be generated through focus group discussions, a likert scale questionnaire, observations and WhatsApp as the social media platform.This study will not involve any risks or discomfort to students. Also, the study will not provide direct benefits for students. I will be implementing a new teaching strategy as an intervention which could assist instudent's learning and understanding.

In the event of any problems or concerns/questions, you may contact me, my supervisor or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

My contact number 0834640856

Email: Email: marksanjeevy@gmail.com Cell:[redacted]

Supervisor: My supervisor is Dr J. Naidoo, who is located at the School of Education, Pietermaritzburg campus of the University of KwaZulu-Natal.

Telephone 033 260 5867, Email address: naidooj@ukzn.ac.za

UKZN Research Office

Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za

Participation in this research study is voluntary, and students may withdraw participation at any point. In the event of refusal/withdrawal of participation, students will not be penalised. There are no consequences for students if they withdraw from the study.
Students will incur no costs as a result of participation in the study, and there are no incentives or reimbursements for participation in the study.
All names of schools and participants will be changed, and pseudonyms will be used so that schools and participants remain anonymous. Information provided by students will remain confidential and will not be shared with anyone else. Data generated through lesson observations, questionnaires and semi-structured interviews will be stored in my supervisor's office, at the School of Education, Pietermaritzburg campus for five years, and after that be destroyed.Thank you for your cooperation.
Yours in Education

Mark Sanjeevy

DECLARATION OF CONSENT

I, ____ (Name of student) have been informed about the study entitled: **Using drawing to learn as an alternate teaching strategy to enhance interpretation and understanding of electrical drawings in my NCV electrical class** by Mark Sanjeevy
I understand the purpose and procedures of the study.
I have been allowed to ask questions about the study and have had answers to my satisfaction.
I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.
If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher at (0834640856).
If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers, then I may contact:
HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557 - Fax: 27 31 2604609
Email: HSSREC@ukzn.ac.za
Additional consent, where applicable
I hereby provide consent to (Please circle response)

Observe lessons and classroom activities	YES / NO
Audio-record my focus group discussion	YES / NO
Complete questionnaires	YES / NO
Take photographs	YES / NO
WhatsApp social media platform	YES/ NO

_____________________ _____________________

Signature of Participant **Date**

Appendix 3: Focus group discussion questions

FOCUS GROUP DISCUSSION QUESTIONS.

Dear student,

To assist you the student, improve your understanding and interpretation of electrical schematics, the following formulated questions will be addressed in our focus group discussions. Please try to answer each question honestly and openly. No one answer is going to be used for or against you.

There are no trick questions! Your responses will be anonymous since pseudonyms will be used. All information that you provide will be handled professionally and confidentially.

1. Do you think you would be confident to read electrical drawings in a factory/work environment?

2. Do you think it’s more important to learn to draw or draw to learn?

3. Now that you have learnt the skill of interpreting drawings, do you think drawing- to- learn has improved your ability to think and reason?

4. By looking at an electrical schematic, can you picture what the connected project would look like?

5. Do you believe lines in a schematic have meaning?

6. What are electrical misconceptions?

7. Did you have challenges with electrical misconceptions before this lesson?

8. Do you have difficulties with electrical misconceptions after the lesson?

9. How did pattern learning help you understand the drawings?

10. Do you think pattern learning should be used in other subjects?

11. Now that you have used pattern learning, can you identify patterns on my own while learning?

12. Do you think that by using pattern learning you could interpret more complex electrical drawings?

13. Do you find it easier to draw than to explain an idea with words?

Appendix 4: Likert scale questionnaire

LIKERT SCALE QUESTIONNAIRE

Dear student, to assist you the student, improve your understanding and interpretation of electrical schematics, the following questions have been formulated to allow us to gain clarity from the practical task you have completed. Please try to answer each question honestly and openly. No one answer is going to be used for or against you. There are no trick questions! We also want you to know that the information you provide here will be handled professionally and confidentially.

Student Name____ Course: Electrical Principles and Practice (NCV Electrical level 2) 2020 Lecturer: Mr Sanjeevy

Electrical schematics:

Tick the appropriate block	Strongly agree	Agree	Not Sure	Disagree	Strongly disagree
1. Pattern learning is easy and helped me understand the drawings.					
2. I felt confused using pattern learning.					
3. I would like to use pattern learning for other subjects.					
4. I can identify patterns on my own while learning.					
5. By using pattern learning, I can interpret more complex electrical drawings.					
6. It is easier to draw than to explain an idea with words.					
7. It is more important to learn to draw than draw to learn.					
8. By drawing to learn, I was able to identify components and understand their function.					
9. I now understand what electrical misconceptions are.					
10. Through this lesson, I recognized the wrong or inaccurate mind pictures (misconceptions) I had.					

Student Signature_______________________________________

Appendix 5: Summative observation schedule

OBSERVATION SCHEDULE FROM A SUMMATIVE ASSESSMENT

This task tests your ability to apply the knowledge and skills acquired in the vocational subject. The work required of you is an essential and compulsory component of your studies.

1. GENERAL INSTRUCTIONS

1.1 Study the task carefully.

1.2 Note the time allocations per task.

1.3 Note the submission dates.

1.4 Pay careful attention to the mark allocated per section and for the total.

1.5 Study carefully the resources required.

1.6 Note the elements of the Assessment Tool that will be used to evaluate your performance.

1.7 You are required to provide evidence of your work.

2. DESCRIPTION OF THE TASK

This task is in line with the world-of-work. If you are deemed competent in this task, you will be able to draw, interpret the drawing, compile a parts list, install, wire and commission a two-way switch under the supervision of an accredited person.
An electrician is required to wire and commission two-way switches from design briefs. These types of switches are used in multiple applications, and electricians are required to fault find and install these types of switches.

3. INSTRUCTIONS FOR THE TASK

<u>3.1 Sub-task 1: Wiring and layout of the circuit diagram.</u>

Draw a complete circuit diagram of the installation consisting of a circuit breaker, two two-way switches and a light bulb.

- Correct symbols must be used, and instructions adhered to.
- Drawings must be neat, labelled and symmetrical.

<u>3.2 Sub-task 2: Write down a parts list from the circuit diagram you drew.</u>

- Take careful note of all the different components in the drawing

3.3 Sub-task 3: Installation and panel wiring

- Connect the circuit breaker, switch and bulb using the electrical schematic you have drawn in sub-task 1.
- When switch one is activated light bulb, A must come on.
- When switch two is activated light bulb, A must go off.
- When switch two is activated again, light bulb A must come on.
- When switch one is activated light bulb, A must go off.

Sub-task	Activity	Time allocation	Mark allocation	Assessment tools
1.	Drawing of the wiring diagram.	10 mins	35	Marking sheet
2.	Draw up a parts list	5 mins	10	
3.	Wiring of the circuit	20 mins	55	
	TOTAL		100	

STUDENT'S MARKING SHEET: INTEGRATED SUMMATIVE ASSESSMENT TASK		
Student's surname and first name(s)		
Student's ID number		
Lecturer's surname and initials	Sanjeevy M	
Sub-task 1: Wiring diagram	**Total Possible Mark**	**Student's Mark**
Live indicated correctly.	2	
The circuit breaker is drawn correctly.	2	
The first, two-way switch is drawn correctly.	2	
The second two-way switch is drawn correctly.	2	
The light bulb is drawn correctly.	2	
Earth connection.	3	

The neutral wire is drawn correctly.	**3**	
Correct labelling was done.	**5**	
Correct symbols were used throughout the drawing.	**4**	
The drawing was neat and logically laid out to assist construction and wiring.	**10**	
SUB-TOTAL	**35**	
Sub-task 2: Compile a parts list SUB-TOTAL	**10**	
Sub-task 3: Wiring	**Total Possible Mark**	**Student's Mark**
All sizes and conductor colours were chosen correctly = five marks. • Most sizes and colours are chosen correctly = three marks. • Some sizes and colours are chosen correctly = one mark. • Few or no sizes and colours are chosen correctly = 0 marks.	**5**	
Wiring of components: • All components were wired correctly = five marks. • Most components were wired correctly = three marks. • Some components were wired correctly = one mark. • No components were wired correctly = 0 marks.	**5**	
Earthing was done in accordance with the SANS 10142 regulations • All metal parts were earthed = five marks. • Most metal parts were earthed = three marks. • Some metal parts were earthed = one mark. • No metal parts were earthed = 0 marks.	**5**	
Task completed within 20 minutes (wiring and basic functionality checked). NB: 5-mark penalty per 10 minutes extra used.	**15**	
Check to see if incoming supply was present before switching on.	**1**	
PPE was worn correctly at all times during the performance of the task.	**4**	
Test instruments (multi-meter) were used correctly.	**4**	
Good housekeeping was exercised (i.e. no clutter in the work area).	**4**	
The student worked safely during the performance of the task.	**4**	
When switch one is activated light bulb, A must come on.	**2**	
When switch two is activated light bulb, A must go off.	**2**	

When switch two is activated again, light bulb A must come on.	**2**	
When switch one is activated light bulb, A must go off.	**2**	
SUB-TOTAL	**55**	
GRAND TOTAL	**100**	

6. RECORD OF PERFORMANCE IN INTEGRATED SUMMATIVE ASSESSMENT TASK

INTEGRATED SUMMATIVE ASSESSMENT TASK College:

Campus:	**Northdale**
Student's Surname and First Name/s:	
Student's ID Number:	
Lecturer's Surname and Initials:	**Sanjeevy M**
Date of conclusion of assessment:	

ASSESSMENT GRID

TASKS	**MARK ALLOCATION**	**STUDENT'S MARK**
Sub-task 1: Wiring diagram	**35**	
Sub-task 2: Draw a parts list	**10**	
Sub-task 3: Wiring of the circuit	**55**	
Total	**100**	

COMPETENCE LEVEL INDICATORS 5 POINT ACHIEVEMENT RATING SCALE				
Outstanding	**Highly competent**	**Competent**	**Not yet competent**	**Not achieved**
80-100%	**70-79%**	**50-69%**	**40-49%**	**0-39%**
5	**4**	**3**	**2**	**1**
Student's Competency Level:				
Student's Signature:				
Lecturer's Signature:				
Date:				

Appendix 6: Rating scale questionnaire

RATING SCALE QUESTIONNAIRE FOR THE WHATSAPP CHAT. (Event planning)

Dear student,

To assist you the student, improve your understanding and interpretation of electrical schematics, the following questions have been formulated to allow us to gain clarity from the social media platform used. Please try to answer each question honestly and openly. No one answer is going to be used for or against you. There are no trick questions! We also want you to know that the information you provide here will be handled professionally and confidentially.

Student Name____

Course: Electrical Principles and Practice (NCV Electrical level 2) 2020

Lecturer: Mr Sanjeevy

Electrical schematics:

Please tick the appropriate block	**YES**	**SOMEWHAT**	**UNDECIDED**	**NOT REALLY**	**NO**
Has blended learning enhanced your understanding of the drawing?					
Do you prefer using WhatsApp as an event planner for your lessons?					
Did your chats via WhatsApp help you complete the practical task?					
Do you prefer working cooperatively in a class only without using WhatsApp?					
Do you prefer working cooperatively in and out of the class using WhatsApp?					

Student Signature____________________________________

Appendix 7: Ethics aproval

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

28 April 2020

Mr Mark Sanjeevy (213569811)
School Of Education
Pietermaritzburg Campus

Dear Mr Sanjeevy,

Protocol reference number: HSSREC/00001251/2020
Project title: Using drawing to learn as an alternate teaching strategy to enhance interpretation and understanding of electrical drawings in my NCV electrical class
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 18 March 2020 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**

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 discipline/department for a period of 5 years.

This approval is valid until 28 April 2021.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/

Founding Campuses: Edgewood   Howard College   Medical School   Pietermaritzburg   Westville

INSPIRING GREATNESS

Appendix 8: Turnitin certification

Turnitin Originality Report

Processed on: 18-Jun-2021 3:03 PM CAT
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DRAWING TO LEARN AS AN ALTERNATIVE TEACHING STRATEGY TO ENHANCE INTERPRETATION AND UNDERSTANDING OF ELECTRICAL DRAWINGS By Mark

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Submission author:	Mark Sanjeevy
Assignment title:	Postgrad chapters
Submission title:	DRAWING TO LEARN AS AN ALTERNATIVE TEACHING STRATE...
File name:	Mark_Sanjeevy_Abstract_and_Chapters_1_-5_15_June_2021.d...
File size:	1.26M
Page count:	143
Word count:	40,728
Character count:	246,070
Submission date:	18-Jun-2021 02:55PM (UTC+0200)
Submission ID:	1608556594

Appendix 9: Language editing certification

Proofwrite Solutions

WRITE • EDIT • RESEARCH • DESIGN

1st July 2021

To whom it may concern

EDITING OF DISSERTATION FOR MR MARK SANJEEVY

I have a master's degree in Social Science, Research Psychology and a TEFL qualification from UKZN. I also have an undergraduate and honour's degree Bachelor of Arts in Health Sciences and Social Services from UNISA.

I have 15 years of teaching experience and have been editing academic theses for students from UKZN, UNISA, the University of Fort Hare, and DUT for the past eight years. I have further undertaken editing, transcribing and other research work for private individuals and businesses.

I hereby confirm that I have edited Mark Sanjeevy's dissertation titled **"Drawing to Learn as an Alternate Teaching Strategy to Enhance Interpretation and Understanding of Electrical Drawings"** for submission of his master's dissertation in Education in Teacher Development Studies at the University of KwaZulu-Natal. Corrections were made in respect of grammar, tenses, spelling and language usage using track changes in MS Word 2013. Once corrections have been attended to, the dissertation should be correct.

Yours sincerely

[redacted]

Terry Shuttleworth (Hons BA Psych Coun, UNISA; TEFL, UKZN; MSocSc, UKZN).

DISCLAIMER

Should the student not attend to the changes suggested by the editor and make additions to the dissertation after editing has been completed, the editor cannot guarantee the language, grammar and tenses are correct at the time of publication.

Table of Figures

List of Tables