Cape Peninsula
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HOW TVET LECTURERS PREPARE ELECTRICAL INFRASTRUCTURE CONSTRUCTION STUDENTS FOR INDUSTRY

by

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DECLARATION

I, Sibusiso Mdletshe, declare that the contents of this dissertation/thesis represent my own unaided work, and that the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Sibusiso Mdletshe | 15 August 2024
Signed | **Date**

ABSTRACT

How TVET lecturers prepare Electrical Infrastructure Construction students for industry

The shortage of skilled lecturers in the technical and vocational education and training (TVET) sector has been pointed out in several studies. This shortage has been a particular challenge in the training of Electrical Infrastructure Construction (EIC) students for the field of practice. This is the "real world" problem that prompted this study. The issue to be addressed is the extent to which TVET lecturers' qualifications and skills, both in the engineering field and in education, as well as the extent to which they have attained the practical knowledge and work-based experience necessary, are suitable to teach and prepare EIC students for the employability in the field. The need for qualified and effective lecturers in NCV programmes underpins this study's specific focus and this study therefore addressed the main research question: "How do NCV EIC lecturers prepare students for industry?"

Drawing on the literature and Legitimation Code Theory's (LCT) Semantics dimension, curricula and pedagogies were assessed in terms of their relative strengths of semantic gravity and semantic density. Ideally, engineering curricula would introduce basic scientific knowledge, then engineering knowledge, procedural knowledge, and implementation knowledge. Pedagogy would, ideally, take the form of a 'semantic wave' in which lecturers move down the wave from conceptual, to applied, to procedures and implementation, and then back up the wave. The activities of conceptualising, applying, proceduralizing and implementing support the students' acquisition of the different knowledge forms. Semantics explains that it is not sufficient to travel only down the wave from theory to implementation; cumulative learning happens through forms of reflection on practice (e.g., reporting, debriefing and reflection on theory). Thus it is necessary to travel both down and up the semantic wave.

The study focused on the subject, Electrical Workmanship 4, as it is a key component of the EIC curriculum. Fourteen lecturers who teach the subject (or parts of the subject) across three TVET sites were interviewed. The study found that, while Electrical Workmanship included both theoretical and practical knowledge, these knowledge forms were disconnected, resulting in gaps in supporting students' cumulative knowledge building towards competent technical engineering practice in the field of EIC. The emphasis on safety and typical electrical installations was evident, but further development in areas such as procedural knowledge and reflection would enhance the curriculum's effectiveness in preparing students for real-world electrical installation work, as would clear linkages between the different knowledge forms. The lecturer interviews highlighted the importance of practical experience. They expressed their concerns about curriculum-industry alignment and made many constructive suggestions

for curriculum revision, collaborative teaching approaches, the role of the basic and engineering sciences, and the need for increased practical training to prepare students for EIC work.

Analysis of the curriculum and lecturers' inputs through the lens of Semantics made visible the underpinning principles of the curriculum and pedagogy, showing how semantic gravity could be strengthened to better align a vocational engineering subject with industry practice. LCT's Semantics also revealed how the relationship between theory and practice within and across subjects might be strengthened – and pointed to the need for TVET colleges to collaborate with industry partners to better align the semantic profiles of practical work activities with those of industry standards. Finally, the study developed LCT tools to assist engineering lecturers in developing a pedagogy of practice that would enable them, beyond the EIC programme, to teach vocational engineering subjects in ways that would better support students' transition into the world of engineering work.

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DEDICATION

For Hlengiwe Precious Mdletshe (my wife), Siyabonga Mdletshe (my brother), Pastor V Khawula, Pastor SG and DJ Gigaba, Pastor T and DH Mthethwa

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GLOSSARY

Abbreviations	Definition
ECA(SA)	Electrical Contractors Association (South Africa)
EIC	Electrical Infrastructure Construction
ESASS	External Summative Assessment
EW	Electrical Workmanship
EWAG 4 (2015)	Electrical Workmanship Assessment Guide, Level 4 (2015)
EWSG 4 (2015)	Electrical Workmanship Subject Guide, Level 4 (2015)
ICASS	Internal continuous assessment
HV	High Voltage
JIPSA	Joint Initiative for Priority Skills Acquisition
LCT	Legitimation Code Theory
LV	Low Voltage
MV	Medium Voltage
NATED	National Accredited Technical Education Diploma
NCV	National Certificate (Vocational)
NQF	National Qualifications Framework
OFO	South African Organising Framework for Occupations
PLC	Programmable Logic Controller
QCTO	Quality Council on Trades and Occupations
SAIEE	South African Institute of Electrical Engineers
SCADA	Supervisory Control and Data Acquisition
SG	Semantic Gravity
SD	Semantic Density
SAQA	South African Qualifications Authority
STEM	Science, Technology, Engineering, and Mathematics
TVET	Technical and Vocational Education and Training
UN	United Nations
WEF	World Economic Forum

CHAPTER ONE
EDUCATING ELECTRICIANS: AN INTRODUCTION

1.1 Introduction

Chapter One provides the background and context to the study (1.2) before explaining the "real-world" problem (1.3), the rationale for the study (1.4), and the research problem, including the research aims, objectives, and questions (1.5). Section 1.6 provides a guide to the thesis structure, explaining what has been called the "golden thread" (Leedy & Ormrod, 2019) that holds the different sections of the thesis together.

1.2 Educating electricians: background and context

The global demand for qualified electricians is on the rise, with many countries experiencing severe skills shortages in this field (World Economic Forum [WEF], 2020). Electricians install, maintain and repair electrical systems; they also rewire fixtures and equipment, install wiring and lighting, solve electrical problems, and conduct safety inspections. In South Africa, there are three types of electricians: single phase electricians, installation electricians, and master installation electricians (who install and service electrical systems and are responsible for safety, documenting and reporting, producing cost and time estimates, and training apprentices). Installation electricians work with both single-phase and three-phase installations. Qualifying as an installation technician enables practitioners to work in residential, commercial and general industrial environments. In South Africa there is a shortage of installation electricians, a situation which has been identified as a significant barrier to economic growth (South African Department of Higher Education and Training [DHET], 2019). Well-trained installation electricians who have prepared for employability are urgently needed in the South African construction industry, as it is not able to grow without them (Mhlongo & Majozi, 2019). The economic impact of load-shedding and the urgent need to stabilize the electricity supply remains one of South Africa's most critical challenges (Govender & Davidson, 2019). As electrical infrastructure ages and needs to be replaced, it is unsurprising that there is critical shortage of installation electricians (Ateba, Prinsloo & Gawlik, 2019). Electrical Engineering Technicians (OFO 311301), Sub-station Managers (OFO 311302) and Installation Electricians (OFO 671101) are at the highest level of skills in greatest demand (Quality Council on Trades and Occupations [QCTO], 2019).

There are several routes to becoming an installation electrician in South Africa. The South African Health and Safety Act (Department of Labour, 1993, revised 2014) outlines the registration criteria for "Single Phase, Installation Electrician and Master Installation Electrician" (South African Department of Labour, 2014). Becoming a qualified electrician requires practical and theoretical study. There are various study options available, for example, the candidate could qualify for a five-year electrician apprenticeship, after which he or she would need to complete the relevant trade test, as well as achieve at least an NQF level N2 qualification. Alternatively, the candidate could register at a Technical and Vocational Education and Training (TVET) college for an appropriate 3-year National Qualifications Framework (NQF) Level 4 qualification that combines theory and practice. To enhance EIC graduates' employability, post qualification, the candidate would need to obtain a valid wireman's licence and pass the electricians' licencing examination. All practicing electricians need to be registered with the South African Department of Labour.

Technical education began in South Africa as "a response to the industrial development in the late 1800s" (Terblanche & Bitzer, 2018:104) and has undergone many changes over the years. TVET colleges (initially known as technical colleges, then re-named Further Education and Training (FET) colleges), were established in 2002 in terms of the Further Education and Training (FET) Act 98 of 1998 (DHET, 2013). In January 2007, the National Certificate (Vocational) (NCV) replaced the National Accredited Technical Education Diploma (NATED) courses (N1–N3) then offered at FET colleges. The implementation of the NCV at TVET institutions changed technical education in South Africa (Matabane et al., 2022). The NCV is available at NQF Levels two, three, and four, which corresponds to general education grades 10, 11 and 12. The focus of this study is the three-year NQF Level 4 qualification, namely, Electrical Infrastructure Construction (EIC), which is an NCV qualification that provides both academic and practical training for students intending to become installation electricians.

The first year of the NCV EIC is at NQF Level 2 and provides a basic introduction to electrical engineering; Level 3 deals with the increasing complexity of electrical engineering; and Level 4 provides more advanced skills development. The NCV EIC has a key role to play in addressing South Africa's electricity crisis. It "integrates academic knowledge with practical skills and prepares learners for careers such as Electrical Engineering Technician, Power Sub-station Manager, Installation Electrician, Electrical Contractor, Foreman and Electrical Inspector" (Electrical Workmanship Study Guidelines Level 4, 2015:2). The practical course, Electrical Workmanship, was selected as the focus of this study as it is a key component of the NCV EIC and is the most practically-orientated EIC subject. The goal of this practical subject is that students learn to master the skills and develop the safe practices needed to install and maintain South Africa's electrical infrastructure. However, the NCV programme in EIC has been critiqued as being insufficiently practice-oriented, resulting in the employability challenges that many of the programme's graduates face (Mtshali & Ramaligeria, 2020; Rageth & Reginold, 2020).

1.3 Who teaches the electricians? The 'real-world' problem

Having developed a range of NCV qualifications across many of technical and vocational fields, the issue of who should teach on the programme had to be considered. Accordingly, in 2013, the South African DHET published its Policy on Skilled Qualifications for Lecturers in Technical and Vocation Education and Training (DHET, 2013). This policy specified the teaching qualifications needed by lecturers in the technical, vocational education and training system. These educational qualifications are specific to TVET college lecturers and different from the qualifications required by schoolteachers in general education. From 2016, all lecturers in TVET colleges were required to obtain a TVET educational qualification. However, this requirement was not possible to implement. There are insufficient skilled teachers who can provide a high quality of teaching for all school subjects and phases within the general school system (Hofmeyer, 2015); and this is also the case in the TVET system. The shortage of skilled lecturers in the technical and vocational education and training (TVET) sector has been pointed out in several studies (e.g., Badenhorst & Radile, 2018; Buthelezi, 2018) and is a particular challenge in the Science, Technology, Engineering, and Mathematics (STEM) disciplines and fields. According to a Joint Initiative for Priority Skills Acquisition (JIPSA) Report (2014), only 38% of TVET lecturers "are confident in their abilities to fully transmit practical skills to learners", while 34% of lecturers urgently required "practical up-skilling intervention". In South Africa, there is a wide range of histories, social backgrounds, and educational credentials among TVET lecturers (Wedekind & Watson, 2016). In the past, many TVET lecturers had industry experience but did not have formal qualifications in their field (Zinn et al., 2019). However, this is no longer the case. Currently, it is claimed that most lecturers have acquired TVET qualifications – or higher-level qualifications related to the field in which they teach – but lack industry experience. In other words, they went from a TVET qualification into teaching a related subject in a TVET college (Taylor & Van der Bijl, 2018). In addition, many lecturers continue to teach in TVET colleges, although they have no teaching qualifications (Buthelezi, 2018). Consequently, it is assumed that there is a need for professional staff development in TVET education and the provision of industry experience to ensure that lecturers are able to teach their subjects in ways that will support students' transition into the world of work. It is this assumption that this study investigates.

1.4 The rationale for the focus of the study on TVET lecturers

The United Nations' sustainable development goals propose "a shared blueprint for peace and prosperity for people and the planet" (Comfort, 2023). An important part of the vision is the provision of quality education, particularly in areas of scarce skills. Electricians and electrical technicians consistently appear in the top ten of global scarce skills lists (World Economic Forum [WEF], 2020), surpassing professional engineers. The South African Qualifications

Authority (SAQA) reports that NCV EIC graduates should be equipped with skills that are in high demand in both the private and public sectors, such as electrical installation, maintenance and repair, as well as project management (SAQA, 2017). For the reasons provided above, it is crucial that the curriculum enables the integration of theory and practice, and that lecturers are well-prepared to facilitate students' learning, given the significant role that the EIC programme plays in the development of the nation's economy (Boutin et al., 2009). According to the DHET (2013), all NCV qualifications include practical work that is intended to help students acquire workplace-relevant technical and practical skills. This should be accomplished using well equipped workshops for skills development, practical exercises and tasks, workplace simulations, laboratory experiments, and industry-based initiatives. Essential workplace problem-solving and collaboration abilities would be acquired through these hands-on activities.

Lecturers’ qualifications and ongoing professional development are key to their students’ success in technical and vocational education. Of all educational sectors, TVET lecturers are the most ill-prepared for their work (Gamble, 2013; Chukwu et al., 2020; Badenhorst and Radile, 2018). While some lecturers might have academic qualifications, they lack the necessary industry experience for effective technical teaching (Taylor & Van der Bijl, 2018). Lecturers clearly cannot prepare students for the world of work if they have no personal experience of it. In the TVET sector, it is also claimed that "lecturers at colleges need to reskill and upskill to stay up to date with the newest technical development" (Nkwanyane, Makgato & Ramaligela, 2020:156). These claims are of concern, as poorly prepared lecturers have a detrimental impact of the TVET system. The focus of this research study is to find out how students enrolled on the EIC programme are prepared for the world of work by their lecturers.

1.5 The research problem: How lecturers prepare students for industry

This study investigates TVET lecturers’ curricular and pedagogical practice regarding Electrical Workmanship 4, a key practical subject within the NCV EIC, to understand the extent to which they are able, or not able, to fulfil their roles in guiding students on their journeys to becoming installation electricians and achieving employability in the electrical infrastructure construction industry. Through a study of TVET lecturers’ pedagogical practices, this study investigates the claim of many research studies that TVET lecturers lack both formal educational qualifications and training, as well as the practical knowledge and work-based experience necessary to teach and prepare NCV EIC students for the workforce (e.g., Nkwanyane, et al., 2020; Zinn et al., 2019).

1.5.1 Aim and objectives

The aim of this study is to investigate the nature and quality of curricular and pedagogical practices in the NCV EIC to understand the effectiveness of lecturers' practices in preparing students for the transition to the world of work. The objectives of the study are:

1. To identify the suitability of the NCV EIC curriculum for preparing students for the world of work;
2. To understand lecturers' practices in preparing students for the world of work;
3. To assess the effectiveness of their pedagogical practices; and
4. To propose solutions to the identified challenges.

By preparing NCV EIC students for the workforce, TVET lecturers can contribute meaningfully to economic growth and alleviating skills shortages. The aim of the study was to understand the important role that lecturers play in enhancing NCV EIC graduates' employability – thereby contributing to addressing the skills gap. The employability of NCV EIC graduates is important for the electrical infrastructure construction and maintenance industries. The skills acquired in a strong and effective programme through the expert facilitation of TVET lectures are likely to be in high demand.

1.5.2 Research questions

The need for qualified and effective lecturers in NCV programmes underpins the study focus. The study therefore responds to the following main research question: How do NCV EIC lecturers prepare students for industry? This guiding research question has two research sub-questions, namely:

1. How does the NCV EIC curriculum prepare students for industry?
2. What prior education, training and experience do NCV lecturers draw on in preparing students for industry?

To address the question, "How do NCV EIC lecturers prepare students for industry?", it was necessary, firstly, to investigate the NCV EIC curriculum that the lecturers are required to use. The reason for the curricular study was to ascertain the extent to which the curriculum enabled or constrained lecturers' pedagogical preparation of students for work in the electrical infrastructure construction industry. The second question was necessary to ascertain the extent to which the lecturers might require additional training, support or engagement in continuous professional development, as well as the kind of training, support and professional development they might require.

1.6 The structure of the thesis

In this section, the structure of the thesis is briefly explained. The central argument that runs through the thesis and which creates coherence and cohesion across its various sections has been termed the "golden thread" (Leedy & Ormrod, 2019). Each chapter or section of the thesis could be understood as a strand that makes up the golden thread of the thesis. The golden thread ties together the literature and theoretical framework, the research design, methodology, data collection and analysis in order to address the research questions in a consistent and scholarly way. Moving through the theory and literature, linking one's research questions, conceptual framework, methodology and analytic framework and, finally, one's skilful answers to the research questions, the golden thread draws together the different sections of the thesis to create a logical central argument.

This thesis argues that assumptions made about TVET lecturers being the cause of the deterioration of technical and vocational education and training should be critically examined. In fact, the thesis argues that TVET lecturers contribute positively to education and training in the TVET sector. The introduction (Chapter One) justifies the relevance of the research study and makes an argument for the focus of the study on the role of TVET educators due to their centrality to the quality of educational provision. The literature review (Chapter Two) explains what we already know about the NCV curricula and about TVET lectures, as well as the gaps in our knowledge. What emerges from the review of the literature is an implied argument for the study's unique contribution to knowledge and to practice. Also in Chapter Two, an argument is made for use of Legitimation Code Theory's (LCT) Semantic dimension as an appropriate theoretical perspective.

In the chapter on methodology (Chapter Three), the appropriateness of the research design for addressing the research questions is argued. A justification on the grounds of rigour and logic is made for the selection of sites and participants, as well as for the choice of data collection techniques and data analysis methods. The two chapters of findings (Chapters Four and Five) cover the basis for the claims made, extending and elaborating upon the central argument with the details of how TVET lecturers contribute positively to education and training in the TVET sector. The central argument is further supported through an LCT semantic analysis of the findings.

The conclusion (Chapter 6) synthesises the argument, showing how the study has adequately and appropriately addressed the research questions.

CHAPTER TWO
A REVIEW OF THE LITERATURE ON VOCATIONAL ENGINEERING CURRICULA AND PEDAGOGIES

2.1 Introduction

The focus of this literature review is how lecturers in vocational engineering prepare students for the engineering industries, in particular, what is known about the kinds of curricular and pedagogical arrangements needed to support students' transition to industry in a vocational context. In Section 2.2 the key debates in engineering education in a TVET context are discussed. Section 2.3 reviews the literature on curricula for engineering trades; and Section 2.4 deals with pedagogy and lecturer development. Chapter 4 begins with a brief introduction to education and training in the field of electrical infrastructure construction (4.2). The sections that follow explain the industry standard for electrical infrastructure trades and occupations (4.3), as well as employer requirements in related fields (4.4). The theoretical framework, Legitimation Code Theory and its Semantics dimension, are explained and justified in Section 2.5. Section 2.6 concludes the review of the literature.

2.1.1 Methodology of the literature review

Six databases (ACM, Emerald, IEEE Explore, Taylor and Francis, Science Direct and Sabinet), as well as peer reviewed TVET and industry journals not in these databases, were searched for literature relevant to engineering education in TVET. The key issues in this literature are presented in Sections 2.2 to 2.4. It was felt that more up-to-date information was required from practitioners (both in TVET colleges and in Industry). To this end an "evidence-informed" systematic review of non-research evidence (Chambers & Wilson, 2012) on the curricula and industry needs was done. The 'evidence-informed' review, developed by McMaster University, includes criteria for the appraisal of the relevance and trustworthiness of non-research evidence (Yost et al. 2014). The non-research evidence is reported on in Sections 2.3.1 – 2.3.3 and comprises educational manuals and materials TVET colleges internationally as well as training providers such as Siemans. Jobs advertised for installations on the South African "Jobs24" website were also surveyed. It was intended that such an evidence-informed systematic review would be likely to provide a wider, richer and more contextualised understanding of the actual practices beingimplemented.

2.2 Preparing students in TVET engineering programmes for the world of work

The literature on engineering education in TVET is centrally premised on the idea that students undergoing college-based studies should be well prepared for the engineering trades (e.g., Brockman et al., 2008; Rauner et al., 2012; Ngu, 2016). However, there is strong contestation on how they should be prepared, as well as ongoing debate on the different purposes, values, and concerns of curricula and pedagogies in vocational education. Is the purpose of engineering education and training to prepare students for specific jobs in the engineering industry, or is it to prepare students more holistically for employability and citizenship? Educators argue that "we have to move away from conveying 'narrow skills' [because] we need 'broad competences' to respond to increasing complexity and rapid technological advance at the place of work" (Spoettli & Loose, 2015:1); however, engineering industry representatives argue that meeting the needs of employers and building a skilled workforce for occupational progression is the key priority (Rageth & Renold, 2020).

Technical knowledge and skills are essential for preparing students for the workplace but students pursuing careers in the electrical trades are entering a rapidly evolving field that requires constant updating of specialized skills and knowledge (Mesuwini & Bomani, 2021). Employers expect TVET programmes to provide students with a practical understanding of the field and its underpinning disciplines, as well as the capacity to think critically and independently in new and challenging settings (Akgunduz & Mesutoglu, 2021). Consequently, engineering in TVET has to equip students with the skills and knowledge required to meet current and future market demands (Kozanidis, Fotis, & Hatzikraniotis, 2015).

In the sections that follow, the literature on how students in the engineering trades are prepared for the world of work and stay abreast of new technologies and developments in their fields and disciplines is reviewed, firstly from a curriculum perspective (2.3) and then from a pedagogical perspective (2.4).

2.3 Curricular arrangements that support students' transition into engineering industries

Curricula in the engineering trades are expected to equip students with the knowledge, abilities and attitudes needed for successful practice in their chosen occupation (Mtshali & Ramaligela, 2020). In most cases, preparing students for occupational competence in the engineering trades requires both academic studies, such as the basic sciences and the engineering sciences, as well as the acquisition of practical skills, attitudes, understanding, and information that are linked to the occupation in a particular sector of economic and social life (United Nations Educational, Scientific and Cultural Organization (UNESCO, 2022).

In initial education for the engineering trades (usually in the students' first year), scientific disciplines are important and take up considerable curricular space (Doorsamy & Bokoro, 2019). Mathematics and the basic sciences provide the underpinning logic of practice for current and future practices in engineering (Kotsifakos et al., 2017). Mathematical and physics knowledge, for example, are important for performing energy calculations, while electrical engineering knowledge is basic to the full range of engineering trades and occupations (Jackson, 2019). Gleeson's (2016) research showed how important physics knowledge is for heat pump installers. When the heat pump installers did not have the necessary applied physics knowledge, errors tended to occur because the scientific basis of practice was not clear to the technicians (Gleeson, 2016). While the basic sciences and the engineering sciences are core subjects in education for the engineering trades, there are debates about the amount of curricular space that should be allocated to these more theoretical forms of knowledge. Some researchers claim that when the basic sciences are reduced or removed, vocational qualifications are "robbed of their educational integrity and are too narrow, too task focused and too tied to particular jobs" (Wheelahan, 2015:127). In vocational engineering, researchers also argue that applied knowledge in the form of the engineering sciences underpins engineering practice (e.g., Canning, 2012; Muller & Young, 2019; Cunningham & Sneider, 2023).

The provision of opportunities for students to engage in practices that approximate practices in the workplace is central in any engineering curriculum (Tūtlys & Spoettl, 2017); and in the engineering trades, practical knowledge-building is a central component of curricula (Smith, 2020). However, while much is known about how students acquire knowledge in the basic sciences and mathematics (e.g., Jawahar and Mukeredzi, 2015; Moloi, 2013) and in the engineering sciences, much less is known about practical knowledge and how to teach it (Khalid et al., 2014; Mesuwini et al., 2020).

Winch proposes three different kinds of practical knowledge that are relevant in TVET education: skill, transversal abilities, and project management abilities (Winch, 2013:281). In the context of TVET engineering, "skills" refer to the specific, technical skills needed for a particular context, for example, for installing, monitoring and repairing equipment. Every occupation has its own unique set of competencies and skills that is constantly developing and emerging (Carnevale & Smith, 2013). Transversal abilities refer to more generic aspects of practical knowledge which are transferable across contexts, such as problem-solving abilities. Project management, including the management of practical activities, including planning and scheduling, is highly relevant to the engineering trades. The specific skills needed for technical engineering practice have been described as a form of "contextual knowledge" (Muller, 2012:116). In technical engineering, contextual coherence, or the logic of practice (rather than the logic of the disciplines), is the logic on which the curriculum is based (Winberg, 2019). Many research studies imply the importance of skills development and contextual coherence for TVET engineering through, for example, calling for practical training that addresses the need for cutting-edge technological training, industry-relevant knowledge and skills, as well as the issue of skills shortages (Marope. Chakroun & Holmes, 2015). Some researchers propose that TVET colleges should focus on teaching “workplace essentials” (Mtshali & Ramaligela, 2020); others go further and claim that all hands-on practical activities and exercises carried out in TVET institutions should follow modern workplace practices in order to offer students an authentic education that supports globalization and affirms diversity (Placklé et al., 2018).

Employers in the engineering sector value employees who have acquired the practical knowledge and skills for workplace effectiveness (Okoye & Nkanu, 2020). The engineering industries rely on TVET colleges to provide up to date practical training for prospective employees and express their dissatisfaction with colleges that operate without industry consultation when developing and implementing crucial industrial skills training programmes (Masha et al., 2021). Innovation and the modernization of training tools and technologies are becoming increasingly important in the light of how workplaces have changed due to technology and Industry 4.0 (Nkwanyane et al., 2020). When occupationally relevant practical training was included in TVET engineering programmes, and when students successfully completed the programme's practical requirements, the students were found to be more confident, competent and work-ready in their field of study than those students who had not been exposed to these aspects (Vollenhoven, 2016). Because engaging in work-like activities have had a significant impact on students’ employability (Amoo & Adam, 2022), TVET colleges have a responsibility to offer programmes that help to develop students' capacity to function successfully in their careers (Smith, 2020).

Researchers have identified the importance of transversal and project management abilities, such as “problem-solving skills”, “adaptability”, “flexibility”, “professionalism”, the “ability to communicate well with all stakeholders and role players in an organisation, at all levels”, “Lifelong learning”, “teamwork skills” or “mediator skills” and “Information and communication technology skills” (Mtshali & Ramaligela, 2020:30). The list of transversal and management skills includes cooperation with others, and aptitude for solving problems (Okoye & Nkanu, 2020). These abilities are underpinned by what some theorists have called “procedural knowledge” (e.g., Gamble, 2013) and others have called “proceduralised knowledge” (Tūtlys & Spoettl, 2017). Unlike contextual knowledge which is more tacit and which develops within specific contexts, procedural knowledge is often codified, for example, in “competence-based occupational standards and vocational curricula” (Tūtlys & Spoettl, 2017:50), and is consequently more transferable across contexts.

Both contextual knowledge (to the extent that it is possible) and procedural knowledge should be developed by TVET colleges, initially through the practical training offered within colleges. This training can then be improved upon through supervised placements in industry (Papier, 2017). Therefore, colleges are advised to provide both in-college practical training and the placement of students in a relevant engineering practice. Colleges should also support students while they are on placement (Mesuwini et al., 2020). In placement, engineering students develop contextual, industry-specific engineering skills, as well as a range of soft skills that will enhance their employability (Khalid et al., 2014).

A transversal skill that is underpinned by procedural knowledge is the ability to work safety in engineering contexts (Cunningham, 2019). Students in electrical engineering must be trained to work safely and in accordance with all applicable regulations and standards, given that electrical work is inherently hazardous (Albert & Hallowell, 2013). The safety of electrical engineering technicians, and the general public, depends on proper training and education in safe work practices, as well as adherence to appropriate safety and electrical codes (Malhotra et al., 2020). The electrical engineering curriculum thus has a crucial role to play in equipping students with the knowledge and skills required to operate safely and in accordance with regulations.

According to a joint World Bank, International Labor Organization (ILO) and UNESCO (2023), it is important for TVET colleges to include both self-employment and employability as key transversal skills in their programmes. Economic growth and development are be facilitated when countries invest in education and training (World Bank, ILO & UNESCO, 2023). There is consequently a need for TVET programmes to be aligned with the skills requirements of the economy so that graduates can contribute to the economy and their own personal development by using the skills they have learned in training institutions. Self-employment is particularly important in the context of development. For example, electrical engineering graduates should be able to establish their own electrical contracting businesses or work as freelance electricians by utilizing their practical skills and knowledge.

Finally, it is important for TVET programmes in engineering to play an essential role in fostering the transversal skill of lifelong learning among electrical engineering students. In a field that is in a perpetual state of change, it is crucial that students continue to develop their skills and knowledge over the course of their careers. According to a South African report, "successful electricians are those who are committed to ongoing learning and professional development" (Electrical Conformance Board of South Africa, 2023). By instilling a culture of continuous learning in their students, TVET NCV electrical programmes can ensure that their graduates remain marketable and competitive.

The literature reviewed identified many types of knowledge to be included in an engineering curriculum. These knowledge types could be clustered into two broad areas, namely theoretical and practical knowledge. Within the broad category of theoretical knowledge, the sub-categories of scientific knowledge and engineering knowledge were identified. Within the category of practical knowledge, the sub-categories of procedural and contextual knowledge were identified. The literature indicated that engineering curricula should include basic scientific knowledge, relevant engineering knowledge, procedural knowledge and contextual knowledge. Both theoretical and practical formers of knowledge are required in engineering curricula, but Winch points out that "the relationship between theoretical and practical knowledge in vocational education" has been neglected in the literature (Winch, 2013:281). It is not enough to understand the concepts of theory and practice in themselves, knowledge of the inferential relations between them is of equal importance. Understanding the relations between knowledge forms is important and should inform procedures of assessing, testing and acquiring new knowledge. For any field of practice, it is important to understand the different forms of knowledge in the field, what their scope and limits are, and how to put them to work (Muller & Young, 2019:205).

The expected role of TVET in preparation of TVET students for the world of work is "the need to upgrade engineering education curriculum to produce more T-shaped graduate engineers required in the changing industrial world" (Babatope et al., 2020:32). By "T-shaped" graduates, the authors mean students who have both deep, underpinning theoretical knowledge (the downstroke of the T) as well as a broad range of practical, transversal skills (the crossbar of the T). The responsibility of TVET engineering education provision therefore is to ensure that: 1) students engage with relevant underpinning scientific knowledge (e.g., Kotsifakos et al., 2017; Doorsamy & Bokoro, 2019); 2) students engage with relevant applied engineering knowledge (Jackson, 2019); 3) students engage with relevant procedural knowledge (e.g., Tūtlys & Spoettl, 2017; Cunningham, 2019); and 4) students engage with contextual knowledge (Khalid et al., 2014; Mesuwini et al., 2020). Equally important is that attention is paid to the relationships among the knowledge forms in the specific engineering field. TVET engineering students are likely to develop the competency for technical engineering practice when the curriculum supports students' acquisition of both relevant practical skills and the underpinning scientific knowledge. Students should also be provided with opportunities to develop and use these skills and abilities, for example, through guided work-like learning activities and through positive work experiences (Spoettli & Loose, 2015).

2.3.1 The Electrical Infrastructure Construction Curriculum

Internationally, courses in electrical infrastructure (or equivalent) are usually specialist electives offered after completion of a general certificate in electrical technology (TAFE, 2020). In an Australian specialist course in electrical infrastructure, for example, students are required to be certified electricians. In Germany, an equivalent course is a four-year programme offered by the Federal Institute for Vocational Education and Training (BIBB) as part of a dual education system. In this dual system, theory-based classroom study takes place in a vocational college (*Berufsschule*) with block periods of supervised, on-the-job work experience over a four-year period. The students usually spend 60 percent of their time in the workplace under the supervision of a certified trainer and 40 percent in the classroom (BIBB, 2020).

Because, by their nature, electrical infrastructure and distribution systems are large, geographically dispersed entities, and because there are stringent safety requirements in high voltage environments, training in preparation for real world practice is generally through simulation (Dai et al., 2017), virtual reality (He & Gong, 2006), or cloud computing (Caino-Lores et al., 2017). As far back as 1998, the key pedagogy for training sub-station technicians was simulation. Such simulation should incorporate a battery of motivational techniques that spur learning engaging trainees in a way that traditional page-turning CBT [competency-based training] cannot. They are most effective when incorporated into a complete program of substation safety and operations training (Frank, 1999:988).

A laboratory for skills development in electrical infrastructure and distribution systems is necessary to introduce students to the specialised equipment used in the field, such as switch controls (Thorson, Greenfield & Misselt, 1981). Combinations of simulation and "real" training on supervisory control systems are signature pedagogies in the training of electrical engineering technicians in electrical infrastructure and distribution systems (He & Gong, 2006).

There have been some South African research studies on the NCV EIC. A key concern in South Africa is that, despite the shortage of electrician and other electrical trades, "many of the NCV-EIC graduates struggle to find employment" (Mesuwini, 2015:35). Mashongoane argues that a curriculum review of the NCV EIC qualification is urgently needed "to strengthen industry participation, experiential learning at the workplace, soft and self-mastery skills including communication proficiency and critical thinking" (2015:211).

2.3.2 Industry standards for electrical infrastructure construction

Occupational specifications for electrical engineering trades and occupations in the broad area of electrical infrastructure construction were studied with a view to determining the kinds of occupational tasks that graduates of the NCV EIC would be expected to undertake in employment. This section focuses on the occupational standard for Electrical Engineering Technicians and Related Occupations (OFO 311301),

Electrical Engineering Technicians (OFO 311301) perform technical tasks "to aid in … the design, manufacture, assembly, construction, operation, maintenance and repair of electrical equipment, facilities and distribution systems" (QCTO, 2019). The tasks that would be expected of an electrical engineering technician include:

1. Assembling, installing, testing, calibrating, modifying and repairing electrical equipment and installations to conform with regulations and safety requirements;
2. Preparing detailed estimates of quantities and costs of materials and labour required for manufacture and installation according to the specifications given;
3. Designing and preparing blueprints of electrical installations and circuitry according to the specifications given;
4. Providing technical assistance in research on, and development of, electrical equipment and facilities, or testing prototypes;
5. Planning installation methods, checking completed installation for safety and controls or undertaking the initial running of the new electrical equipment or systems;
6. Monitoring technical aspects of the manufacture, installation, utilisation, maintenance and repair of electrical systems and equipment to ensure satisfactory performance and compliance with specifications and regulations (QCTO, 2019).

The QCTO occupational specifications cover many areas of electrical technicians' work. Of particular interest for this study is the installation, testing, maintaining, monitoring, adapting and repairing of electrical equipment and infrastructure, in alignment with safely regulations. The competences of the technician's occupation include inter-professional support, such as collaborative planning, which includes reading technical drawings and plans. The task list above is broad as there are several specializations within the electrical engineering technician designation, such as Hydraulic Power Controller, Turbine Room Controller, Electrical Engineering Laboratory Technician, Electrical Instrument Technician, Electrical Engineering Technical Officer, and Heavy Current Electrical Technician. The expected focus of the NCV-EIC would be on the electrical infrastructure and installations, rather than on the electrical equipment. An example of a more focused qualification is the NQF level qualification, Electrical Substation Operations Technician (Power System Controller), which is accredited by the QCTO and offered by the Eskom Academy of Learning. A Power System Controller maintains the safety, security and stability of an electrical power system within a specified geographical area by controlling conditions and coordinating operations and events (SAQA Qualification 91761, 2018).

A key competency for power system controllers is the practice of "supervisory control and data acquisition" (SCADA), identifying and responding to issues and distributing system information to key receivers. The Training Academy of the South African Institute of Electrical Engineers (SAIEE) offers a short HV/MV switching course that accredits engineers and technicians to perform the function of carrying, making, or breaking the normal load current in order to perform the function of clearing the fault, as well as providing metering and regulating the various parameters of electrical power systems. The inclusion of these more specialized aspects of technical work within electrical infrastructure in the NCV-EIC could enhance the employability of TVET graduates (Mesuwini & Bomani, 2021).

2.3.3 South African employer requirements

This section reports on 50 recent job advertisements (January to June 2023) for Electrical Engineering Technicians in the broad field of electrical infrastructure construction, obtained from the Jobs 24 website as part of the evidence-based critical review. The occupation designators used in the job advertisements included terms such as: Electrical Technician, Electrical Engineering Technician, Field Service Technician and Heavy Current Technician. The advertised positions included a wide range of contexts in which electrical infrastructure construction is performed, for example, mining, manufacture, power generation, municipal electrical distribution and reticulation systems, and refrigeration. The list below shows the main competences required by employers. The job advertisements usually contained more than one of the competences listed below:

1. Supervisory Control and Data Acquisition (SCADA)
2. Programmable Logic Controllers (PLCs)
3. Systems Applications and Products in Enterprise Resource Planning (SAP ERP)
4. Health, Safety, Environment, and Quality (HSEQ)
5. Heavy current experience
6. Protection Relay testing
7. HV & LV Switchgear
8. AC/DC Drives
9. Microsoft Office
10. Power Transformers
11. Maintenance on Big Generators
12. Technical Drawing/CAD
13. Code B motor driver’s license
14. Heating, Ventilation, and Air Conditioning (HVAC)/refrigeration systems
15. Variable Refrigerant Volume (VRV) and Variable Refrigerant Flow (VRF) air-conditioning systems
16. Technical Assets control
17. Human Machine Interfaces (HMIs)/Dashboards
18. Injection Moulding and Heater Bands
19. Fast-moving consumer goods (FMCG).

A variety of commercial products were named in the advertisements, such as Siemens, Omron or Allen-Bradley for PLCs, Wonderware for SCADA, Megger for testing Insulation Resistance, maintenance software (SAP preferably), and Eliwell Controls for air-conditioning systems. Several advertisements specified the commercial product as either essential or advantageous, for example: “The candidate must be competent on Siemens PLCs, Siemens S5 and S7, AC/DC Drives” (Electrical Technician, February 2023), or the candidate must be familiar with “Wonderware and Siemens, Delta, Siemens and Allen-Bradley” (Electrician, May 2023), or stated that being “familiar in the use of Omicron and Megger equipment and software is an advantage” (Field Service Technician, April 2023).

General skills required in the advertisements included: being fully conversant with environmental, health and safety standards with regard to “3 phase 400 Volt AC electricity” (Electrical Engineering Technician, February 2023); providing “preventative maintenance of equipment” and having “knowledge of low voltage (4-24) for the electronics that controls equipment” (Electrical Technician, May 2023); being “able to read a circuit diagram and have good computer skills” (Electrical Technician, March 2023); and having “hydraulic knowledge will be an advantage although training on specific products will be compulsory” (Field Service Technician, June 2023).

Several job advertisements specified that the candidate should have a passed a trade test or hold a valid licence. The items below provide an idea of the certification requirements for many of the jobs listed above:

1. Accredited to supply Electrical Certificate of Compliance;
2. Wireman’s licence;
3. Operating Regulations for High Voltage Systems Certificate;
4. Instrumentation Trade Test;
5. Electrical Trade completed with an electrical engineering qualification;
6. Accredited to perform Factory Acceptance Test (FAT);
7. Comptia A+ Certification;
8. Trade Test in Industrial or Commercial HVAC/Refrigeration;
9. Gas Testing Certificates;
10. Fitter Trade Certificate;
11. Millwright trade test.

Industry requirements in several recent job advertisements were aligned to the QCTO standard for Electrical Engineering Technician (OFO 311301); that is, the job advertisements specified competences regarding the installation, testing, maintaining, monitoring, adapting and repairing of electrical infrastructure in alignment with safely regulations. The equipment that would be installed and maintained was not domestic equipment, but equipment related to electrical infrastructure, such as the environmental testing of mechanical, structural or electrical equipment, telemetering and recording instrumentation and circuitry. The job advertisements also specified the type of training required (e.g., maintenance of PLCs and SCADA on site), as well as the preferred commercial products with which potential employees should be familiar.

2.4. Pedagogical arrangements

Teaching engineering in TVET is highly demanding because of the complex knowledge systems that lecturers are expected to master (Wedekind & Watson, 2016). The literature on engineering curricula showed that scientific, engineering, procedural and contextual knowledge are important if students are to develop the competencies for the engineering trades. Studies on engineering pedagogy suggest that acquiring these different forms of knowledge poses a range of pedagogical challenges for TVET lecturers in the engineering fields (Alexander & Masoabi, 2017). In addition to acquiring these different forms of engineering knowledge, TVET lectures also need to acquire appropriate forms of “pedagogical content knowledge” (Shulman, 1987: 8) and its more recent version, namely “technological pedagogical content knowledge (TPACK)” (Koehler & Mishra, 2009: 60). Shulman (1987:8) lists the range of different knowledges that comprise pedagogical content knowledge: 1) content knowledge; 2) general pedagogical knowledge, “with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter”; 3) curriculum knowledge, with a particular grasp of the materials and programmes that serve as "tools of the trade" for lecturers; 4) pedagogical content knowledge, “that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding”; 5) knowledge of learners and their characteristics; 6) knowledge of educational contexts, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures; and 7) knowledge of educational ends, purposes and values, and their philosophical and historical grounds. Beyond educational technologies, in a time of AI-enabled teaching and learning, there are even more new skills for lecturers to learn, such as the use of simulation and augmented reality in engineering education (Ismail et al., 2019). Moloi and Matabane point out that as teaching becomes ever more AI enabled, such as the teaching of mathematics in Fourth Industrial Revolution (4IR) classrooms, lecturers will be need to be more concerned, beyond the technical know-how and skills, “to promote core values and qualities of social justice” (2020 :181).

Teaching the basic sciences requires lecturers to engage students in active learning (Bonwell & Eison, 1991). This is important as TVET students find the basic sciences challenging, particularly mathematics (e.g., Moloi, 2010), and tend to engage more in practical work (Du Plooy & Du Preez, 2022). The engineering sciences are challenging to many students for similar reasons, but also because they are very different from the science subjects taught in general education (Zeid et al., 2014). The engineering sciences are usually focused on the science of machines (Streveler et al., 2006).

There are many ways of teaching the basic and engineering sciences effectively (Brockmann et al., 2008) and inclusively (Moloi, 2010; 2013), but engineering education has been identified as having a “signature pedagogy”, that is, a way of organising learning so that “future practitioners are educated for their new professions”:

> There are certain fundamental courses in math and physics … the [initial] preparation of engineers begins to break apart fairly early as they move to electrical and mechanical, and civil .... And yet … where they’re really doing practice, I think there are a lot more family resemblances in the signature pedagogies, even though what they’re designing may range from circuits to robotics, to models of bridges or airplanes (Shulman, 2005:35).

A typical pedagogy for the engineering sciences is the “lecture-demo” in which a lecturer explains an engineering concept and, using equipment or devices, shows how the concept works or is applied in practice (Lucas & Hanson, 2016). Jawahar and Mukeredzi (2015) explain the concept of “conceptual integration” which occurs when a lecturer uses one concept (or, as in this case, an artefact) to illustrate another concept. Although some lecturers perform “conceptual integration” intuitively, many need more explicit instruction regarding its principles and practice. In engineering contexts, lecturers have access to several appropriate artefacts to illustrate how the basic sciences are applied in engineering (Zeid et al., 2014). Students find a pedagogy that integrates abstract concepts with concrete examples to be more effective than abstract explanations (Abanilla et al., 2018). Teaching procedural knowledge can often be integrated with the engineering sciences, as the procedures and protocols followed by practitioners are not arbitrary but based on scientific principles (Zeid et al., 2014). Practitioner-led inquiry has been proposed in vocational education and training as an effective way of helping students to understand the principles on which a practice is based (Higgins, 2018).

Teaching contextual practical knowledge in the engineering fields usually requires specialized laboratories and equipment. It is essential that appropriate work-orientated practical tasks are given to students (Ahmad & Latib, 2015) and that the teaching approaches are suited to the practical tasks to ensure that students acquire the necessary technical skills (Ali & Muhammad, 2012). Jawahar and Pop explain that performing tasks in appropriate work-like environments enables students' cumulative knowledge-building "through [the] affordance of specialised contexts of application which contribute to providing epistemological access to abstract concepts" (Jawahar & Pop, 2019:302). For this reason, practical training is best done by TVET lecturers with the relevant industry experience (Gamble, 2013). A study observed "a pedagogy of practice in which laboratory technicians not only demonstrated the craft of technical engineering, helping novice students to acquire more skilful techniques, but also made connections between laboratory procedures and theoretical knowledge" (Winberg, 2021:244). TVET lecturers similarly need to play a role in integrating theoretical and practical knowledge in teaching the engineering trades. Teaching in technical and vocational contexts is witnessing the emergence of an additional signature pedagogy of "collaborative teaching" (Smith, 2018), in which engineering lecturers teach in areas in which they are strong. This mimics the way in which teamwork is accomplished in engineering practice.

Rauner et al. (2012) argue strongly for competence-based assessment practices in practical vocational subjects. Using a competence-based framework enables the logical planning of assessment tasks that are clearly aligned to the occupational standard and industry needs. Within a competence-based framework, such as Rauner et al's (2012) 'COMET' model, assessment tasks can be meaningfully aligned with curricular and occupational outcomes. With a strong guiding framework and innovative forms of assessment, including the application of e-learning and e-assessment practices, assessment can be aligned to industry standards. In practical subjects, "performance assessment and authentic assessment" is the "gold standard", rather than class tests and assignments (Deutscher & Winther, 2019:4). Projects and practical work, including teamwork, could be understood as "performance assessment" if these tasks are typified by "higher levels of cognitive complexity, communication, real world applications, instructionally meaningful tasks, significant commitments of student time and effort, and qualitative judgments in the marking process" (Palm, 2019). When assessment criteria are generic, or when rote learning of content is required, it is unlikely that the assessment tasks would meet the criteria of performance assessment (Davies & Ecclestone, 2008). By contrast, authentic assessment in vocational contexts is intended to prepare students for "life beyond the classroom" (Deutscher & Winther, 2019:2). The authentic assessment of vocational subjects combines competence testing with holistic and meaningful forms of assessment. Authentic assessment tasks motivate students to achieve levels of excellence in assessment tasks (Guzzomi, Male & Miller, 2017). A portfolio of evidence that is based on performance assessment and authentic assessment would be "pre-eminently suitable for an assessment approach emphasizing that proof of competence is gathered by having learners perform authentic tasks under changing assessment conditions at regular intervals" (Sluijsmans et al., 2008:159). All students need supportive supervision and feedback on their performance (Amoo & Adam, 2022).

There are concerns about the lack of practical expertise that students demonstrate after completing their NCV programmes (Okoye & Nkanu, 2020). Some researchers claim this lack of practical expertise is caused by the lecturers being unable to impart the necessary practical knowledge to students (Taylor & Van der Bijl, 2018). However, Matabane et al. point to an alternative explanation:

> … although an expert teacher might know what quality teaching and learning means, the system might lead to the teacher's not being productive as s/he is not in a position of power and therefore cannot implement what s/he regards as best practice (2022:59).

The point that these authors make is an important one. They explain that lectures might well have the theoretical and practical knowledge demanded, as well as practical experience, but that they might be constrained in systemic ways from implementing their expertise, for example, by the lack of up-to-date equipment. This is an issue of concern because TVET college lecturers are charged with ensuring that students are ready to enter the workforce and participate in it effectively. The provision of up-to-date training equipment that is aligned with that used by industries is also necessary (Anindo, Mugambi & Matula, 2016). Workshops have been found to be underequipped (Mtshali, 2020), a situation which is of concern as training equipment has a significant impact on students' acquisition of practical skills (Mtshali & Ramaligela, 2020). Several studies of lecturers' teaching methods found that many tended to rely on lectures, demonstrations, and group discussions due to large classes and inadequate training equipment (Zinn et al., 2019).

Several recent studies have pointed to the different mindset of the generation entering TVET in a time of ubiquitous computing, artificial intelligence, smartphones, and so on (Shiohira, 2021). This is a challenge facing education and educators more broadly across education levels within formal schooling and beyond it in a time where students attention spans and desire to sit through scheduled blocks of lessons or lectures is diminishing due to accessibility of online information on demand (McHaney, 2023). Additionally, lecturers should have the necessary knowledge and skills for encouraging environmentally sound, sustainable development and poverty alleviation. College lecturers should also equip students for lifelong learning and responsible citizenship (UNESCO, 2022).

2.5 Conclusion to the review of the literature

To conclude, this literature clearly shows through the research studies reviewed that students' preparation for the world of work is enhanced where curricula are conceptually and contextually relevant (Muller, 2012; Muller & Young, 2019), and where lecturers have both educational knowledge and knowledge of the workplaces that employ students (Gamble, 2013; Taylor & Van der Bijl, 2018), and where lecturers collaborate across areas of strength (Smith, 2018). Lectures (or teaching teams) who can best serve students' requirements in TVET colleges are those who not only possess the necessary industry-linked credentials but also have relevant practical experience combined with pedagogical training (Zeid et al., 2014). If a high quality of teaching and learning is offered in TVET colleges, students are more likely to develop the skills and competencies needed by both developed and developing economies (Zinn et al. 2019). The literature also suggests that many TVET lecturers avoid practical teaching, not necessarily because they lack practical industrial experience or because they are hired as new graduates from vocational and technical institutes and universities, but because the curriculum makes many demands on them, a situation which they might not be empowered to change (Matabane et al., 2022), or well-equipped laboratories and workshops are not always available (Mtshali, 2020). While all lecturers benefit from continuous professional development (Akgunduz & Mesutoglu, 2021) and it might be necessary to address variability in subject proficiency among vocational lecturers (Akoojee, 2008: 299), it should not be assumed that lecturers are at fault. Attempts to impart a working culture to the students should not be ascribed to lecturers, as such attempts could also be hampered by the lack of an industry-aligned working culture within TVET (Chappell & Chapman, 2018). For TVET colleges to transform, they would need many forms of support – of which lecturer support is only one (Zeid et al., 2014).

This review of literature on lecturers' curricular and pedagogical knowledge for the education of electricians reveals a complex landscape. On the one hand, there is a clear emphasis on industry alignment and equipping students with practical skills for the workplace. On the other hand, lecturers grapple with theoretical knowledge, limited resources, and a curriculum that may not fully reflect industry needs. This underscores the importance of frameworks that can analyse not just the content of TVET knowledge, but also the processes by which knowledge is built and legitimated within TVET institutions.

This is where Legitimation Code Theory (LCT) offers a valuable lens. LCT goes beyond surface-level curriculum content to explore the underlying "rules of the game" (Maton, 2014a) that shape what counts as legitimate knowledge in a particular field. By applying LCT to TVET education, we can start to understand how theoretical and practical knowledge are positioned and valued within TVET programs, the power dynamics at play in curriculum development and the unspoken assumptions and dispositions that shape teaching and learning experiences in TVET classrooms. In the next section, LCT is introduced as a way to analyse knowledge-building processes in TVET education, with a specific focus on the case of the NCV-EIC program and the challenges identified in the literature review.

2.6 Theoretical framework: Legitimation Code Theory

In this section, the theoretical framework that guides the research study is explained. Legitimation Code Theory (LCT) (Maton, 2014a) is a social realist theory that reveals the underpinning principles of curricula and practices. LCT has been used across a variety of STEM disciplines and fields, including: primary science education (Lee & Wan, 2018), general science education (Jawahar & Pop, 2019), TVET (Matabane et al., 2022), the STEM disciplines (Dankenbring, Guzey & Bryan, 2024) and engineering education in a variety of contexts (Doorsamy & Bokoro, 2019; Quintana-Cifuentes & Purzer, 2022; Winberg, 2019). For this study, LCT was chosen because it shows how different forms of knowledge contribute to TVET engineering lecturers' ability to facilitate TVET students' learning for different purposes, such as for understanding concepts and for developing practical, work-orientated skills. LCT has many dimensions and the one proposed for this study is the Semantics dimension which has been used in engineering studies (Doorsamy & Bokoro, 2019; Quintana-Cifuentes & Purzer, 2022; Winberg, 2019). Semantics explains that there are two basic features of knowledge that characterise knowledge and knowledge practices, namely semantic density (SD) (or abstract, theoretical knowledge) and semantic gravity (SG) (or practical, applied knowledge). These two knowledge forms have infinite variations, which can be represented by two intersecting continua on a plane (Figure 2.1).

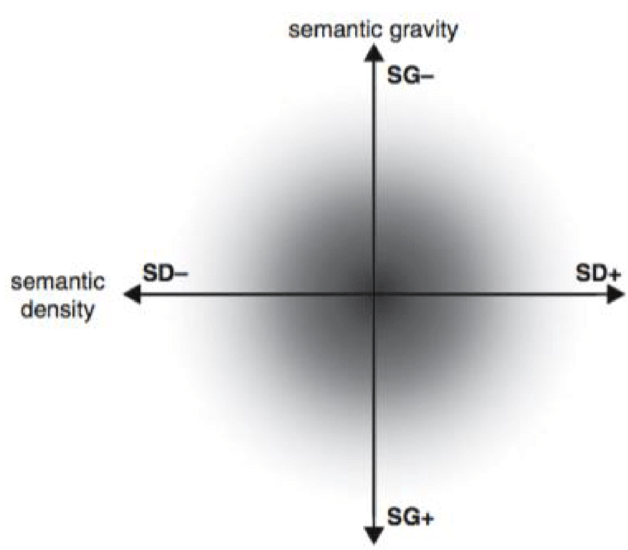


Figure 2.1: The Semantic Plane

(Maton, 2014a:131)[1]

Figure 2.1 shows that semantic density could be stronger (SD+) or weaker (SD-) along a continuum. In other words, a curriculum or a TVET lecturer might shift between more complex (SD+) or less complex (SD-) forms of theoretical knowledge. Semantic gravity also has stronger (SG+) or weaker (SG) forms, indicating that a curriculum or TVET lecture might contain more practical knowledge making the lecture more contextualised (SG+) or less practical knowledge making the lecture less contextualised (SG-). In this study, the concepts of semantic density and semantic gravity were used to characterise forms of knowledge in an engineering curriculum, as well as to characterise the pedagogic practices of lecturers, thus highlighting the strengths and weaknesses of their pedagogic work in terms of the degree of conceptual complexity and degree of contextualisation. Semantics was also drawn upon to determine the extent to which lecturers had attained a mix of theoretical and practical knowledge, with the focus on their practical knowledge, as this is necessary to prepare students for industry. Typically, TVET lecturers would need both theoretical and practical knowledge to teach TVET students and would be expected to engage students along both continua of learning. Clearly, engineering lecturers need theoretical knowledge to explain, for example, concepts in electricity to students; but they would also be expected to facilitate students' practical learning – from active and engaged learning in the classroom to problem-based learning, practical work in laboratories, simulated workplaces, and work-based learning (Ajithkumar & Pilz, 2019). Practical knowledge is crucial for enabling lecturers to bridge the theory-practice gap, from developing students' practical competence through to applying knowledge and skills to tasks, and for increasing their employability (Grollmann, 2018).

In the context of practical work, semantic density indicates lecturers strategic variation in their use of semantic density and can make visible their ability to link theory and practice in drawing on relevant scientific and engineering knowledge to explain and facilitate students' reflection on practical work. In the context of an engineering curriculum, stronger semantic density refers to lecturers' reference to the more complex concepts that underpin practice or facilitate reflection on practice. Typically, terms such as 'explain' or 'reflect' indicate a shift to a higher degree of semantic density in subject outcomes or assessment criteria. Because the degree of complexity is relative, it important to be aware of the shift that is happening between semantic density and semantic gravity, and in what direction the shift is moving. For example, explaining a theoretical concept in simpler terms would decrease the semantic density (SD+↓), while reflecting on practical experience and linking it to concepts or theories would increase the semantic density (SD+↑).

[1] Note that Maton (2014) reverses the standard positioning of the Y-axis to represent the 'downward pull' of gravity. The semantic plane is not intended to be a mathematical representation.

Weaker semantic density refers to more procedural forms of knowledge that are required for practices, such as a list of the components required to install or repair technical equipment. Terms such as 'describe', 'state', 'list', and 'report' are terms associated with weaker forms of semantic density. The terms listed above could be characterised as entailing lower semantic density (SD-) than is associated with conceptual or theoretical knowledge. While semantic density describes more abstract forms of knowledge, semantic gravity describes the contextualisation of practice. Greater semantic gravity characterizes practice, particularly the practical skills associated with technical work. Terms like 'install', 'test', 'maintain', and 'repair' are frequently employed to describe technical work. Weaker semantic gravity describes the less contextualised pre-practice knowledge, while stronger semantic gravity describes activities more closely related to context, such as planning, equipment setup, and other preparations. Following practice, "debriefing" is also associated with weakening semantic gravity and strengthening semantic density for purposes of generalising or reflection that is linked to theory or theoretical concepts.

Where there is stronger semantic density (SD+), there is often weaker semantic gravity (SD-), and vice versa. These changing relationships between semantic density and semantic gravity are often shown as a semantic wave (Figure 2.2).

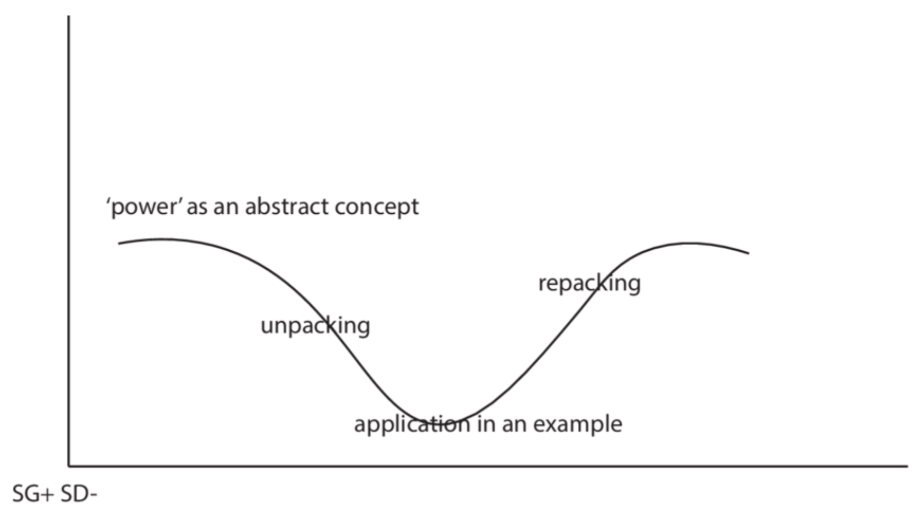


Figure 2.2: A semantic wave
(Clarence, 2016)

In Figure 2.2, a pedagogy for the effective teaching of a practical subject is represented by a semantic wave. The lecturer starts by explaining a concept, such as 'power in this example and then unpacks or explains the concept with examples or analogies. Students then apply the concept in a practical task, after which the lecturer repacks or reflects on the task in the light of the conceptual knowledge that was taught. The semantic wave is an ideal pedagogy that is associated with cumulative, effective learning (Maton, 2014a). It could be expected that most curricular outcomes and evaluation criteria in a TVET practical subject would demonstrate greater semantic gravity than in more theoretical courses. The Semantics dimension is appropriate for understanding learning through practical work, how different forms of practical work differ across a continuum, and how the theory-practice divide could be bridged by different forms of practical work.

Maton (2019) points out that the greater 'generating power' offered by LCT's Semantics dimension is to avoid a deep-seated dichotomies in general vs technical education:

> Education debates have been dominated by a recurring opposition between 'theoretical' and 'practical' knowledges. This takes many forms, including 'academic' / 'everyday', 'commonsense' / 'uncommonsense', and 'horizontal' / 'vertical'. These pairs are usually represented as exhaustive and mutually exclusive. However, semantic codes reveal this opposition as false. Using the new concepts, the oppositions offered in debates can be understood as representing rhizomatic codes (SG–, SD+) and prosaic codes (SG+, SD–), respectively. Put simply, each of the pairs contrast context-independent and complex knowledge with context-dependent and simpler knowledge. They thereby exclude the possibility of rarefied codes (SG–, SD–) of knowledge that is context-independent but condenses few meanings (such as empty jargon) and worldly codes (SG+, SD+) of knowledge that is context dependent but complex (such as professional and vocational knowledge). Semantic codes thus allow us to see what has been previously hidden by debates and dominant thinking in education (2019:5).

2.5.1 A practical theory for studying practical work

The difference between practical work undertaken as part of an internship or other forms of workplace learning, and practical work done in college laboratories, studios, or simulated office environments, is the presence or absence of the real work context. It is important, however, that practical learning in TVET colleges is purposefully aligned with industry standards and practices to construct meaningful knowledge development, skills acquisition and practical competence (Rauner et al., 2012). The Semantics dimension enables theory- and research-informed decision making regarding appropriate forms of practical work within a practical subject and across a vocational curriculum more generally. Together, semantic density and semantic gravity make visible the knowledge practices in educational contexts, including vocational education, by identifying a range of possible semantic profiles that typify particular programmes and their "signature pedagogies" (Shulman, 1987: 8). The theoretical component of a vocational subject is likely to have stronger semantic density and weaker semantic gravity than the practical component of the subject which is likely to have stronger semantic gravity and weaker semantic density. Both semantic gravity and semantic density can be operationalised across a particular curriculum to reveal its semantic profile (Maton, 2013). The study draws on the concepts of semantic gravity and semantic density to identify best practices in practical work from the literature, as well as to compare the semantic profiles of vocational subjects with international best practices.

←Stronger semantic density/weaker semantic gravity			**Weaker semantic density/stronger sematic gravity→**		
Theory-based vocational subjects			Practical and workplace learning		
Lecture	Classroom	Tutorial	Laboratory	Site visits	Workplace

←--Sites of Learning---→

Figure 2.3: Different forms of practical work in TVET engineering

A continuum of practical learning (Figure 2.3) – from active and engaged classroom learning, problem-based learning in tutorials, practical work in laboratories, to site visits or observations, and work-based learning – is generally necessary to bridge the theory-practice gap towards developing students' ability to apply knowledge and skills to tasks, and to improve their employability (Grollman, 2018).

2.6.2 Translation device

To operationalize LCT's Semantics for this study of TVET lecturers' preparation for facilitating TVET students' development, a "translation device" (Maton & Tsai-Hung Chen, 2016) was required to connect the high-level concepts of semantic gravity and semantic density with their application to a specific engineering context. Based on the key concepts with regard to curricular and pedagogical tasks for engineering education identified in the literature review and the principles of sematic gravity and semantic density, a translation device (Table 2.1) was developed to analyse the study findings.

Table 2.1: Translation device for analysis of engineering curricula and pedagogy

Range	Knowledge description	Codes	Values	Task descriptors
↕	Scientific knowledge	SG-, SD++	4	Explain/reflect
	Applied knowledge	SG+, SD+	3	Apply/debrief
	Procedural knowledge	SG+, SD-	2	Plan/report
	Practical knowledge	SG++, SD-	1	Install, test, maintain, repair

Weaker semantic gravity (SG-) indicates the foregrounding of concepts and principles, while stronger semantic gravity (SG+) is evident in contextually embedded forms of knowledge that develop through practice and that are often tacit and difficult to explain and to teach. The arrow in the "Range" column indicates that weaker and stronger forms of semantic gravity can be positioned along a continuum. The difference between practical work undertaken as part of an internship or other form of workplace learning, and the training implied by practical outcomes within a TVET subject, is the presence or absence of real work. While there are many forms of learning in TVET engineering, such as active and engaged classroom learning, problem-based learning, laboratory work, and simulations, these would not be equivalent to actual workplace practice. However practical work, such a projects undertaken in laboratories, is likely to have stronger semantic gravity and might adapt ideas from actual work practices. Curricular and pedagogical practices are likely to draw on a range of knowledge types: concepts from the basic sciences and the engineering sciences; codified forms of procedural knowledge; and practical knowledge arising from practical tasks and activities.

The translation device (Table 2.1) ascribes numerical values for the combinations of SG and SD as shown on the table. Practical knowledge (SG++,SD-) was given the value of 1; procedural knowledge (SG+,SD-) was given the value of 2; engineering knowledge (SG+,SD+) was given the value of 3; and scientific knowledge was given the value of 4. These numerical values enabled the plotting of subject content on the semantic plane. The resultant “semantic profile” (Maton 2014a) makes visible the extent to which the subject outcomes include both stronger or weaker semantic gravity and stronger or weaker semantic density. While the full range of semantic density and semantic gravity is expected across a vocational programme, in practical subjects, it would be expected that the focus would be on stronger semantic gravity and weaker semantic density.

Cumulative learning, or traversing the full extent of the semantic gravity and semantic density range, has been shown to enable students to draw on theoretical concepts to formulate solutions to the challenges that they confront in practice (Maton, 2014a). The translation device (Table 2.1) was used to make visible the extent to which the studies focused on different forms of knowledge in practical training and provided the theoretical basis from which curricular and pedagogical practices in vocational subjects could be critically appraised. The translation device is further developed in the V-model below:

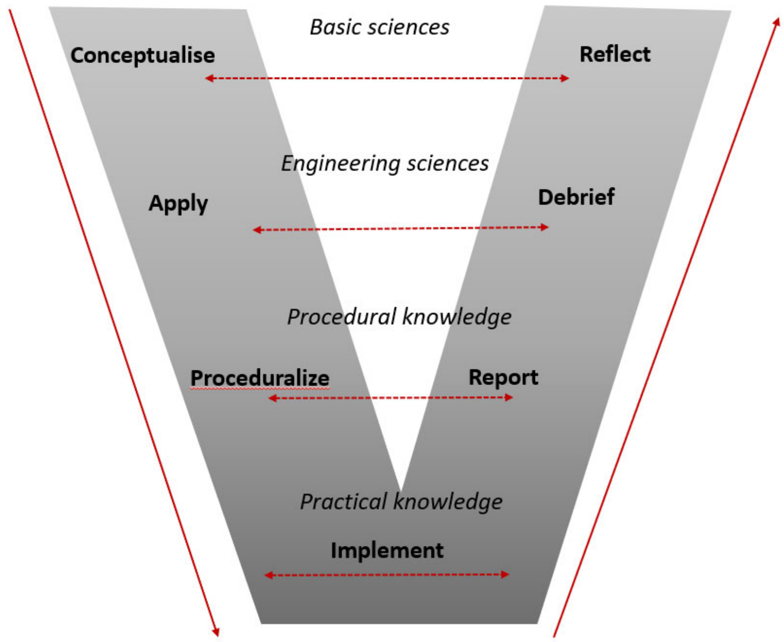


Figure 2.4: A representation of knowledge and pedagogy in vocational engineering

The V-model (Figure 2.4) is a graphical representation of a vocational engineering curriculum and pedagogy. The labels in italics represent the forms of knowledge in the curriculum: the basic sciences, the engineering sciences, procedural knowledge and practical knowledge. Pedagogy is represented in the downstroke and upstroke of the V. The lecture initially explains the conceptual, basic scientific knowledge that underpins practice; the lecturer then introduces the relevant applied engineering knowledge. This is followed by procedural knowledge, including the important safety procedures, before an appropriate, work-orientated practical task is given. Following implementation, there is reporting on the tasks – particularly on the procedures undertaken, with debriefing through, for example, formative assessment, and finally reflection on the task, drawing on the basic and engineering sciences. This pedagogy has been represented in the form of a stylized "semantic wave" (Maton, 2014b) in which the curriculum involves shifts from conceptual, to applied, to procedural to contextual, and then back up the wave to procedural, applied and conceptual knowledge. The activities of conceptualising, applying, proceduralizing, and implementing support the students' acquisition of the different knowledge forms. Travelling back up the wave, following implementation, the students engage in reporting (usually on the procedures, thereby consolidating procedural knowledge), debriefing (on the results of the implementation in order to consolidate applied knowledge) and, finally, critically reflecting (on the results or outcomes in order to consolidate conceptual or theoretical knowledge). Semantics explains that it is insufficient to travel only down the wave from theory to implementation because, for there to be cumulative learning, which happens through different forms of reflection on practice (usually reporting, debriefing and reflection on theory in vocational education), both travelling down and travelling up the wave is necessary in order to avoid segmented learning.

The ideal semantic profile for a practical curriculum is illustrated in Figure 2.5. “Flatlining” at level 1, that is, stronger semantic gravity, would not enhance practical competence. Thus, the ideal profile might start with theoretical explanations of practice (4) and relevant engineering knowledge (3), instruct students on the procedures to follow to enable students to plan their practical task (2), then involve implementation of a practical task (1). Before going on to the next task, students would report on the practical task (2), ‘debrief’ (3), and draw on theory to reflect on their learning (4). This profile is key to effective practical training. However, it would be important that the majority of the outcomes in a practical subject show stronger semantic gravity and weaker semantic density.

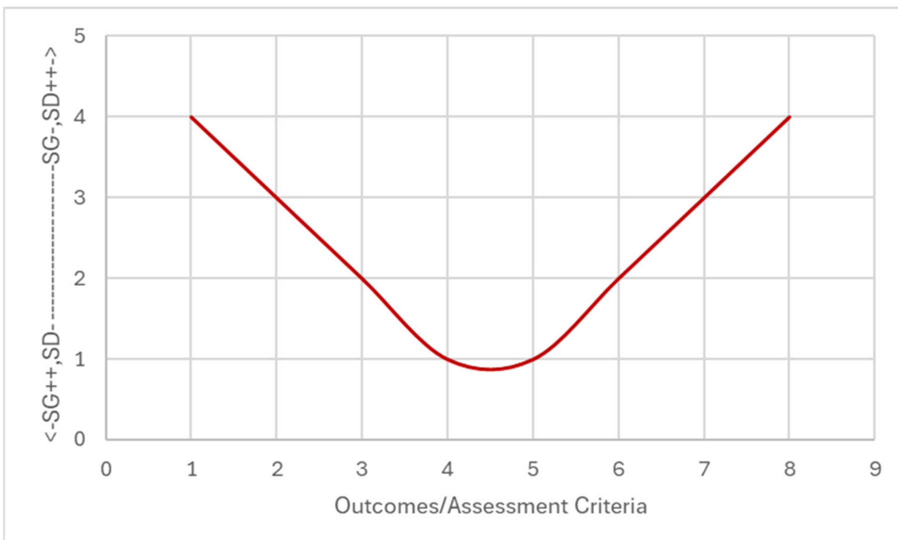


Figure 2.5: An ideal semantic profile for engineering

There are likely to be several iterations of this profile in a practical subject; and when these profiles are joined together across the practical subject, the resultant sematic profile becomes a semantic wave (Figure 2.6).

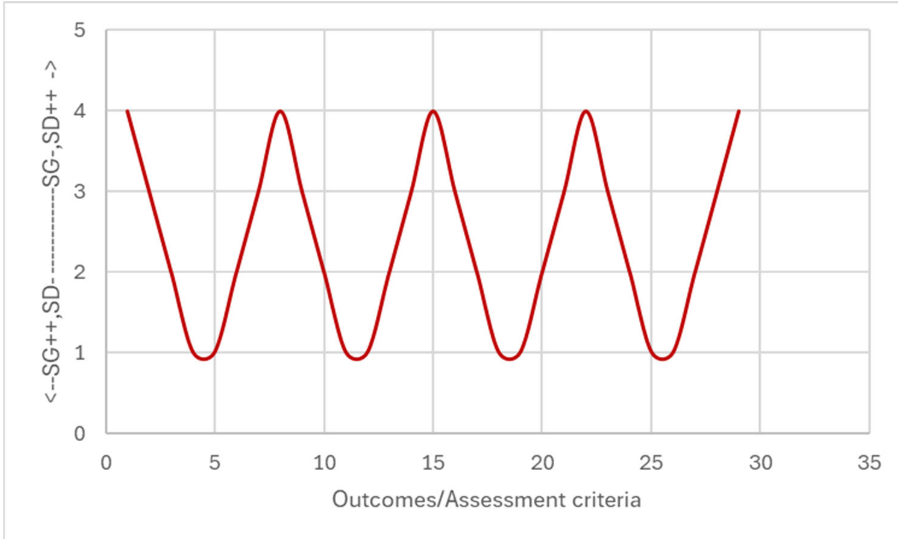


Figure 2.6: An ideal semantic wave for engineering education pedagogy

Figure 2.6 shows that engineering education pedagogy usually begins with conceptual input (SG-,SD++) then shifts down and back up the scale. In this way texts and practical tasks create a semantic wave over the course of a practical subject. These shifts up and down the semantic density and semantic gravity range enable cumulative learning (Maton, 2014a). The rises in the wave shown in Figure 2.2 represent the important theoretical and engineering concepts that can be drawn on to explain practice and that enable students to reflect on practice towards improvement. The troughs in the wave represent highly contextualised activities.

In the study, ideal semantic profiles in which the concepts or theory were the starting point were referred to and compared with the actual semantic profiles that were evident in the outcomes of the Electrical Workmanship 4 course that is the focus of the study. In the next chapter, before the translation device is applied, the research methodology is discussed and justified.

CHAPTER THREE:
A METHODOLOGY FOR RESEARCHING CURRICULA AND PEDAGOGICAL PRACTICES

3.1 Introduction

The research design for the study of how students are prepared for industry is discussed in Section 3.2. Section 3.3 then justifies the selection of the practical subject, the study sites and participants. In Sections 3.4 and 3.5 respectively, the data collection methods and data analysis methods are explained. The trustworthiness of the data is explained and justified in Section 3.6. Section 3.7 explains the positionality of the researcher; and Section 3.8 addresses the study's ethical considerations, including ethics clearance and permissions. Section 3.10 concludes the methodology chapter.

3.2 Research design

The ontological foundation of the research design for this study is social realism (Archer et al., 2013), a philosophical perspective that seeks to understand the structures and mechanisms that underpin social phenomena. Social realism recognises that an external reality exists independently of human perceptions but acknowledges that human understanding of this reality is mediated by interpretations and experiences. In the context of qualitative research, a social realist approach aims to uncover the deeper structures and causal mechanisms that shape social phenomena, while also recognizing the importance of context and interpretation (Maxwell, 2012). Thus, while recognising the existence of external structures, a realist approach acknowledges that understanding is mediated by human interpretation. Researchers using a realist approach in qualitative research recognise the importance of exploring how individuals interpret and make sense of their experiences within specific contexts (Maxwell, 2012). The research design for the study also drew on realist evaluation principles (Pawson & Tilley, 1997). Pawson and Tilley (1997) argue that realist evaluation needs to be realistic, by which they mean that the methodology needs to be accessible and the recommendations implementable for those who are likely to use the research findings. Both formative and summative realist evaluations need to be based on clear criteria (Pawson & Tilley, 1997).

The translation device for the analysis of curriculum and pedagogy in TVET engineering (Table 2.1) is based on the literature on TVET engineering and on educational theory. The research data were studied with realist evaluation questions in mind, such as: 1) Do the lecturers have the relevant underpinning scientific knowledge for engineering work?; 2) Do they have the applied engineering knowledge?; 3) Do they have the technical knowledge/skills for facilitating a practical task?; 4) Do they facilitate students' engagement in practical activities that are close to, or prepare them for, the industry equivalent?; 5) Do they require students to write a report on practical tasks?; 6) Do they provide constructive feedback on practical work?; and 7) Do lecturers help students to reflect on the practical task, including drawing on relevant scientific and engineering knowledge to explain errors and enhance future practice?

The research design drew on Maxwell's interactive research design model which shows how all parts of the research design are related and aligned with one another (Figure 3.1).

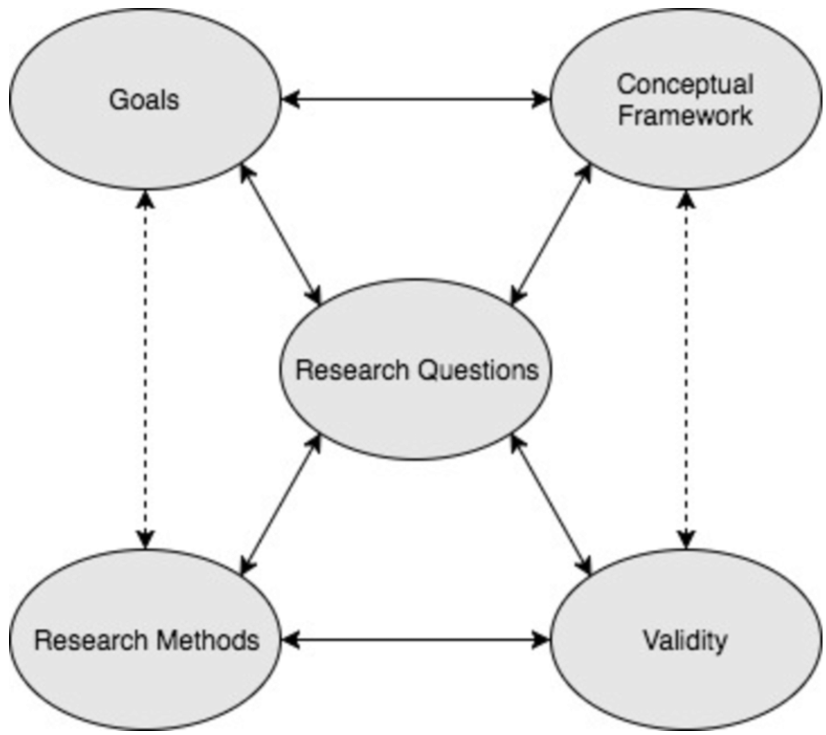


Figure 3.1: An interactive model of research design (Maxwell, 2012: 78)

Maxwell's model, which could be understood as a version of the "golden thread" (Leedy & Ormrod, 2019), was adapted for the study of how engineering lecturers prepare students for the world of work in the following ways:

3.2.1 Goals

The aim of this study was to investigate the quality of teaching in an engineering programme for the purpose of preparing students for the world of work. The objective was to understand TVET engineering lecturers' strengths and challenges and propose constructive solutions to the challenges. Uncovering lecturers' practices, their knowledge and experience of the engineering trades, and their pedagogical approaches, provided the central logic for the research design.

3.2.2 Research questions

The need for qualified and effective lecturers in NCV programmes underpins the specific focus of this study. Consequently, the study responds to the following main research question: How do NCV EIC lecturers prepare students for industry?; and its component sub-questions: How does the NCV EIC curriculum prepare students for industry?; and What prior education, training and experience do NCV lecturers draw on in preparing students for industry?

3.2.3 Conceptual framework

The conceptual framework was derived from LCT's Semantics dimension and is founded on a realist epistemology that seeks to uncover the underlying social structures and mechanisms of curricular and pedagogical practices. The realist position is that reality exists independently of individuals' interpretations (Maxwell, 2012; Maton, 2014). For example, the knowledge bases of engineering education practice in TVET exist independently of the curriculum developers and lecturers. However, the curriculum developers and TVET engineering lecturers have different interpretations and understandings of the curriculum and of what is important for student success in the engineering trades. A qualitative approach in this study was justified as the researcher needed to access TVET lecturers' experiences and perspectives on their training, their choice of pedagogy, and so forth. To assess the lecturers' theoretical and practical knowledge of electrical engineering, it was thus important to elicit from lecturers how they interpreted curriculum documents and made pedagogical and assessment choices.

The study employed a qualitative approach because the research problem, namely the preparation of TVET engineering students for the world of work, required "inquiring into the meaning that individuals or groups attribute to social or human problems" (Creswell & Poth, 2016:37). A qualitative approach enables an exploration of "the world of human experience" (Cohen & Manion, 1994:36), thus interpretivist researchers discover reality through participants' views, backgrounds and experiences (Yanow & Schwartz-Shea, 2015; Creswell & Poth, 2016). Researchers who seek to understand participants' positions "tend to favour qualitative methods such as case studies and ethnography" (Willis et al., 2007: 90). This is because qualitative approaches provide researchers with the rich and deep data that are necessary to fully understand contexts. A qualitative approach was thus used in this study to foreground the experiences, understandings and perceptions of the research participants (Yanow & Schwartz-Shea, 2015).

3.2.4 Methods

Two main research methods were used. Firstly, a document study of the curriculum was undertaken, including the official study and assessment guides and textbooks, to develop an understanding of the lecturers' teaching contexts. Secondly, semi-structured interviews were used to explore engineering lecturers' subjective meanings, while the translation device (Table 2.1) enabled an examination of underlying patterns and structures. Section 3.4 provides the details and rationale for the data collection and data analysis methods.

3.2.5 Validity

Content validity for the study was provided by the translation device (Table 2.1) that was developed from the empirical research literature on engineering education in TVET, as well as educational theory (Maton, 2014a; Maton, 2014b). The translation device guided the study – for example, the main research instrument, a semi-structured interview, was based on the translation device developed for qualitative research (Maton, 2016). The translation device adequately covers the curricular and pedagogical range required to facilitate practical work in TVET colleges. Construct validity was ensured through the consistent use of the translation device to represent curricular content and pedagogical practices accurately and reliably. The translation device correlates with external criteria (that is, scientific, engineering, procedural and practical knowledge) that are known to be valid through both empirical research findings in the literature, as well as from educational theory. The study can therefore be said to have criterion-related validity.

3.3 Subject, site, and participant selection

For this study, a suitable subject had to be selected: one that included a practical component and which was specifically intended to prepare students for the world of work. Suitable college sites had to be selected, and participants had to meet relevant selection criteria.

3.3.1 Subject selection

The NCV EIC is the case under investigation for the reasons explained in Chapter 1; it is a case worthy of being explored because of its importance for the South African development economy which has an urgent need for skilled installation electricians to maintain, repair and replace electrical infrastructure. The NCV EIC is a qualification that has the intention of integrating academic knowledge with practical skills to prepare students for careers as installation technicians.

The subject Electrical Workmanship 4 (NQF Level 4) was selected as a practical subject intended to facilitate students' mastery of the key skills and practices required for the installation, testing, maintenance, and repair of electrical infrastructure. As a subject, Electrical Workmanship 4 focuses on practical electrical skills development, although students also extend their theoretical knowledge in the course. The course prepares students for employment as an installation electrician in residential, commercial, and light industrial contexts of electrical infrastructure, or to be self-employed.

3.3.2 Site selection

Three college sites in the Western Cape were selected for the study: one in an urban setting, one in a peri-urban/township setting, and one in a rural setting. The following selection criteria were applied to the selection of the three college sites:

- The TVET colleges sites should offer the NCV EIC from NQF levels 2–4;
- The TVET college should offer Electrical Workmanship 4;
- The TVET college sites should be representative of both urban, peri-urban/township and rural settings (i.e., Site 1 was urban, Site 2 was peri-urban, and Site 3 was rural)
- The TVET college sites should represent the diversity of TVET provision in South Africa across urban, rural and peri-urban/township sites; and
- The TVET college sites should have established partnerships with appropriate industries, private power providers, and/or public/private partnerships in the region.

The selection criteria are summarised in Table 3.1.

Table 3.1: Site selection criteria.

Criteria	Description	Rationale
Program Offered	NCV Electrical Infrastructure Construction (EIC) from NQF Levels 2-4	Ensures the colleges offer the specific program under investigation.
Course Offered	Electrical Workmanship 4 (EW4)	Ensures the colleges provide the practical component relevant to the study.
Location Type	Urban, Peri-urban/Township, Rural	Represents the diversity of TVET college settings in South Africa.
Provision Diversity	Reflects diverse TVET provision models (public, private, etc.)	Captures a broader range of TVET college experiences.
Industry Partnerships	Established partnerships with relevant industries (electrical), private power providers, or public-private partnerships	Investigates the potential impact of industry collaboration on program quality.

3.3.3 Participant selection

EIC lecturers were the focal point of this investigation, so their perspectives and experiences were central to the study. Participants were purposively sampled for the study (Table 3.1). Purposive sampling entails selecting information-rich cases that are especially helpful for comprehending the research query. In this manner, the researcher selects cases that best answer the research query or provide pertinent insights (Schreier, 2018:85). In accordance with this, a complete sample of TVET lecturers who teach Electrical Workmanship 4 at each of the three selected sites was selected and invited to participate in the study. Ten of the participants who agreed to take part in the study were included and criteria were applied to ensure that the sample was representative of language, race, gender and educational levels of TVET lecturers and students. The criteria for lecturer selection were as follows:

- Lecturers with and without educational qualifications were included;
- Lecturers with and without vocational certification (e.g., a trade test) were included;
- Lecturers with various industry experience were included;
- Lecturers were representative of both genders; and
- Lecturers were representative of national South African demographics.

Table 3.2: Description of research participants

Lecturer	Sex	"Race"	College site	Formal qualifications: Engineering	Trade Test	Formal education qualification	Other education certificate
Angela	F	White	Urban	N Dip (Electrical Eng.)	-	PGCE (TVET)	AutoCAD Certificate
Bertus	M	Coloured	Urban	NATED (Electrical) NATED (Mechanical)	Electrician	-	Assessor (SACE) Moderator (SACE)
Cebo	M	African	Urban	N Dip (Electrical Eng.) BTech (Electrical Eng.)	Electrician	PGCE (TVET) B Ed (Hons) (TVET)	Assessor (SACE) Moderator (SACE)
Dumisani	M	African	Town-ship	N Dip (Electrical Eng.) BTech (Electrical Eng.)	-	PGCE (TVET)	-
Esihle	F	African	Town-ship	N. Dip (Electrical Eng.)	-	PGCE (TVET)	-
Fezile	M	African	Town-ship	N Dip (Electrical Eng.) BTech (Electrical Eng.)	-	PGCE (TVET)	-
Gcobani	M	African	Town-ship	N Dip (Electrical Eng.) BTech (Electrical Eng. MEng (Mechatronics)	Electrician	PGCE (TVET)	-
Hennie	M	White	Rural	N Dip (Electrical Eng.)	Electrician	-	-
Isaac	M	Coloured	Rural	BTech (Electrical Eng.)	Electrician		
Jane	F	Coloured	Rural	N Dip (Mechanical Eng.)	-	PGCE (TVET)	Assessor (SACE) Moderator (SACE)

3.4 Data collection methods

Data were collected from two sources: 1) from a study of curriculum documents and related texts; and 2) from semi-structured interviews with relevant TVET college lecturers. In order to acquire a comprehensive understanding of how lecturers prepared students for the world of work, both curriculum data and interview data were required. Hence, this study used documentary study and semi-structured interviews to gather data. The data collection methods are fully described in the Sections 3.4.1 and 3.4.2.

3.4.1 Curriculum data

Documents are “any written material … that was not prepared in response to the investigator's specific requests” (Ahmed, 2010:2). In this instance, the documents were curriculum-related, specifically the Electrical Workmanship Subject Guide 4 (2015) and the Electrical Workmanship Assessment Guide 4 (2015). The latter contained the guidelines for Internal Continuous Assessment (ICASS), External Summative Assessment (ESASS), and the Integrated Summative Assessment Task (ISAT) for the Electrical Workmanship 4 subject. The prescribed textbook for Electrical Workmanship 4 was included in the curricular documents. An earlier version of the textbook, as well as the more recent one, were included, as most students were using the older (2008) version which is available free of charge online. The 2015 version contains much of the same material but includes new sections of the course (such as Illumination) that were added in 2015. At the time of this study, the new textbook cost R559.00, unaffordable for most students. The curriculum documents were studied to understand the curriculum and assessment logic. This study provided a comprehensive overview of the lecturers' expected level of competency. The curriculum documents used in the study are shown in Table 3.2.

Table 3.3: Curriculum data

Curriculum Documents	NQF Level	Year	Abbreviation
Electrical Workmanship Subject Guide	4	2015	EWSG 4
Electrical Workmanship Assessment Guide	4	2015	EWAG 4
Textbook			
Jowaheer, S. *Electrical workmanship NQF: Level 4: Student's book*. Troupant/MacMillan.	4	2008	EW Textbook (2008)
Jowaheer Consulting and Technologies. *Electrical workmanship NQF: Level 4: Student's book*. Troupant.	4	2014	EW Textbook (2014)

Occupational standards for installation electricians and related occupations (OFO 671101) were studied with a view to understanding the occupation roles, particularly in infrastructure construction. Job advertisements for electricians in the broad field of infrastructure construction and distribution systems were studied over the January to May 2020 period. The intention was to understand the particular occupational roles advertised, as well as the skill sets that employers were seeking. The Electrical Workmanship 4 subject outcomes were compared with the QCTO Computer Technician occupational standard, as well as with recent job advertisements, to evaluate the extent to which the Electrical Workmanship 4 subject outcomes aligned with the occupational standard and the certifications and skills that employers were seeking. The assessment criteria, as specified in the Assessment Guides for the selected subjects, were similarly compared to the occupational specifications and industry needs.

3.4.2 Semi-structured interviews

Qualitative data collection methods prioritize the perspectives and experiences of individuals and seek to convey their complexity and richness (Adeoye-Olatunde & Olenik, 2021). This typically entails accumulating data from a relatively small sample size to generate detailed and comprehensive information about the phenomenon of interest (Braun & Clarke, 2019). Semi-structured interviews are associated with qualitative research (Walther et al., 2016) as these interviews attempt to access the subjective understanding of individuals, recognising that people interpret and give meaning to their experiences in unique ways – but they also provide structure for interviews which, in this case, was derived from the translation device. The appropriateness of semi-structured interviews is further justified by their use in engineering education, such as in a study on diversity in engineering faculty staff (Kirn et al., 2019) and a study on engineering education researchers' practices (Walther et al., 2013).

Semi-structured interviews with EIC students and lecturers were the study's primary source of data. For the semi-structured interview protocol used in the study, please refer to Appendix A which includes the covering letter to participants and the list of interview questions. The prompts for questions are included; these were used by the researcher but were not provided to the participants.

A semi-structured interview includes "both open-ended and more theoretically driven questions, eliciting data grounded in the experience of the participant as well as data guided by existing constructs in the particular discipline within which one is conducting research" (Galletta, 2013:24). To be effective, semi-structured interviews must demonstrate "reciprocity" and "reflexivity" (Galletta, 2013:76). To achieve reciprocity and reflexivity, participants must engage in "clarification, meaning-making, and critical reflection" (Galletta, 2013:78). Reciprocity and reflection were incorporated into the interviews by allowing for exchanges between interviewee and interviewer, and through the interviewer probing the interviewees for more information about, and reflection on, their teaching and learning practices. Through semi-structured interviews, the interviewee can be prompted to provide more detail, as well as provide specific and more descriptive responses.

The interviewees who had a wide range of qualifications (in the EIC field and in education) and experience (within education and industry) provided variety and depth to the interview process. Ten lecturers were interviewed, following Galletta's (2013) guidelines for semi-structured interviews. The interviews were also conducted over time, usually in two parts, because this “creates space for both interviewee and interviewer to reflect more deeply on responses to interview questions and to revisit points from a previous session” (Galletta, 2013:78). Each lecturer was invited to an initial interview estimated to take approximately 45 minutes to one hour. A follow-up interview was requested in cases where further clarity was necessary.

In cases where some participants preferred an online interview, best practices for video-conferencing software usage in semi-structured interviews were adhered to (Archibald et al., 2019). The interviews were conducted during working hours (lunch breaks), thus ensuring that all participants had access to college-wide Wi-Fi. Some interviews were conducted via MS Teams.

3.5. Data analysis

The translation device was applied to analyse both the curricular and interview data; however, the analyses of documents and interview data followed different processes, which are outlined below.

3.5.1 Document data analysis

Qualitative document analysis (QDA) is “a research method for rigorously and systematically analysing the contents of written documents. The approach is used … to facilitate impartial and consistent analysis of written policies” (Ward & Ward, 2013:1). QDA, which was used to analyse the curriculum and related documents, requires two rounds of analysis: the first addresses the underpinning principles (in this case, the curricular provisions, requirements and logic); and the second compares the principles and practices across the selected documents to establish levels of coherence. Thus, curriculum documents were studied to identify and understand the scope of the lecturers’ expected practice, including the explicit and implied competencies and qualifications.

3.5.2 Interview data analysis

Semi-structured interviews generate an abundance of data. The interview data analysis adhered to Roulston's three steps: 1) data reduction; 2) data reorganization; and 3) data representation (Roulston, 2014:301). Data reduction involves “cleaning” and anonymizing the data, whereas “data reorganization” largely consists of data coding, Saldaña’s (2021) five-part coding system was followed and comprises the fofllowing: 1) labelling the data; 2) defining the characteristics of the data; 3) clustering the data into categories and themes; 4) qualifying themes and exclusions to the themes; and 5) selecting positive and negative examples of the themes. Stages 3–4 of Saldaña’s system were informed by the codes derived from LCT’s Semantics dimension, such as whether a response indicated higher semantic density and lower semantic gravity (e.g., theory-oriented), higher semantic gravity and lower semantic density (i.e., oriented towards practical tasks).

Roulston's approach to the final phase, ‘data representation’, was drawn on so as to “consider assertions and propositions in light of prior research and theory in order to develop arguments” (Roulston, 2014:307). Figure 3.2 provides an example of the data analysis process:

FIRST INTERVIEW: GCOBANI			**EMERGING**	**THEORETICAL**
SPEAKER	**TRANSCRIPTION**	**IN VIVO**	**THEMES**	**CODING**
GCOBANI	Before I became a lecturer of NCV I used to work, I was an electrician [indistinct]. So I gained a lot of experience when it comes to electrical department, electrical equipment. So at some point I know [indistinct] I understand most of the things or most of [indistinct] electricity [indistinct]. So I end up having that passion to take out the information that was within me [indistinct] to someone else because I had a lot of experience when it comes to electrical equipment whereby I can count [indistinct] also building generators and so forth and so forth. So I was working with it so now I wanted to take that information and pass it through to the next generation therefore I decided to [indistinct].	*I was an electrician [indistinct]. So I gained a lot of experience when it comes to electrical department, electrical equipment. ... I understand most of the things or most of [indistinct] electricity [indistinct ... because I had a lot of experience when it comes to electrical equipment whereby I can count [indistinct] also building generators and so forth and so forth*	**Practical experience** as an electrician. Has **applied knowledge** (understands electricity). **Practical experience** with installation (building generators)	SG++, SD- SG+,SD+ SG++,SD-

Figure 3.2
Example of interview data analysis

3.6 Trustworthiness

The term “reliability” refers to the “importance of facts” and the “transparency of the study's conduct” (Denzin, 2012:82). There are two primary considerations regarding the dependability of interview data. The first concerns the reliability and conformability of participants' interviews, while the second concerns the integrity and transferability of the researcher's analysis of the narrative data (Polkinghorne, 2007:471). To address the reliability and conformity of participant narratives, I included curriculum and framework documents in the study. These documents were used to understand the scope of the Electrical Workmanship 4 lecturers' expected practice and to triangulate issues raised in the interviews with the required topics and assessment criteria stated in these documents. This method is recommended by Galletta (2013) who explains that the inclusion of artifacts (e.g., PowerPoint slides) and documents (e.g., lesson plans) is useful for the analysis of semi-structured interview data because it enables a deeper understanding of the research participants’ intentions and actions.

After the interviews were transcribed, each member was sent a copy of their interview transcription so that they could correct errors and contest what they perceived to be incorrect interpretations.

3.7 The researcher's position

As a lecturer at a TVET college, I am an insider in that I have experience and knowledge of the TVET sector in general and the EIC programme in particular. I was the interviewer for the TVET college lecturer data collection. The interviewees were my peers, which implies that there was little to no power differential between us. They did not report to me and I had no authority over them. Thus, they were free to decline an invitation to be interviewed, or to chose not to answer any question. My responsibility was to establish a rapport of trust with the lecturers who taught the EW subjects. I have a high regard for technical and vocational education, respect all my colleagues, and have compassion for those who must teach outside their area of expertise. It was my intention to treat lecturers with the utmost respect in the course of a study where the aim was to help them to understanding and receive the support they might require to become more proficient educators. As the interviewer, I posed all the questions to the participants. To avoid researcher bias, I ensured that there were member-checks of the interview transcriptions and analyses.

3.8 Ethical considerations

Research ethics play a crucial role in ensuring that no poorly designed or harmful research is authorized (Israel, 2014). In South Africa, the Protection of Personal Information Act (POPIA) No. 4 of 2013 came into effect on July 1, 2021 and it has impacted research ethics. As a lecturer at The TVET College, I paid particular attention to ethical considerations and POPIA requirements during the planning and execution of the research. I paid special attention to obtaining informed consent and using pseudonyms to protect the identities of the institutions and interviewees. Appendix A iincludes the letter of information requesting participant consent, and it also provided the participants with the list of the questions that they would be asked.

For the purposes of this study, the interviews were conducted at the times and dates chosen by the participants selected. A conducive environment, such as the interviewee's own office, and ample time for the interviewees to describe their experiences as TVET lecturers were provided. Any participant was free to leave the study and/or withdraw their permission to participate at any time.

3.8.1 Access and permission

Ethics clearance was obtained from the Education Faculty of the Cape Peninsula University of Technology (see Ethics Letter, Appendix B). Once approval had been confirmed, I then requested permission to conduct the research at the TVET college sites by writing to the CEO and campus administration. It should be noted that the TVET colleges fall under the DHET's Technical and Vocational Education and Training Directorate.

This study is supported by the Vocational Education and Training Directorate and is part of a larger ‘Evaluating TVET’ project that has the purpose of improving provision at TVET more generally. A letter of authorization from the Technical and Vocational Education and Training Directorate to conduct research at public TVET college sites was sent to the supervisor and postgraduate candidate. The additional permissions documents are included in Appendix B.

3.8.2 Confidentiality

Interviewees were informed that their names had been replaced with pseudonyms, and that their TVET institutions and departments were not named. Interviewees were also told that all interview recordings and notes and contact information would be stored in a locked filing cabinet at the researcher’s home, with only the researcher having access to the key. Electronic copies were encrypted and stored on the candidate and supervisors’ personal laptops. Following the recommendations of POPIA, anonymised transcripts could be kept, but all recordings and notes would be destroyed. Data management had to comply with CPUT’s requirements, for example, the university library provides secure storage for anonymised data.

3.8.3 Informed consent

It is important to ensure compliance with POPIA in all aspects of research practice, but particularly in handling informed consent. Ethics concerns were firstly addressed by informing all participants of the purpose of the study. In addition, each participant was provided with a consent form that explained that their participation was entirely voluntary. As informed consent “involves autonomy, and it derives from the participants' right to freedom and autonomy” (Neuman, 2014), I informed all participants that they had the right to withdraw from the study at any time and that they were welcome to ask questions at any time. Each participant received a copy of the signed informed consent form, and they were informed that they would each receive a copy of the final thesis.

3.9 Conclusion

This chapter has explained the research design and research methodology used in this study. In addition, the chapter expanded on the identified population and the sampling methods used in the study. The methods and procedures used in the data collection for the study, namely, data scrutiny and semi-structured interviews, were also clarified in this chapter. This chapter further explained the presentation and the analysis of the data. The findings of the study are presented, interpreted, and discussed in the chapters that follow.

CHAPTER FOUR:
CURRICULUM FINDINGS

4.1 Introduction

Section 4.2 provides an overview of the NCV-EIC curriculum and thereafter the focus in on the Electrical Workmanship NQF Level 4 subject. Section 4.3 and its sub-sections provide a detailed description of the Electrical Workmanship 4 curriculum, while Section 4.4 provides a brief overview of the prescribed textbook for Electrical Workmanship 4. Section 4.5 provides a LCT semantic analysis of Electrical Workmanship 4; and the chapter ends with reflections on the NVC EIC and Electrical Workmanship 4 – in particular the relationship between the curriculum (i.e., its subject outcomes and assessment criteria) and industry specifications and employment requirements – and whether a student emerging from the NVC EIC is likely to be effective in employment.

4.2 The National Curriculum Vocational: Electrical Infrastructure Construction (NCV EIC) Curriculum

The intention of the NCV EIC is to build capacity and experience in the electrical sector for the installation, expansion and evaluation of electrical transmission networks, substations and electrical reticulation and distribution infrastructure. The NCV EIC is a three-year qualification at NQF Levels 2, 3 and 4. The minimum entrance requirement for the NCV EIC is a Grade 9 Certificate with Mathematics and Physical Science, or other Level 1 equivalent subjects. The NCV EIC covers these subject areas: 1) heavy current, including overhead power lines, as well as domestic, civil and industrial industries; 2) light current in the form of digital and electronics in the communications, industrial electronics; and 3) sound engineering fields, as well as instrumentation. The NCV EIC aims to prepare students adequately for entry to the world of work by equipping them with practical knowledge and skills associated with electrical infrastructure construction. It is grounded in the South African context, but also comprises global imperatives with the intention of helping the South African economy to compete internationally. This qualification is expected to provide learners with the knowledge, skills, values and attitudes which should allow them admission to learning in the higher education band. The NCV EIC subjects are shown in Table 4.1. The subject in bold, Electrical Workmanship 4, is the focus of the study.

The NCV EIC qualification (Table 4.1) has a total credit value of 130 credits. There are three Fundamental subjects: First Additional Language, Mathematics, and Life Orientation. Each of these subjects is worth 20 credits with Life Orientation worth 10 credits. A learner who chooses the NCV-EIC is required to take the compulsory practical subjects, Workshop Practice (Level 2) and Electrical Workmanship (Levels 3 and 4).

Table 4.1: NCV-EIC subjects

NQF Level	Two	Three	Four
Vocational subjects	1. Electrical Principles and Practice 2. Electronic Control and Digital Electronics 3. Workshop Practice 4. Physical Science* 5. Electrical Systems and Construction* 6. Renewable Energy Technologies*	1. Electrical Principles and Practice 2. Electronic Control and Digital Electronics 3. Electrical Workmanship 4. Electrical Systems and Construction* 5. Physical Science* 6. Renewable Energy Technologies*	1. Electrical Principles and Practice 2. Electronic Control and Digital Electronics **3. Electrical Workmanship** 4. Electrical Systems and Construction* 5. Physical Science* 6. Renewable Energy Technologies*
Fundamental subjects	○ First Additional Language ○ Mathematics ○ Life Orientation	○ First Additional Language ○ Mathematics ○ Life Orientation	○ First Additional Language ○ Mathematics ○ Life Orientation

Source: DHET (2020).

The qualification has the intention to equip students with both the theory and the practice of electrical infrastructure construction; but the brief course description above suggests a partial mismatch between the course title (Electrical Infrastructure Construction) and some of the course content. This mismatch is possibly caused by the large number of specializations within the NCV-EIC, such as industrial engineering, sound technology, theatre technology, process level control and digital electronics instrumentation. The course description suggests that graduates of the programme could expect to find work at a power station, at an energy producing company or power plant, a telecommunications company, or recording studio.

The NCV-EIC subjects are shown in Table 4.1 and include two theory-based subjects which are taken across Levels 2 to 4: 1) Electrical Principles and Practice; and 2) Electronic Control and Digital Electronics. There are also a number of electives (marked with an asterisk). There is a practically-orientated subject at each level: Workshop Practice at Level 2 and Electrical Workmanship at Levels 3 and 4.

It appears from the curriculum overview in Table 4.1 that the NCV EIC is a wide, generic course but, despite its name, does not focus on electrical infrastructure construction. The title of the course, ‘Electrical Infrastructure Construction’, and the course description (that it covers “heavy current, overhead power lines as well as domestic, civil and industrial industries; light current in the form of digital and electronics in the communications, industrial electronics and sound engineering fields as well as instrumentation") is broader than the stated focus of the NCV-EIC with regard to the installation of electrical reticulation and distribution infrastructure. In addition, the elective courses from which students can choose, including Physical Science, Renewable Energy Technologies, and Electrical Systems and Construction, suggest a broad, more general educational approach than might be expected in a technical vocational programme.

4.3 The Electrical Workmanship 4 Curriculum

The NCV-EIC curriculum includes scientific and engineering concepts, as well as practical skills development in the laboratory and areas of specialisation and choices. No subjects in the EIC are 100% practical, but the Workshop Practice and Electrical Workmanship subjects are more practically-orientated than the other EIC subjects. They are required to contain a 40–60% practical component. According to the subject guides, the subjects, Workshop Practice and Electrical Workmanship (Table 4.2), are intended to introduce students to the technical field and to equip them with the necessary practical skills for the construction industry. Workshop and fieldwork procedures that conform to safety regulations and safe working practices will also be learned. Students will have been introduced to the subject, Workshop Practice, at Level 2, then to Electrical Workmanship at Level 3. At Level 4, students continue with "the practical implementation of theoretical concepts that are more representative of the workplace" (EWSG 4, 2015:1).

Table 4.2: Workshop Practice and Electrical Workmanship topics

Level 2 WP Topics	Level 3 EW Topics	Level 4 EW Topics
2.1 Safety and Regulations 2.2 First Aid 2.3 Engineering Hand Tools 2.4 Engineering Power Tools 2.5 Engineering Measuring Equipment 2.6 Worksite Procedures and Lifting Techniques 2.7 Soldering	3.2 Trade practices 3.3 Testing and measuring equipment 3.4 Domestic Appliances 3.5 Maintenance and repair of domestic appliances and electric power tools 3.6 Installation of single-phase AC machines and control gear 3.7 Shielded metal arc welding (SMAW)	4.1 Safety 4.2 Typical electrical installations 4.3 Illumination 4.4 Domestic appliances and portable electrical power tools 4.5 Electric machines and control gear.

Source: DHET, 2020

The focus of this section is on Electrical Workmanship 4, which is a full-time, one year practically-orientated subject (although it is also offered part-time), comprising 200 teaching and learning hours. The subject, Electrical Workmanship 4, is intended to include enough "trade specific skills, knowledge, attitudes and values for students to develop confidence in the maintenance, repair and construction of basic electrical systems in practice" (EWSG 4, 2015). This subject is intended to "equip students with the necessary hand-skills for the construction industry" (EWSG 4, 2015). It follows on from Workshop Practice (NQF Level 2) and Electrical Workmanship (NQF Level 3) but has greater focus on "the practical implementation of theoretical concepts that are more representative of the workplace" (EWSG 4, 2015). The practical subject has the intention to provide students with opportunities to experience work situations during the period of study and, according to the subject guide, could be offered in a real workplace environment or in a simulated workplace environment (EWSG 4, 2015).

Electrical Workmanship 4 plays a crucial role in the EIC curriculum: it serves to synthesise and apply the scientific and engineering knowledge learned in earlier stages of the curriculum. Before reaching this level, students go through preparatory steps, starting at Level 2 with Workshop Practice. From there, they advance to Level 3 where they gain proficiency in Electrical Principles and Practice, Electrical Control, and Digital Electronics. The subject, Electrical Workmanship 4, equips students with the fundamental technical know-how needed in the construction sector. Its main goal is to teach students how to follow safety procedures and industry best practices when carrying out jobs in the workshop and in the field. The foundations of electrical installation practice at Level 3 and the introduction to workshop practice at Level 2 are expanded upon in this course. Students refine their practical abilities and apply theory in a way that closely resembles real-world work environments at Level 4 (EWSG 4, 2015).

4.3.1 Topic areas for Electrical Workmanship 4

There are five topics in EW4:

- Topic 1: Safety
- Topic 2: Typical electrical installations
- Topic 3: Illumination
- Topic 4: Domestic appliances and portable electrical power tools
- Topic 5: Electrical machines and control gear (EWSG 4, 2015).

The topics offer a general introduction to electrical work without specifically focusing on electrical infrastructure. Several studies confirm that Electrical Workmanship 4 addresses safety and hand-skills in the electrical industry generally (Munishi, 2016; Amoo & Swart, 2018). A comparison of the Electrical Workmanship 4 topic areas with the Electrical Engineering Technician work specification reveals considerable gaps, particularly regarding electrical infrastructure. As evident in Table 4.3, gaps exist between the tasks of an Electrical Engineering Technician as specified by the QCTO (OFO 311301) and the Electrical Workmanship (Level 4) topic areas. While the whole qualification might show better alignment across the vocational subjects, it might be expected that the Level 4 practical component would cover the key practical functions of an Electrical Engineering Technician: assembling, installing, testing, calibrating, modifying and repairing electrical infrastructure and related equipment.

Table 4.3: Comparison between Electrical Engineering Technician (OFO 311301) task descriptors and Electrical Workmanship (Level 4) topic areas

No.	Electrical Engineering Technician (OFO 311301) Task descriptors	No.	Electrical Workmanship (Level 4) Topic areas
1.	Assembling, installing, testing, calibrating, modifying and repairing electrical equipment and installations to conform with regulations and safety requirements;	2. 1.	Typical electrical installations Safety
2.	Preparing detailed estimates of quantities and costs of materials and labour required for manufacture and installation according to the specifications given;		-
3.	Designing and preparing blueprints of electrical installations and circuitry according to the specifications given;	2.	Typical electrical installations
4.	Providing technical assistance in research on and development of electrical equipment and facilities, or testing prototypes;	4. 5.	Domestic appliances and portable electrical power tools; Electrical machines and control gear
5.	Planning installation methods, checking completed installation for safety and controls or undertaking the initial running of the new electrical equipment or systems;		-
6.	Monitoring technical aspects of the manufacture, installation, utilisation, maintenance and repair of electrical systems and equipment to ensure satisfactory performance and compliance with specifications and regulations		-
	-	3.	Illumination

Source: QCTO (2019) and EWSG 4 (2015).

4.3.2 Subject and learning outcomes for Electrical Workmanship 4

In this section, the Electrical Workmanship 4 curriculum is explained in greater depth with regard to its subject and learning outcomes. Table 4.4 provides the subject and learning outcomes for Electrical Workmanship (Level 4).

Table 4.4 Subject and Learning Outcomes in Electrical Workmanship 4

No.	Subject outcomes	Learning outcomes
1	Subject Outcome 1: Apply safety in the workplace.	Explain the effects of electrical accidents on humans and property;
2		Explain potential causes of harm to workers;
3		Describe safe work practices with electrical appliances and power tools;
4		Explain why a workplace should implement hazard control;
5		Perform and apply risk assessment procedure in the workplace;
6		Describe the hierarchy of control and where they are used.
7	Subject Outcome 2: Describe typical electrical installations.	Identify and interpret electrical drawing symbols from diagrams;
8		Design, draw and explain basic electrical control circuits;
9		Design, draw and explain lighting, socket outlet, geyser, stove and distribution board circuits;

10		Interpret and apply the SANS 10142-1 regulations;
11		List and explain the different types of short-circuits that can occur in an electrical installation (including three-phases systems);
12		List and explain the consequences of short-circuits in an electrical installation;
13		Calculate the cross-sectional area of protective conductors with regard to thermal stress due to currents of short duration.
14	Subject Outcome 3: Explain illumination and different lamp circuits.	Explain terms used in illumination and their respective units of measurement.
15		List the characteristics of a good lighting scheme;
16		With the aid of diagrams list and explain light fitting classifications;
17		Explain with the aid of a sketch the design, principle of operation, circuitry needed, advantages and disadvantages of the different types of lamps;
18		Explain the stroboscopic effect of fluorescent lamps and how it can be minimized;
19		Discuss the colour emitted, efficiencies, environmental impact, power consumption and life expectancy of different types of lamps and choose the best lamp for the application.
20	Subject Outcome 4: Fault-find, repair and test domestic appliances and portable electrical power tools.	Describe the techniques used to identify the cause of and to locate faults or faulty components in domestic appliances and portable power tools;
21		Fault-find in domestic appliances and portable electrical power tools including electrical appliances and tools fitted with motors;
22		Repair domestic appliances and portable electrical power tools to fully serviceable condition.
23		Explain the procedure for safe testing of domestic appliances and portable electrical power tools to ensure that it is safe to connect to the mains supply.
24	Subject Outcome 5: Install, test and commission electrical machines.	Describe the preparation for installing electrical machines;
25		Install electrical machines;
26		Test and commission electrical machines;
		Over hall electrical machines and control gear.

The subject outcome for Topic 1, "Apply safety in the workplace", is relevant and important. According to the Occupational Health and Safety Act 1993 (Act No. 85 of 1993), the work of South African electricians must comply with SANS 10142-1 (Edition 2), which is the most recent legislation applicable to the electrical trades. This, along with the OHS Act's regulations. such as the Electrical Installation Regulations, Electrical Machinery Regulations, and General Safety Regulations (amongst nine different sets of regulations), comprises the legal safety framework for all electrical installations. The SANS 10142-1 standard is included under Topic 2. It could be useful to consider consolidating the legislated electrical Health, Safety, Environment, and Quality (HSEQ) standards, in particular SANS 10142-1 (Edition 2), in Topic 1. Knowledge of the health and safety regulations is a requirement in many of the jobs advertised for electrical technicians. Topic 2 and its related outcomes introduce students to the world of electrical drawings, circuits, conductors, and electrical installations – but not to electrical infrastructure.

Some learning outcomes for Topic 3, such as, "Explain illumination and different lamp circuits", are inappropriate as they are too basic. Learning outcome 15, "List the characteristics of a good lighting scheme", seems to come from the world of interior design rather than electrical infrastructure. Street illumination and related distribution systems might be more appropriate for the NCV-EIC qualification, and with an infrastructural rather than a domestic focus. Similarly, the outcomes related to Topic 4, “Fault-find, repair and test domestic appliances and portable electrical power tools”, are at too basic a level and are not appropriate to the intended qualification focus. It would be expected that a clearer focus on the specifics of electrical infrastructure construction and related work and equipment would be present in the subject outcomes. The literature suggests that, because of safety concerns and the size and geographical dispersion of electrical infrastructure, the “gold standard” for the training of installation electricians makes use of computer simulation that is supported by field visits and the observation (either in real life or with the use of video and multimedia) of technical work on electrical infrastructure (He & Gong, 2006). Simulation, field visits and observations are notably absent from the course. It is thus unsurprising that there is a misalignment between Electrical Workmanship 4 and the occupation standard.

The learning outcomes for Topic 5, “Install, test and commission electrical machines”, are the most closely aligned to the occupational specification. The assessment criteria (EWAG4, 2007) require students to be able to “install, connect, commission, clean, inspect, test, and maintain electrical machines and control gear”, criteria which align well with the occupational standard. The outcomes for Topic 5, “Install, test and commission electrical machines”, are similarly aligned to the occupational standard and employment requirements. However, these outcomes might not be attainable when taking all the subject and learning outcomes into account. The misalignment between the intention of Electrical Workmanship 4 and its actual focus on repairing domestic equipment, rather than the installation and maintenance of electrical infrastructure, is a concern. Mashongoane’s study on the NCV-EIC quotes a student’s understanding of the course: “Studying the [NCV-EIC] has given me knowledge on how to work with electrical appliances and how to repair them, what to do when there is a fault on the circuit, how to wire” (2015:189-190). Thus, while students enjoyed the practical subject and found value in acquiring the skills that enabled them to repair appliances such as a “stove, geyser, socket outlet and light”, it did not equip them to play a meaningful role in electrical infrastructure construction.

4.3.3 Assessment practices in Electrical Workmanship 4

Table 4.5 shows only the assessment criteria for the learning outcomes for Electrical Workmanship 4. The table headings indicate the topic of Electrical Workmanship 4: the left column lists the learning outcomes (EWSG 4); and the right column lists the assessment criteria for each learning outcome (EWAG 4).

Table 4.5: Learning outcomes and assessment criteria for Electrical Workmanship 4

Learning outcomes	Assessment criteria
Topic 1: Safety **Subject outcome: Apply safety in the workplace**	
1.1 Explain the effects of electrical accidents on humans and property. 1.2 Explain potential causes of harm to workers. 1.3 Describe safe work practices with electrical equipment and power tools. 1.4 Perform and apply risk assessment procedures in the workplace. 1.5 Explain why a workplace should implement hazard control. 1.6 Describe the hierarchy of control and how it is used.	1.1. The effects of electrical accidents on humans and property are explained. 1.2. Potential causes of harm to workers are explained. Range: injury, health effects, quality of life, machinery, handling processes, hazardous substances, slips, trips and falls, workplace conditions. 1.3. Safe work practices with electrical equipment and power 1.4. Risk assessment procedures in the workplace are performed and applied. Range: Probability – very likely, likely, unlikely, highly unlikely. Consequences – fatality, major, minor, negligible. Priority: 1&2 – high priority; 3&4 – medium priority; 5&6 – low priority; power tools are described. 1.5. Reasons for implementation of hazard control in the workplace are explained. 1.6. The hierarchy of control and its use is described.
Topic 2: Typical electrical installations **Subject outcome: Describe typical electrical installations**	
2.1 Identify and interpret electrical drawing symbols from diagrams. 2.2 Design, draw and explain basic electrical control circuits. 2.3 Design, draw and explain lighting, socket outlet, geyser, stove and distribution board circuits. 2.4 Interpret and apply the SANS 10142-1 regulations. 2.5 List and explain the different types of short-circuits that can occur in an electrical installation (including three-phase systems). 2.6 List and explain the consequences of short-circuits in an electrical installation. 2.7 Calculate the cross-sectional area of protective conductors with regard to thermal stresses due to currents of short duration.	2.1 Read and interpret electric circuit diagrams. 2.2 Use and describe International Electrotechnical Commission (IEC) and Systeme International (SI) symbols, units and abbreviations for electrical and mechanical quantities correctly. 2.3 Understand and use DC theory and network analysis in solving RLC circuits. 2.4 Understand the application of electromagnetic theory in electric machines and transformers. 2.5 Have a basic knowledge of, and be able to interpret and apply, the SABS 0142 (SANS 10142) regulations (e.g., flame-proof environments, permissible volt-drops in supply cabling, conductor and insulator factor values and fault current calculations). 2.6 The consequences of short-circuits in an electrical installation are listed and explained. The cross-sectional area of protective conductors with regard to thermal stresses due to currents of short duration are calculated. Range: $Sp = \sqrt{(I^2 t)} \div k$ (SANS 60439-1)
Topic 3: Illumination **Subject outcome: Explain illumination and different lamp circuits**	
3.1 Explain terms used in illumination and their respective units of measurement.	3.1 The terms used in illumination and their respective unit of measurement are explained Range: luminous flux, luminous intensity, luminous efficiency or efficacy, illuminance and luminance.

3.2 List the characteristics of a good lighting scheme.	3.2 The characteristics of a good lighting scheme are listed.
3.3 With the aid of diagrams list and explain light fitting classifications.	3.3 Light fitting classifications are listed and explained with the aid of diagrams Range: direct, semi-direct, indirect, semi-indirect and general diffusing.
3.4 Explain with the aid of a sketch the design, principle of operation, circuitry needed, advantages and disadvantages of the different types of lamps.	3.4 The design, principle of operation, circuitry needed, advantages and disadvantages of the different types of lamps are explained with the aid of sketches Range: incandescent, tungsten halogen (including low voltage halogen lamps), Hg- and Na-vapour, fluorescent lamps (including compact fluorescent lamps) and LEDs.
3.5 Explain the stroboscopic effect of fluorescent lamps and how it can be minimised.	3.5 The stroboscopic effect of fluorescent lamps and how it can be minimised are explained.
3.6 Discuss the colour emitted, efficiencies, environmental impact, power consumption and life expectancy of different types of lamps and choose the best lamp for the application.	3.6 The colour emitted, efficiencies, environmental impact, power consumption and life expectancy of different types of lamps are discussed and the best lamp for the application is chosen.
Topic 4: Domestic appliances & portable electrical power tools (EWSG 4, 2015) Fault-find, repair and test domestic appliances and portable electrical power tools	
4.1 Describe the techniques used to identify the cause of, and to locate faults or faulty components in domestic appliances and portable power tools.	4.1 Identify the appliance and explain the operating principles of the appliance.
4.2 Fault-find domestic appliances and portable electrical power tools including electrical appliances and tools fitted with motors.	4.2 Distinguish between the various types of appliances that may be used for the same application.
4.3 Repair domestic appliances and portable electrical power tools to fully serviceable condition.	4.3 State the maintenance procedures relevant to each domestic appliance.
4.4 Explain the procedure for safe testing of domestic appliances and portable electrical power tools to ensure that it is safe to connect to the mains supply.	4.4 State regulations regarding domestic appliances. 4.5 Draw circuit diagrams to wire a stove plate for low, medium and high heat. 4.6 Explain the procedures to replace components in domestic appliances (simmerstat and oven switches, heater elements and thermostats; wash, spin and tumble-dry motors).
Topic 5: Electrical machines and control gear **Subject outcome: Install, test and commission electrical machines**	
5.1 Describe the preparation for installing electrical machines.	5.1 The preparation for installing electrical machines is described. Range: Check electrical supply, suitability for operating environment, inspection of machines for damage, lubrication, cleanliness, foundation.
5.2 Install electrical machines.	5.2 Electrical machines are installed. Range: Positioning, alignment of shaft, electrical connections, control and protection equipment, installation of guards and covers.
5.3 Test and commission electrical machines;	5.3 Electrical machines are tested and commissioned. Range: Commissioning includes tests, adjustments and conformation of operation of control equipment such as switch gear, over-temperature, open-circuit, short-circuit and overload protection,

5.4 Overhaul electrical machines and control gear.	direction of rotation, temperature rise and current drawn. 5.4 Electrical machines and control gear are overhauled. Range: Mechanical and electrical inspections including testing of brush spring pressure and brush-arm insulation, replacing bearing and seal, replacing damaged parts, cleaning of parts, replacing capacitors, relays and protection devices.

The assessment criteria for Topic 1 on Workplace Safety does not require knowledge of the Occupational Health and Safety Act of 1993, the Mine Health and Safety Act 29 of 1996, NOSA and NOSA ratings in factories and workshops, and the Safety, Health, and Environment (SHE) program, or other updated legislation in alignment with current Health, Safety, Environment, and Quality (HSEQ) standards. Regarding Topic 2, "Typical Electrical Installations", most of the assessment criteria are aligned with industry requirements, such as familiarity with SABS/SANS standards, but the outcomes are theoretical rather than practical. The overall description is that "Typical electrical installations are understood", but they are not installed, maintained, tested or repaired. In contrast to Topic 5, the assessment criteria for the topic "Electrical machines and control gear" are considerably more practical and are also well-aligned with the occupational standard and industry requirements, particularly the installing and maintaining of machines and control gear. The topic on domestic appliances is, as explained above, not appropriate to the qualification or level. In the 2007 version of the Electrical Workmanship 4 subject, the topic, "Low voltage transformers and switchgear" (EWSG 4, 2007) was taken out of the 2015 Electrical Workmanship 4 Subject Guidelines and apparently replaced by "Illumination". The removed topic included learning outcomes such as, "Know and apply procedures to effectively clean, inspect, test and maintain low voltage transformers and switchgear". Clearly, the topic "Low voltage transformers and switchgear" is relevant to electrical infrastructure, while domestic appliances are not. It is not known why a topic that is highly relevant to the qualification was removed.

4.3.3.1 Relationship between learning outcomes and assessment criteria

As can be seen in Table 4.5, the Electrical Workmanship 4 Subject and Assessment Guidelines are packed with subject learning outcomes. Electrical Workmanship 4 has 27 learning outcomes. This level of detail makes time consuming and perplexing demands on lecturers (Atkinson, 2016). Each outcome is understood separately and has no explicit relationship to the one before or after, suggesting segmented learning. A detailed study of Topic 4, "Domestic appliances & portable electrical power tools" (EWSG 4, 2015) and its learning outcomes, as well as the matching assessment criteria (Topic 2: "Domestic appliances" (EWAG 4, 2007), reveals that there is a tendency to conflate the learning outcome and its assessment criteria (Table 4.6).

Table 4.6 Learning outcomes and assessment criteria: Fault-find, repair and test domestic appliances and portable electrical power tools

No.	Learning outcomes	No.	Assessment criteria
1	Describe the techniques used to identify the cause of, and to locate faults or faulty components in domestic appliances and portable power tools.	1	The techniques used to identify the cause of, and to locate faults or faulty components in domestic appliances and portable power tools are described. *Range: Observation, asking customer questions, simulation, measurement, sound, smell, identification of loss of function, comparison, previous fault occurrence and using manufacturer's service manual.*
2	Fault-find domestic appliances and portable electrical power tools including electrical appliances and tools fitted with motors.	2	Fault-finding is performed on domestic appliances and portable electrical power tools including electrical appliances and tools fitted with motors.
3	Repair domestic appliances and portable electrical power tools to fully serviceable condition.	3	Domestic appliances and portable electrical power tools are repaired to fully serviceable condition.
4	Explain the procedure for safe testing of domestic appliances and portable electrical power tools to ensure that it is safe to connect to the mains supply.	4	The procedure for safe testing of domestic appliances and portable electrical power tools are explained to ensure that it is safe to connect to the mains supply.

The assessment criteria restate the topic area content, sometimes even repeating the same sentence phrasing. For example, the outcome, "Explain the procedure for safe testing of domestic appliances and portable electrical power tools to ensure that it is safe to connect to the mains supply" is re-stated in the assessment criteria: "The procedure for safe testing of domestic appliances and portable electrical power tools are explained to ensure that it is safe to connect to the mains supply". When assessment standards repeat the learning outcomes, there is no indication of the performance level required, thus students might not be developing necessary skills. Assessment in vocational education usually requires students to demonstrate or apply what they have learned in ways that are relevant to the occupation (Billett, 2018). The repetition of the outcome in the assessment criterion suggests a misunderstanding of assessment standards. Conflation results in: 1) a lack of clarity with regard to the expected performance; 2) this can also lead to unfair assessment practice (due to the lack of clarity and reduced validity and reliability); 3) as a result, feedback is likely to be inconsistent; and 4) for students, conflation can lead to a lack of focus, and a shift from learning and skill development to merely achieving the desired outcome, leading to a 'teaching to the test' mentality. When outcomes and criteria are conflated, the design of assessment tools and rubrics is less effective. Clear assessment criteria are necessary for creating valid and reliable assessment instruments. In the case of Electrical Workmanship 4, clear assessment criteria would specify the level of performance required.

4.3.4 Internal continuous assessment (ICASS)

The description of the ICASS seems to be generic across most NCV assessment guides; in the case of the Electrical Workmanship 4 Assessment Guide, the specific practical competencies of the occupational specification are not addressed. The assessment criteria focus on more general "knowledge, skills values, and attitudes (SKVAs) … throughout the year using assessment instruments such as projects, tests, assignments, investigations, role-play and case studies" (EWAG 4:5). The ICASS exercises for Electrical Workmanship 4 include the following: 1) tests and calculations; 2) lists (e.g., advantages and disadvantages, identification of procedures); 3) production and interpretation of basic circuit diagrams; 4) identifying safety standards and other regulations; 5) a practical task (e.g., replace component of an appliance); and 6) maintaining and testing electrical machines and control gear in accordance with standard procedures. These generic assessment methods are not entirely appropriate for assessing technical skills, as many researchers in the field have pointed out (e.g., Caino-Lores et al., 2017; Dai et al., 2017; Guzzomi et al., 2017). It is only Topic 5, which is relevant to practical work on electrical infrastructure, as it has an electrical infrastructure focus and more detail on the assessment requirements. While the "theoretical assessment" of Topic 5 only states, "asses the student on the achievement of the learning outcomes listed" (EWAG 4:18), the "practical assessment" contains more detail, including the following:

- Test and identify the terminals of a DC machine
- Measure armature resistance of a DC machine
- Test a DC machine for continuity and insulation resistance
- Connect, start, run and reverse a DC series, shunt and compound motor
- Overhaul a DC machine (EWAG 4:18)

The Assessment Guide does not provide similar detail on the other ICASS exercises. Practical vocational subjects need to be assessed using up to date and industry-aligned assessment tasks (Rauner et al., 2012). The ICASS practical component is expected to be "undertaken in a real workplace, a workshop or a 'Structured Environment'" (EWAG 4:5). The literature on practical training for electrical infrastructure suggests that, where a real workplace is not available or poses a risk to students, a simulated environment is necessary to ensure that occupational competencies are developed over time (Frank, 1999). It is not clear whether the "Structured Environment" referred to in the Assessment Guide involves training on an electrical infrastructure simulator. In the 2007 Assessment Guide, a "simulated accident" was used for first aid training under the topic on Safety, but this was omitted from the 2015 Assessment Guide.

4.3.5 External summative assessment (ESASS)

ESASS comprises an Integrated Summative Assessment Task (ISAT) and an examination. The Assessment Guide explains that there are "two approaches to the ISAT":

> The students are assigned a task at the beginning of the year which they must complete in phases during the year to obtain an assessment mark. A final assessment is made at the end of the year when the task is completed;
> OR
> Students achieve the competencies during the year but the competencies are assessed cumulatively in a single assessment or examination session at the end of the year (EWAG 4:19).

The ISAT is set by an externally appointed examiner; and students should be informed of the nature of the task in the first quarter of the year. In addition, "the integrated assessment approach enables students to be assessed in more than one subject with the same ISAT" (EWAG 4: 19).

An integrated summative assessment task (ISAT) that assesses students' cumulative learning throughout the year is required for external summative assessment. The integrated summative assessment task assesses the "integrated application of competence and is executed under strict assessment conditions" (EWAG 4, 2007:4). It is proposed that the integrated summative assessment task take place in a "simulated or Structured Environment" (EWAG 4, 2007:4). The integrated summative assessment task will test "students' ability to apply acquired knowledge" (EWAG, 2007:4). The integrated assessment approach enables the assessment of more than one subject in a single assessment task. If application and analysis, synthesis and evaluation are tested in a practical way, this would contribute to the development of the required competencies that need to be developed in extended and integrated ways (Rauner et al., 2012). The ISAT therefore has the potential to demonstrate equivalence to the occupational standard but requires further investigation.

Electrical Workmanship 4 students have to write a national examination which is conducted at the end of the academic year and externally moderated. Guidelines for the examination are that there should be a section on "comprehension" worth 30–40% of the final mark; "application" should be allocated 40–50% of the final mark; and "analysis, synthesis and evaluation" should count 0–20% of the final mark (EWAG 4:19). These categories seem to be based on Bloom's taxonomy of cognitive demand. It is not logical that "application" in a largely practical subject should be awarded a maximum of 50% of the final mark, nor that "analysis, synthesis and evaluation" need not be included. From the literature (e.g., Rauner et al., 2012), it is clear that written assessment 44 are not an appropriate means of testing occupational competence.

4.3.6 Facilities and resources

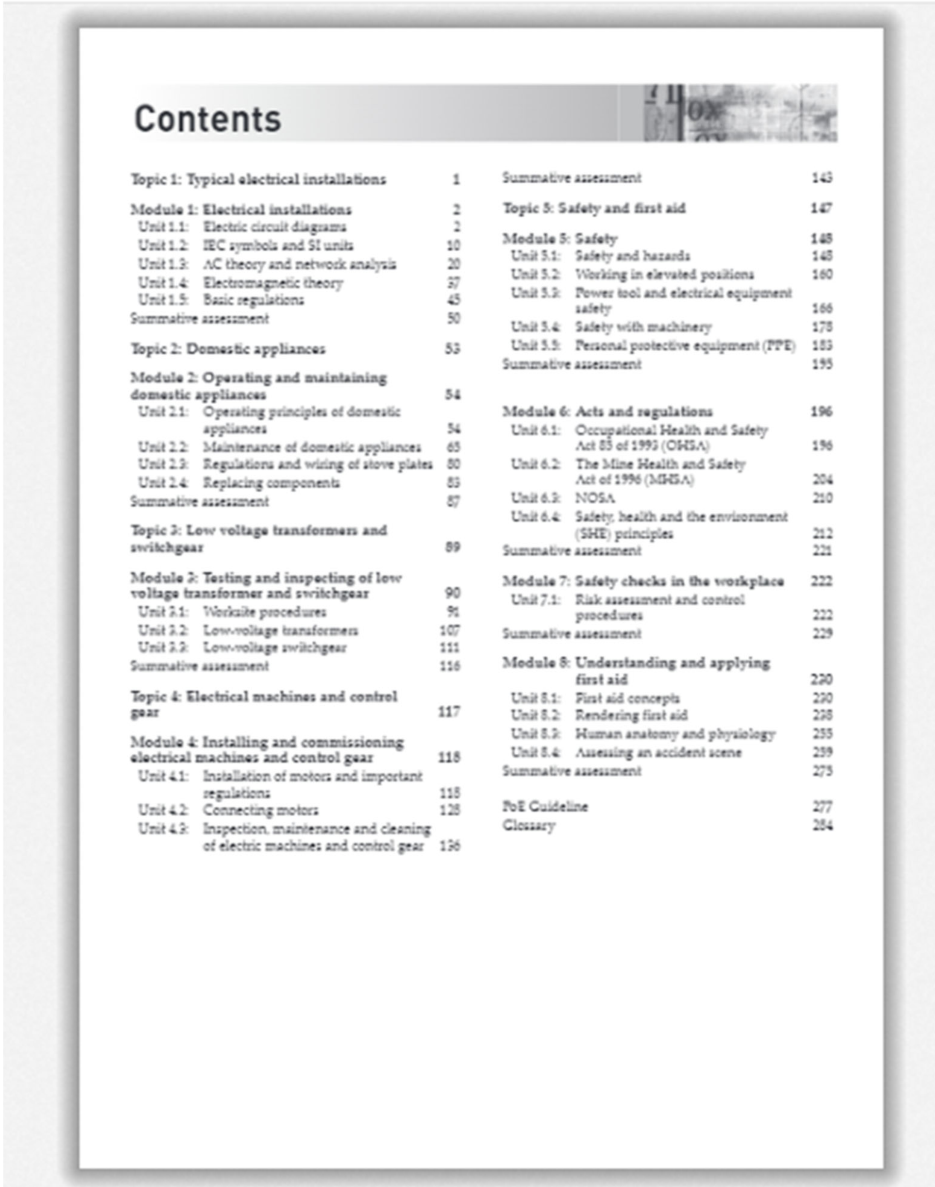
The curriculum lists the 1) physical resources, 2) human resources, and 3) other resources needed to implement the curriculum. The Electrical Workmanship 4 Subject Guide stipulates that "well equipped classrooms and workshops are essential for this practically orientated subject" (EWSG 4, 2015:9). No mention is made of simulated or virtual teaching and learning environments, which are the "gold standard" for training in the field (Frank, 1999; Dai et al., 2017). With reference to physical resources, the Guide suggests that, where possible, "the facilities of employers in the electrical field, for training, is preferred" (EWSG 4:9). Students cannot be safely trained on high voltage/heavy current equipment, which is why simulation is so important in their training. Site visits and observations are important to supplement the simulated training environment.

Regarding human resources, lecturers with appropriate electrical qualifications and industry experience are required; the Electrical Workmanship 4 Subject Guide also specifies that lecturers need to participate in continuous professional development in the field.

Other resources include the "consumables required to perform practical assignments and examinations", the "maintenance of physical recourses" and the "purchasing of new equipment". No mention is made of simulation software or other forms of electrical infrastructure simulation.

4.4 The textbook

The prescribed textbook (see Figures 4.1 and 4.2) covers conceptual and applied engineering knowledge. Its focus is on helping students to understand circuits involving resistors, inductors and capacitors. It lacks practical tasks in the sense of, for example, showing students how to build a circuit or a device. There are many calculations that are intended to enhance students' understanding of the course content, rather than practical applications. The quizzes and questions test students' theoretical and applied knowledge, usually through calculations. As can be seen in Figure 4.1, the textbook closely follows the topics and learning outcomes of the official curriculum, although it rearranges the topics in a way that follows a more logical sequence. Note that the topic, 'Illumination', is missing because this textbook studied in the 2008 text, available as a free e-book and used by students and lecturers (in preference to the 2015 textbook, available at R559, which is unaffordable for many students).



Contents

Figure 4.1 The textbook follows the official curriculum

Jowaheer, S. 2008. *Electrical workmanship NQF: Level 4: Student's book*. Troupant/MacMillan.

Figure 4.2 illustrates a typical set of exercises in the prescribed textbook. These exercises tend to be calculations. There is a high level of challenge in the calculations involving circuits and resistors. These exercises build the underpinning engineering science for practice in the field of electrical infrastructure.

c) The current flowing through the circuit.
d) The phase angle.
e) The voltage across the resistor.
f) The voltage across the capacitor

2. A resistor of 10 Ω is connected in series with a capacitor of 45 μF. The supply voltage is 240 V, 50 Hz. Calculate:
   a) The capacitive reactance.
   b) The impedance.
   c) The current flowing through the circuit.
   d) The phase angle.
   e) The voltage across the resistor.
   f) The voltage across the capacitor.

RLC Series circuits

Figure 1.46 shows an RLC circuit. It consists of a resistor, an inductor and a capacitor in series with an AC source.

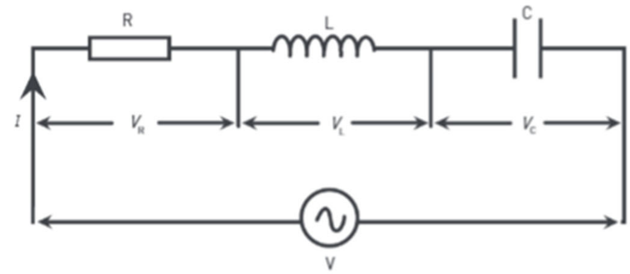


Fig. 1.46: Series RLC circuit

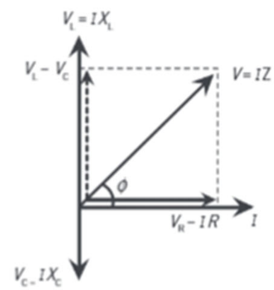


Fig. 1.47: Phasor diagram when $X_L > X_C$

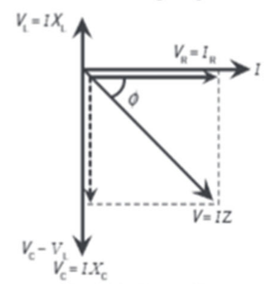


Fig. 1.48: Phasor diagram when $X_C > X_L$

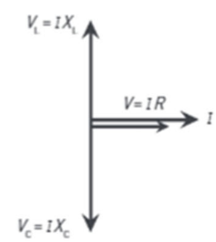


Fig. 1.49: Phasor diagram when $X_L = X_C$

In this type of circuit there are three possible phasor diagrams, as follows:

- $X_L > X_C$ (See Figure 1.47.) The circuit is inductive and has a lagging phase angle.
- $X_C > X_L$ (See Figure 1.48.) The circuit is capacitive and has a leading phase angle
- $X_L = X_C$ (See Figure 1.49.) The applied voltage and the current I are in phase. This is called series resonance and will not be discussed because it is not part of the curriculum.

According to Pythagoras and because the impedance (Z) is the phasor sum of R, X_L and X_C,

When $X_L > X_C$ then impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$ Ω

And $\tan \phi = \frac{X_L - X_C}{R}$

When $X_C > X_L$ then impedance $Z = \sqrt{R^2 + (X_C - X_L)^2}$ Ω

And $\tan \phi = \frac{X_C - X_L}{R}$

28 Module 1: Electrical installations

Figure 4.2: Calculations required for Electrical Workmanship
Jowaheer, S. 2008. *Electrical workmanship NQF: Level 4: Student's book*. Troupant/MacMillan.

4.5 An LCT semantic analysis of Electrical Workmanship 4

To develop a semantic profile of Electrical Workmanship 4, all the learning outcomes and assessment criteria were studied, both in the subject and assessment guides as well as in the textbook. The underpinning knowledge for each learning outcome was then identified as belonging to one of the following four categories: scientific knowledge (SG-,SD++), engineering knowledge (SG+, SD+), procedural knowledge (SG+, SD-), and practical knowledge (SG++,SD-). The identification of the categories was made through the application of the translation device (Table 2.2). For example, learning outcome 11, "List and explain the different types of short-circuits that can occur in an electrical installation (including three-phases systems)", was identified as engineering knowledge (SG+,SD+); learning outcome 24, "Describe the preparation for installing electrical machines", was identified as procedural knowledge as it explains procedures (SG+,SD-); while learning outcome 25, "Overhaul electrical machines and control gear", was classified as practical knowledge (SG++,SD-) as it requires implementation in context. We did not find any instances of theoretical or scientific knowledge in the curriculum topics, outcomes or assessment criteria.

Table 4.7 Subject and Learning Outcomes in Electrical Workmanship 4

No.	Subject outcomes	Learning outcomes/assessment criteria	Underpinning knowledge	Semantic code	Value
1	Subject Outcome 1: Apply safety in the workplace.	Explain the effects of electrical accidents on humans and property;	Engineering	SG+, SD+	3
2		Explain potential causes of harm to workers;	Procedural	SG+, SD-	2
3		Describe safe work practices with electrical appliances and power tools;	Procedural	SG+, SD-	2
4		Explain why a workplace should implement hazard control;	Procedural	SG+, SD-	2
5		Perform and apply risk assessment procedure in the workplace;	Procedural	SG+, SD-	2
6		Describe the hierarchy of control and where they are used.	Engineering	SG+, SD+	3
7	Subject Outcome 2: Describe typical electrical installations.	Identify and interpret electrical drawing symbols from diagrams;	Engineering	SG+, SD+	3
8		Design, draw and explain basic electrical control circuits;	Engineering	SG+, SD+	3
9		Design, draw and explain lighting, socket outlet, geyser, stove and distribution board circuits;	Engineering	SG+, SD+	3
10		Interpret and apply the SANS 10142-1 regulations;	Procedural	SG+, SD-	2
11		List and explain the different types of short-circuits that can occur in an electrical installation (including three-phases systems).	Engineering	SG+, SD+	3
12		List and explain the consequences of short-circuits in an electrical installation;	Engineering	SG+, SD+	3
13		Calculate the cross-sectional area of protective conductors with regard to thermal stress due to currents of short duration.	Engineering	SG+, SD+	3

14	Subject Outcome 3: Explain illumination and different lamp circuits.	Explain terms used in illumination and their respective units of measurement;	Engineering	SG+, SD+	3
15		List the characteristics of a good lighting scheme;	Engineering	SG+, SD+	3
16		With the aid of diagrams list and explain light fitting classifications;	Procedural	SG+, SD-	2
17		Explain with the aid of a sketch the design, principle of operation, circuitry needed, advantages and disadvantages of the different types of lamps;	Procedural	SG+, SD-	2
18		Explain the stroboscopic effect of fluorescent lamps and how it can be minimized;	Engineering	SG+, SD+	3
19		Discuss the colour emitted, efficiencies, environmental impact, power consumption and life expectancy of different types of lamps and choose the best lamp for the application.	Engineering	SG+, SD+	3
20	Subject Outcome 4: Fault-find, repair and test domestic appliances and portable electrical power tools.	Describe the techniques used to identify the cause of and to locate faults or faulty components in domestic appliances and portable power tools;	Procedural	SG+, SD-	2
21		Fault-find in domestic appliances and portable electrical power tools including electrical appliances and tools fitted with motors;	Practical	SG++, SD-	1
22		Repair domestic appliances and portable electrical power tools to fully serviceable condition;	Practical	SG++, SD-	1
23		Explain the procedure for safe testing of domestic appliances and portable electrical power tools to ensure that it is safe to connect to the mains supply.	Procedural	SG+, SD-	2
24	Subject Outcome 5: Install, test and commission electrical machines.	Describe the preparation for installing electrical machines;	Procedural	SG+, SD-	2
25		Install electrical machines;	Practical	SG++, SD-	1
26		Test and commission electrical machines;	Practical	SG++, SD-	1
27		Overhaul electrical machines and control gear.	Practical	SG++, SD-	1

The list of outcomes (Table 4.7) suggests a disconnection between the five topics; it also suggests segmentation. In the first three topics, engineering and procedural knowledge are foregrounded, while the last two topics foreground procedural and practical knowledge.

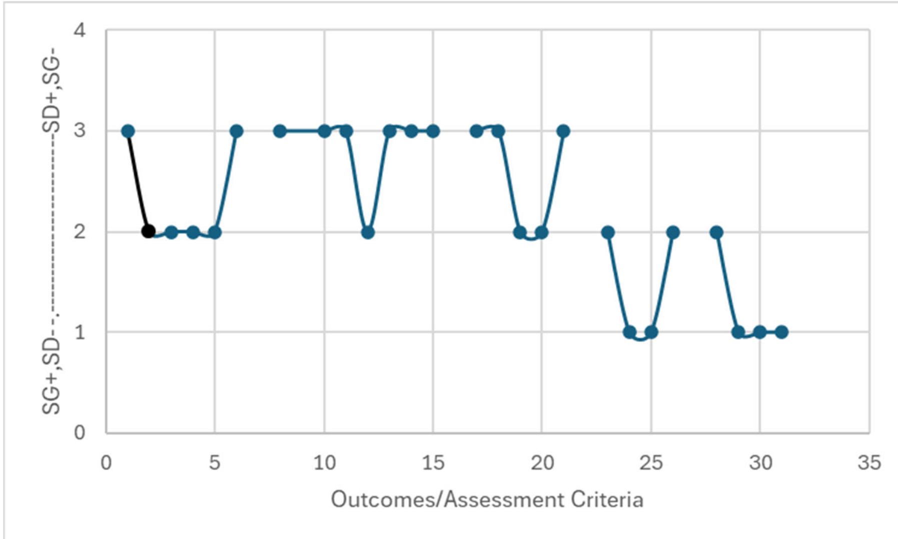


Figure 4.3: The semantic profile of Electrical Workmanship 4

A semantic profile offers a snapshot of the more abstract (SG-,SD+) and more contextualised (SG+,SD-) knowledge in a curriculum, as well as the relationship between these knowledge forms. In this case, the translation device (Table 2.2) that identified four different knowledge types (where each outcome/assessment criterion was given a numerical value) was to develop a semantic profile from Table 4.7. The values given to each knowledge type were plotted on a scatter graph (Figure 4.3). The semantic profile was thus created by plotting the learning outcomes and assessment criteria along the X-axis and the knowledge types on the Y-axis.

The resultant semantic profile shows the disconnection between the five topics as a discontinuous graph (Figure 4.3). This discontinuity is a typical profile of segmented learning that "constrains knowledge-building" (Dankenbring, et al., 2024: 49). There is also an association between semantic range and the ability of a curriculum to enable cumulative learning (Maton, 2007; 2019). When the range enables shifts between areas of stronger and weaker semantic gravity and stronger and weaker semantic density, cumulative learning is enabled (Doorsamy & Bokoro, 2019). In other words, a "curriculum that presents ideas through the formation of semantic waves, or oscillations between areas of stronger and weaker semantic gravity, is linked to enhanced learning of complex ideas" (Dankenbring, et al., 2024: 49).

The semantic profile of Electrical Workmanship 4 shows the five topics included in the subject. These are represented as a discontinuous graph as there are no clear linkages between the five topic areas. The scatter graph shows the distribution of knowledge types across the five topics. Topic 1 on "Safety" shows outcomes in engineering and procedural knowledge, with more outcomes in procedural knowledge (as might be expected in a section on safety). Topic

2 on "Typical electrical installations" shows that six of the seven outcomes are in engineering knowledge and only one in procedural knowledge. Topic 3 on "Illumination" has a similar profile, with most outcomes in engineering knowledge and one in procedural knowledge. Topic 4 on "Domestic appliances" has two procedural and two practical knowledge outcomes. Topic 5 on "Install, test and commission electrical machines" contains one procedural and three practical outcomes.

Each topic has a distinctive semantic profile. Semantic profile 1 approximates a V-shape, which is typical of engineering disciplines (Doorsamy & Bokoro, 2019), although this is an incomplete V-shape as it does not include scientific or practical knowledge. However, the upward stroke of the V-shape suggests the possibility of reflection on the procedures from the perspective of engineering knowledge. It was pointed out that the 2007 Assessment Guide recommended a "simulated accident" as an assessment exercise which has potential for building practical knowledge for safe practices. The lack of scientific underpinning and the removal of the simulation exercise from Topic 1 has reduced the depth of the ideal V-shape and created one of reduced range. Maton (2019) found a positive correlation between curricula that exhibited a wide semantic gravity and semantic density range and cumulative learning across fields and disciplines.

The semantic profile of Topic 2 on electrical installations shows its focus on underpinning engineering knowledge which is highly relevant to Topic 5 on installing, testing and commissioning electrical machines. It would make sense to link Topics 2 and 5, rather than separate them. Combining Topics 2 and 5 would then show a V-shape with a wider range, providing students with the engineering, procedural and practical knowledge for a key area of the curriculum. In its current form, Topic 5 would be termed a "down escalator" (Maton, 2014a). Maton explains that "downward shifts from decontextualised and highly condensed ideas (SG, SD+) towards more concrete and simpler meanings (SG+,SD-)" is a common practice in curricula, pedagogy and textbooks (2014a:39). It is "typically associated with teachers 'unpacking' and illustrating meanings from source documents such as textbooks. For example, teachers often focused on reading through texts with students, explaining words or ideas in less technical language and using everyday examples" (Maton, 2014:39). Maton explains that the downward escalator "is not in itself problematic" as "it can form part of a semantic profile that aids knowledge-building" (2014:39). However, movements downwards but not back upwards often represent "segmented knowledge" (Maton, 2019). This represents a problem for cumulative knowledge-building because "knowledge characterised solely by stronger semantic gravity and weaker semantic density may be too tied to specific contexts and too disconnected from other meanings to either build upon previous knowledge or be built upon in the future" (Maton, 2019:10-11). The downward escalator profile evident in the Topic 5 profile does not enable debriefing or reflection and constrains what Maton calls “greater generality and abstraction and interconnecting them with other ideas, thereby moving back into the specialised academic discourses teachers often returned to the text to unpack and exemplify further” (2014:39).

Topic 3 has a profile similar to that of Topic 2, but with fewer engineering knowledge outcomes, suggesting that it is less complex than Topic 2, yet it has a similar restricted range. Topic 4 on domestic appliances has no engineering knowledge, only procedural and practical knowledge, which is indicative both of the practical orientation and the lack of complexity in the outcomes (i.e., SG+,SD-). The inclusion of the upstroke of the V-shape suggests the possibility of reflection and building practical knowledge through debriefing and reflection on practice.

The semantic profile of Electrical Workmanship 4 as a whole shows that, while most of the outcomes (12) are underpinned by engineering knowledge, fewer are underpinned by procedural knowledge (9), with only 5 outcomes underpinned by practical knowledge. In a practically orientated course such as Electrical Workmanship 4, it would be expected that the majority of the outcomes would be underpinned by practical and procedural knowledge and include appropriate selections from scientific and engineering knowledge. The profile also shows the disconnection between the five topics. This disconnection and the inappropriate distribution of knowledge forms across the curriculum indicate that cumulative learning will be difficult. Many of the elements that support the development of practical knowledge and skills are not related to the two practical tasks. It is also not clear how the implementation activities in Topics 4 and 5 are underpinned by the engineering knowledge and procedures of Topics 1, 2 and 3. Expansion of the semantic range from SG-,SD++ to SG++,SD- are areas in which the EW4 curriculum could be improved.

4.6 Curriculum: conclusions and reflections

The curriculum findings show a lack of alignment between the NCV-EIC and the occupation standard for electrical infrastructure technicians. There is also a disconnect between the NCV-EIC curriculum and employer requirements. The broad generic outcomes of the NCV-EIC thus suggest that the programme prepares students for further learning, such as transfer to a university of technology electrical engineering technician diploma, rather than for practice in the field of electrical infrastructure construction.

Focusing on Electrical Workmanship 4, the curriculum encompasses a wide variety of topics, but there is no clear logic linking these different sections. This means the work of the linkages and relevant scientific knowledge is left to the lecturers to address in order to build students’ knowledge in electrical installation work. The subject and learning outcomes include safety, typical electrical installations, illumination, domestic appliances, electric machines, and control gear. The outcomes imply the development of students' understanding and practical skills in these areas. The curriculum content includes engineering science and procedural and practical knowledge. However, there the sequencing logic of the curriculum is missing and there are insufficient practical work-orientated activities to build students' practical knowledge for work-readiness. The assessment criteria tend to repeat the learning outcomes, such as the use of the same statement for the outcome and the assessment criterion for "Fault-find, repair and test domestic appliances and portable electrical power tools". However, the assessment criteria do sometimes include a range, which implies that particular fault identification techniques and ways of conducting fault-finding, repairing appliances and tools, and explaining procedures for safe testing, should be followed.

The prescribed textbook for Electrical Workmanship 4 primarily includes engineering knowledge. It focuses on helping students understand circuits involving resistors, inductors, and capacitors. While the textbook enhances students' theoretical understanding of the course content, it lacks work-orientated practical tasks and applications. It includes many calculations intended to reinforce theoretical knowledge and offers quizzes and questions that assess students' engineering knowledge.

The semantic profile analysis of the Electric Workmanship topics indicates gaps in the curriculum. While the curriculum includes practical elements, such as safety, typical electrical installations, illumination, domestic appliances and electrical machines, it lacks a logical relationship in the content selection to support cumulative vocational learning. Key elements, such as more work-orientated practice (preferably through simulation or supervised practice in work-like environments), reporting, debriefing, and reflection, are missing from the curriculum. This is a challenge for cumulative learning and for students' work-readiness.

The Electrical Workmanship 4 curriculum largely builds theoretical knowledge of electrical infrastructure construction. While it offers engineering, procedural and practical knowledge, these knowledge forms are disconnected. There are therefore gaps in supporting cumulative knowledge building for work-orientated learning. The emphasis on safety and typical electrical installations is clear; but further development in the selection and sequencing of content and the inclusion of reporting, debriefing and reflection would enhance the curriculum's effectiveness in preparing students for real-world electrical installation work, as would clear linkages between the different knowledge forms.

CHAPTER FIVE
FINDINGS: LECTURER INTERVIEWS

5.1 Introduction

Chapter Five presents and analyses the data produced through interviews with lecturers. Ten lecturers (see Table 3.1) who teach on the Electrical Workmanship 4 course were asked about their qualifications and experience, their understanding of the purpose of Electrical Workmanship 4 within the NCV-EIC, and their teaching, learning and assessment practices, including how they used the subject and assessment curriculum documents and textbooks. The interviews focused on the practical aspects of Electrical Workmanship 4, although lecturers were encouraged to raise other issues. Sub-section (5.2) describes lecturers' journeys from their own education experiences to their current positions at a TVET college. The next sub-section (5.3) outlines their general pedagogical practices on the EIC programme. Section 5.4 focuses on their practices in facilitating the practical sections of Electrical Workmanship 4. Thereafter, key challenges in facilitation are discussed (5.5) and lecturers' own suggestions and recommendations for improvements are put forward (5.6). Section 5.7 synthesizes the different sub-sections through a semantic analysis of the lecturer interviews; and the chapter concludes with a reflective summary. Chapter Five addresses this research sub-question question: What prior education, training and experience do NCV lecturers draw on in preparing students for industry?

5.2 Lecturers' journeys

The lecturers had different backgrounds and life journeys before being appointed as lecturers on the NCV-EIC. They also had diverse engineering qualifications and educational qualifications, along with different kinds of work experience in fields related to engineering infrastructure construction, as well as in teaching. For example, Isaac had previously taught at a university:

> I taught Electrical Engineering [at a comprehensive university] for 25 years. And then I moved to [a rural area] and I joined the college. Initially, I was teaching theory subjects and then it progressed into just teaching the practical side and being involved with the practical side of things (Isaac).

Dumisani had studied at a university of technology, where he obtained both a National Diploma and a BTech in Electrical Engineering. He also had a formal educational qualification, having obtained a postgraduate certificate in TVET education. He compared his experience as a student at a university of technology with the training offered at the college as follows: "There it was more focused on theory than practical [and] here it's more practical than theory". Dumisani also had industry experience:

> Before I started working here I [worked] at a company … which was in [town, suburb]. We design[ed] transformers and manufactur[ed] them from scratch. My role there was in various departments, but the main department was in the testing department where we test[ed] copper losses, test[ed] the oil and, so everything that [was] done in a transformer before it goes out to the site (Dumisani).

Gcobani had also studied at a university of technology and had obtained a National Diploma and BTech in Electrical Engineering, as well as an MTech in Mechatronics. He was a qualified electrician and had obtained a postgraduate certificate in TVET education.

Hennie had a National Diploma in Electrical Engineering and was an electrician with considerable industry experience:

> I worked at a power station …. In the power station I worked at three different positions … doing the maintenance and then the construction. I worked for my brother-in-law doing normal house wiring, even the maintenance on that house wiring. So I'm fully aware of what – during construction periods – what needs to be done. I know what the industry requires in general for a maintenance electrician (Hennie).

Cebo explained his journey as follows:

> Before I became a lecturer of NCV I used to work [as] an electrician. I gained a lot of experience when it comes to electrical department, electrical equipment. At some point I end[ed] up having that passion to take out the information that was within me to someone else because I had a lot of experience when it comes to electrical equipment also building generators and so forth ... I wanted to take that information and pass it through to the next generation (Cebo).

Angela had a National Diploma in electrical engineering as well as a postgraduate certificate in TVET education. She had also obtained a certificate in AutoCAD:

> I worked in industry for a few years – I was an electrical technician and then I decided to leave the industry to pursue my role as a lecturer, and then … I lectured EIC. I started at 2020 as a lecturer and I've been teaching EIC – this is my third year (Angela).

Jane had a National Diploma in Mechanical Engineering, a postgraduate certificate in TVET education, and non-formal certifications as an assessor and moderator:

> I was working for [Company Name]. So my qualification is in mechanical engineering so at [Company Name] I was working in the maintenance department. So with the maintenance department, you get to work with electricity, so I do have like advanced experience in the electrical (Jane).

Bertus completed the NATED programmes, N3 to N6, in "both mechanical and electrical". He undertook an apprenticeship "in electrical" and worked for the municipality after qualifying as an electrician. He explained:

> I was like working on the subcontractors there by the mines whereby I was like working, taking a full responsibility as a qualified electrician to do all the tasks [given] to me on a daily basis and also during different shifts, day-shift and night-shift (Bertus).

Bertus had completed short courses in assessment and moderation and took up the opportunity to teach the "N1 Trade Theory" but returned to industry and worked "as a rigger"; he also worked on a QCTO curriculum, developing a unit standard for advanced rigging skills. Thereafter, Bertus took up his current college position, teaching on the NCV-EIC.

Esihle had been a student on the NCV EIC; she obtained an apprenticeship in industry, and then returned to the college as tutor and then lecturer:

> So, I was like nominated as the AST which is Academic Support Tutor. And then from there, my love for lecturing developed. So I started to lecture from that (Esihle).

Given the differences in the lecturers' engineering and teaching qualifications and their work and educational experiences, it could be expected that they might engage in different teaching practices. Their general teaching practices are explored in the next section.

5.3 Teaching on the Electrical Infrastructure Construction (EIC) programme

In this extract, Esihle explains the range of subjects on the EIC programme:

> We prepare our students by firstly, by giving them the theory part of the subjects that we are teaching. With the NCV EIC, we have got seven subjects. The first three is your fundamental subjects and then the last four is your core subjects. So, on the

> fundamental subjects we have got Maths, we have got Life Orientation and then we have got English First Additional Language, which is compulsory to all of them. And then, we have got the four subjects which are core, so specifically for EIC, we have got Workshop Practice, we have got Electrical Principles and Practice, we have got Engineering Systems and Constructions and then we've got Electro Discipline and Digital systems (Esihle).

The lecturers interviewed taught these four "core" subjects that Esihle outlined. Angela's description of her teaching practice on these core subjects is worth quoting at length, as it provides a useful picture of the breadth and depth of her competence:

> I teach purely electrical subjects, I teach electrical principles and practice Level 2 and Electronic, and ECDE in Level 2 and in Level 3 for two years … and then in the third year I teach drawings in the ERT side and EPM and PEP, and now this year I'm back to teaching EIC. … I teach the electrical principles and practice which is more about the electrical side … like when we talk about electrical you get different streams. Like you get your heavy current … which is your high voltages and then you get you medium current and then you get your low voltages like you will say more instrumentation, more digital. You can also say programming. But so your EPP will concentrate more on your higher voltages, like circuits, light circuits, how to light a circuit. Basic circuits … how will you connect a circuit in order for electricity to flow, and then in EPP Level 3 there is also transformer calculations which is more concerning your high current. And then ECDE is more the electronic side of component of the subject where we focus more on integrated circuits … IECs, we focus on rectifiers and on power supplies but the physical circuit of the rectifier – like if you want to convert alternating current to direct current you will use a power supply but inside your power supply you will have your specific rectifier circuit which is also low voltage. So that is more low voltage where we deal with the different components like your voltage regulator or … your resistor and then there's also a digital component in that module which refers more to digital electronics like coding of computers and the different, not languages, but the different number systems. Like we only use for the normal number systems, the decimal number system, but in … there is a topic in ECDE where they introduce our students to the binary number system and in Level 3 they are introduced to the octal number system and the hexity single number system and they also, like there is in ECD Level 3 also a little bit of PLC programming also within the module. So that's what I'm teaching, that is my two subjects …. So the EPP is more to heavy current side where we concentrate on high voltages, 220 volts and transformers, and ECDE is more the electronic and the

> digital side of electrical engineering where we concentrate more on the programming and the small components and small circuits, lower voltage (Angela).

The range of Angela's practice and her underpinning knowledge of engineering science is impressive and contradicts claims that South African college lecturers lack the basic knowledge, experience and teaching skills to teach their TVET subjects (e.g., Wederkind, 2016; Alexander & Masoabi, 2017; Papier, 2017; Taylor & Van der Bijl, 2018; Zinn et al., 2019). Most of the interviewees taught a wide variety of subjects on the NCV-EIC and shared their extensive knowledge and experience.

Hennie had taught most subjects on the EIC programme:

> ECDE, EPP and Workshop as well as the Renewable Energy which we started basically in 2019 and prior to that we had the other electrical subjects which are Systems, Electrical Systems. So those five subjects all five of them I taught extensively (Hennie).

Hennie and Isaac taught at the same college and worked collaboratively. Hennie tended to teach the theoretical component of the subject, while Isaac took charge of the practical component:

> I worked mainly on the academic section where [Isaac] took the students into the workshop and completed the workshop part. But we worked together in close proximity meaning that, I know that he is going to do this particular practical and then we would take that practical and make sure that the students are prepared knowing the academic aspect that is required so that they can carry out that practical in a good way. And sometimes that caused us to change the curriculum order slightly (Hennie).

Isaac confirmed that he was "mainly responsible for the practical work of the students". He elaborated on Hennie's description (above), as follows:

> We followed an approach where some of the lecturers would be teaching the theory subjects and then one lecturer was designated to do all the practical work. And that was then for all four of the subjects that we offered. And the idea was that we will have good continuity in terms of the practical work …. So that's the role that I played …. The last three years that I was involved in NCV I did only the practical components (Isaac).

Bertus worked in a similar, collaborative way. Like Isaac, he was “more on the practical side” and had “been working … with the NCV Lecturers”, assisting them with the practical course components:

> We have a joint venture – the facilitators in the theoretical component cover the whole section regarding all the theory that needs to be covered, and then from there they will come to me and then give me all the necessary information that needs to be completed regarding the practical that the students will have to cover in the workshop. And then I will just go through all the manuals, collect all the components, get together with the students, present it first, like on the board, whatever, drawing or whatever practical that they need to cover in the workshop so that when we go to the workshop, they go with the full information coming from the theoretical component of the lecturer and the facilitator from the workshop (Bertus).

Other lecturers took responsibility for both the theoretical and practical elements of the subject that they taught. Dumisani explained that he brought practical engineering equipment into class to help students to learn the difficult engineering science content. Angela also explained the importance of including engineering tools in the class (in this case, measuring equipment) to help students to understand and consolidate concepts in measurement:

> Now there is a topic in EIC where we deal with measuring equipment. So you get your different types of measuring equipment so what I will then do is I will physically get a multimeter and then physically get the resistor or physically get the battery and show them how to use the multimeter, like they must then physically measure the voltage of the battery, or physically measure the resistance of the resistor. So that is how I will go about in that (Lecturer G).

Bringing engineering tools and equipment into class was the way in which Angela linked theory and practice. Similarly, Cebo saw his teaching approach as:

> … combining both the theory part and the practical part. …. We need to understand both the theory part and the practical part. … when I’m in the practical you do the practical in the workshop or sometimes you book to go [to a workplace] and see the working environment, how things work … and the theory part is just a book. My job to then combine both theory and the practical (Lecturer S).

Cebo explained that linking theory and practice involved not only doing practical work in the laboratory, but also seeing practice in “the working environment”. Speaking generally about the NCV EIC curriculum, Gcobani reflected that:

> There are some modules that require a lot of practical. But not all. Some will require you to explain more, and some they require you to practise more. For instance, in a workshop if we are talking about current you can explain it but then when you go to the workshop, to the working environment, they should see it. .... They understand that you have to apply it when they get there. And when we are talking about maybe how to use the certain tool, you can explain it less and instead you bring the tool into the working environment or into the workshop or even into the class, I can bring a tool, either it’s a measuring tool or maybe an equipment, whatever tool that I might get at that time, then I can give it to them then they can see how to use that tool (Gcobani).

Gcobani clearly explains the high level of challenge that vocational teaching demands – an important part of which is constantly switching between theory and practice, classroom, laboratory and workplace – and the need for the lecturer to have a solid understanding of the different forms of engineering, with procedural and practical knowledge that shifts between theory and practice demands.

5.4 Teaching Electrical Workmanship 4

All interviewees were specifically asked about their teaching practice on the Electrical Workmanship 4 subject and how their teaching on this practically-orientated subject prepared students for the world of electrical infrastructure practice. Electrical Workmanship 4 was understood by the lecturers as a mainly practical subject, requiring the lecturer to focus more clearly on students’ practical skills and competencies for the world of work. Cebo explained it like this:

> When you are talking about Electrical Workmanship … mostly it’s practical in that the students or the learners or the apprentices has to apply when they are the workshop in the working environment or what they need to apply when they are working with electricity, the things that they need to know, the things that they need to understand (Cebo).

Gcobani provided a thoughtful response to the purpose of practical work in the Electrical Workmanship 4 subject:

> When you are talking about Electrical Workmanship we are talking about mostly, it's what the student needs to apply when they are in the working environment, working with electricity, the things that they need to know, the things that we need to understand. ... For instance, if you're working with a motor you must first apply the precautions. … You must first isolate your motor, do the lock out, prepare it so that you can work on it. That's what we mean when we are talking about the Electrical Workmanship (Gcobani).

In the extract above, Gcogani emphasises that Electrical Workmanship 4 is about application, in particular, building procedural knowledge for how to install, maintain and repair machines related to electrical infrastructure.

As previously mentioned, in teaching Electrical Workmanship 4, Hennie collaborated with Isaac, who had the main responsibility for the practical work in this subject:

> Every week the students must go into the workshop and actually know what's going on in the workshop. Otherwise we spend too much time on simply the academics and … there's no time for me to kind of prepare them so that when they walk into the workshop, [Isaac] actually has a prepared student (Hennie).

Hennie explained it was important that students understood and could use the tools that they would be using for the practical workshop exercises:

> It is of great benefit for a student if they can have the actual thing that you're talking about, be it a circuit breaker or a DB board or just a resistor, if they can actually handle it with their hands and many of these things we also realised that to do it just once is not going to work (Hennie).

Hennie makes the important point that students need to become familiar with the tools of the trade, and that repeated practice is important in developing the skills and manual dexterity needed for using tools effectively – thus, "to do it just once is not going to work". For Isaac, the starting point for Electrical Workmanship 4 was, similarly, getting to know the tools of the trade: "showing them components I've given them – the first task was just a simple one where they just have to identify the components" (Isaac).

For Cebo, the Electrical Workmanship 4 workshop and the working environment had many elements in common:

> When we are talking about maybe how to use the certain tool, you can explain it, then you bring the tool into the working environment or into the workshop or even in the class, I can bring a tool, either it's a measuring tool or maybe an equipment, whatever tool that I might get at that time, then I can give it to them, then they can see how to use that tool. If you have to do the precaution that the work is in a safe condition and so forth … (Cebo).

As Cebo explains above, learning about a tool, and even seeing the tool demonstrated in a lecture, is quite different from applying it in practice.

For Fezile, the practical nature of Electrical Workmanship 4 did not diminish the need to apply a humanizing pedagogy and ensure that students developed critical thinking skills in practice:

> [Topic] One it's about safety … how to apply safety in the workplace … I would close the textbook and start opening the discussion to the class. 'What do you know about safety?', okay? Or 'Whenever you hear about the term, safety or safe, what comes into your mind?', okay? Under safety maybe we will end up discussing things like accident, incidents, and stuff, near misses, and then, okay, 'This is what we know about safety. What is it that you know about accidents? What is it that you think may cause an accident? Picture yourselves in the workshop. Let me say you are in the workshop you are working – you could be doing a panel - during that specific time what is it that you think may cause an accident while you are busy with your work?' Then they will start discussing, giving the answers and … when you get back to the textbook or when we focus more now on the content of the book, already some of important things that you need to discuss along the way, you will find out already the students they have given me some answers (Fezile).

In the above description of his practice, Fezile shows how he draws on students' prior knowledge to prepare them for practically-orientated learning. In the following extract, he explains how he supports students in practice:

> Sometimes even the ones who are falling behind, they tend to be shy. Like, 'No, we're fine,' so, continually fine, only to find out they are not fine. But now … they can see, man, 80% of class is moving now … if I raise my hand like now and then like say, 'Can you go back there, what was happening?' Now, that's where now I'll be able to help because the moment I see, man, no, this was a one-hour job, everyone is almost done but it's been two hours for you, since you've been doing the same task. Then I can start from the bottom where we started with the theory part, up until where we are now. So

> it gives me, like it makes it easier for me to see how my students are progressing. So that's one method that I normally apply when it comes to practical part. I just facilitate it, they know that when it comes to the practical part I'm not there to teach, I'm just there to facilitate. I just guide from what I taught them based on theory, now I'm just guiding them now to practice, apply the knowledge that I have given them (Fezile).

The lecturers explained that having well-resourced workshops and the right tools for the job are key to teaching practical skills. Cebo explains the process of aligning workshop conditions to an industry standard:

> Firstly, we make sure that our workshop is more or less equal to what is needed in the industry, like that. All right. So we have received materials from [Company Name], they supply us with the electrical components from [Company Name] at the standard of the industry. So we have got PLCs … we have got connectors and all those electrical devices, built on the panels and we have got a pre-wired panel that the learners have to use for testing and so on. So those are the things that we basically also find in the industry. It's better to go to, you go to the [Municipality Name], the Electrical Department, you'll see that most of the material they use there, we also do have them here. So it doesn't make a difference, we're training the learners at the college and if we send them into the workplace – of course, when they get into the workplace they will learn more because we are only an educational institution, and the industry are industry – they may have different things that we might not have, but at a certain stage we all have certain things that can put the learner at the certain level to go with the practical session (Cebo).

Cebo clarified the difference between the college and the industries that students are being prepared for, and that students would continue to develop and learn in the workplace – because, as Cebo put it, the college is "an educational institution, and the industry are industry". However, as he explained, alignment between the two institutions, such as happens when an industry partner provides tools and other components for practical training, can greatly enhance students' acquisition of industry-relevant practical knowledge. Jane similarly confirmed the importance of industry-standard equipment:

> We have a workshop where we offer our occupational programmes and it's actually having the equipment that is being used in the industry. For instance, the facilitators in the workshop, they constantly make sure that we are using the latest machines that are in the industry. So, our NCV EIC students get exposed to those type of machines. And also to add to that, we do have excursions that forms part of our work base

> exposure at the WBE, so we recently went to [Company Name] here in [Town Name]. So, we recently went there, where they showed them how they actually produce electricity (Jane).

Many of the lecturers were satisfied that they had been provided with the facilities, equipment and resources for Electrical Workmanship 4, as Dumisani confirms:

> So fortunately for us, for the college we have the latest technology that is used in the industry, so the components that are there are the ones that they're going to see when they go out. It's not like the outdated components or equipment. So it's the latest equipment. So I use that and I also show them the other equipment, using videos and try and show them some demonstrations in class of the equipment that they might find in the industry so that they know that there's different designs to the equipment. It's not just it looks the same way all of them. Some of them are different, but they do the same thing. That's what I try and prepare them for (Dumisani).

Dumisani pointed out that practical training in the college could not replicate practice in industry, but that the college could prepare students through the provision of practical experience, using industry-standard equipment. He also supported the importance of preparing students through developing their understanding of engineering theory which includes the underpinning principles of engineering practice. Understanding the engineering principles, he explained, is key to enabling students to transfer their experience from one set of components to another.

5.5 Challenges experienced by lecturers

A lack of industry-standard tools and components, and a lack of well-resourced workshops, negatively impacted lecturers' ability to prepare students for practice in the field of electrical infrastructure construction. As might be expected, key challenges experienced by the lecturers related to the lack of proper equipment and facilities for teaching the practical components of the EIC curriculum:

> … when it comes to practical parts there are some difficulties in terms of shortage of equipment and sometimes you found out that there are some things that we don't have in our workshop and we have only two things to work with or to use. So that's the difficulty that I'm facing. For instance, if I have to teach them welding – we only have one point of welding in the workshop and I have about 20-something students. So it makes life difficult because it's going to be very, very slow for me to finish that practical (Cebo).

Angela expressed concern that not all students had equal access to resources:

> Resources for the students to understand might be a problem because we all know they, not all of them, have the same resources. So if I maybe tell them go watch a YouTube video then not all of them might be able to go watch that specific YouTube video. I would say for me as a lecturer … for the students, resources might be a problem (Lecturer G).

Hennie expressed the benefits of site visits, but also the many challenges associated with arrangements and the logistics of site visits:

> … we try and arrange with [Municipality Name]. Previously with [Company Name] but also with some of the other companies all over, that we had an opportunity to go and visit them so that they can have a broader understanding, not of what house work and house wiring is all about, I mean, that's kind of common sense and that we have enough knowledge and that was transferred to them during that two to three year period. But when we have an opportunity to actually pay a visit to one of the bigger companies in [Town Name 1] or in [Town Name 2] and so forth that we visited previously, we made sure that the students had the opportunity to ask questions and, you know, and kind of nudge them forward and say, 'This is your opportunity to actually look at this and decide, Am I going to do this, be involved in bigger industry working with contractors and panels and high voltage and stuff like that?' And we also had a visit that we planned. Unfortunately it never came through where we wanted to visit [Power Station 1] and [Power Station 2], but with the fact that [Power Station 2] is now under construction for two years, we haven't been able to visit them in the past two years. But yes, we are trying to allow the student to actually see during their training period what – and what the working conditions should be (Hennie).

For some lecturers, teaching both the theoretical and the practical parts of their subject was a challenge. Although Dumisani had worked in industry, his practical experience was limited, and he was concerned that he was not always able to teach the theoretical and practical engineering knowledge and skills that students need for practice in the field:

> It's me as a lecturer understanding the content so that I can be able to explain and demonstrate to students. … And then the practical side – I don't have the practical skills to demonstrate to students in order for them to help them with the practicals of that content (Dumisani).

Angela explained that the demands made on lecturers to be proficient in both theory and practice was very challenging:

> We are not … all of us aren't strong at the same thing – like most of us, you have your strong points and then there is stuff that you [are less confident to teach]. There were modules in the subjects that I did in the beginning find difficult to teach, like electronics. The electronic side like transistors and what does a transistor look in the inside and with all the dials and stuff. But I think as I teach the subject, you learn together … and you broaden yourself with watching YouTube videos and stuff like that. So, I'm not where I want to be but I'm not where I was like when I started off (Angela).

Many lecturers found the practical aspects of Electrical Workmanship 4 difficult to implement. Gcobani explained this:

> As for me, when it comes to the theory parts, I haven't experienced any difficulties because most of the things, almost everything that I have to teach I have worked with … so I have more experience on those things. So it's easier for me to explain that thing. So the theory part has never given me any difficulty (Gcobani).

Concerns were raised about the curriculum and the required textbook. Gcobani found the Electrical Workmanship 4 textbook useful with regard to the theory underpinning electrical practice. As he put it, "When I look at the textbook there are the things that the student must know"; but the textbook was "not practical".

Lecturers with industry experience, or who were (or had been) qualified electricians, felt that there was a mismatch been the curricular outcomes and industry requirements:

> I don't know how to explain this but some of the things on the curriculum doesn't make sense why they are there, whereas they have nothing to do on what they are doing on the industry. … There is unnecessary information. For example, even on the practicals, when they are busy with their practicals, sometimes we used to take some of the modules out … because we've noticed that they have nothing to do with the stuff they are supposed to do. … Whereas, when they are going to the industry, they have to do the wiring, they have to do the maintenance (Bertus).

For Esihle, the curriculum needed revision:

> I think it needs to be revised a bit because – like for instance, there's too much theory in the subjects that I'm teaching. Okay – the Workshop Practice. So, if there can be maybe 40%, like your practical component which the student gets to calculate. You know the engineering students, they hate theory. They won't sit the whole day studying theory but if you give them an engineering problem, then they will get excited and then they will do it (Esihle).

Lecturers tended to be critical of the official curriculum documents for their subjects (such as the Subject Guide and the Assessment Guides). However, many felt that they were able to draw on their own knowledge so that "what they're doing here is exactly related to what they're going to do in the workforce" (Cebo). Others resented constantly having to supplement or adapt the official documents to meet the needs of industry more closely, while also preparing the students to meet the curricular outcomes, for example, by using old examination papers as class exercises. Angela expressed her frustration, explaining that the easier path was just to follow the textbook:

> I feel if I use the textbook, use some of the assessment activities that come out of the textbook – I think it's just fair for the student (Angela).

5.6. Recommendations and improvements suggested by the lecturers

Many of the lecturers felt that the NCV-EIC, and Electrical Workmanship 4 in particular, needed to be better aligned with industry standards. For Dumisani, this involved including digital and computer competencies:

> A little bit of programming because when you go to industry things are moving … they're going to need you to understand a bit of programming, now, because everything is shifting to that way (Dumisani).

Others such as Isaac had been proactive in terms of obtaining industry-aligned equipment and facilities:

> When I joined here there was very little equipment and resources available – it was very limited. And then I sat down with [the HoD] and we did a lot of planning into developing the facility and putting infrastructure in place – equipment to facilitate the teaching (Isaac).

Isaac explained the process of achieving alignment with industry standards:

> When we put our workshop together … what we tried to do is to make it as realistic as possible in relation to the industry … so the panel work that they would experience would be typically things that they would see in industry. The hand skills tools that we are using and the setup of the workshop is typical of a hand skills workshop that you will find in the industry. So when we planned the whole layout and the development of the lab and the workshop, we tried to keep it as close to industry standard as possible. And then when we hand out tasks and prepare them for work we try and do it in a manner that they would experience in the industry, to give them that type of exposure. And yes, we've taken them to industry visits quite a few times. We used to take them to a company in [Town Name] where they do a lot manufacturing work – not only electrical work – but a lot of mechanical manufacturing work and so on. And then the comments that I get from the students: 'But sir, the workshop looks the same as our workshop'. And, so ja, so from that they would see that it is as close to the industry reality as possible (Isaac).

Esihle felt that the practical component was insufficient and needed more curricular space:

> I think the tasks they are doing are not enough. Yes, they learn almost everything in theory but when it comes to the practical side, what they are doing is not enough for them like to just go and work on the industry. So, I think the colleges need to add more time on that practical stuff. And I think because they are electrical students, they don't need the lecturer to just impart the information to them. They need more practical experience because we have to prepare them for the industry (Esihle).

Hennie felt that there was a need for students to be more specialised within the Electrical Workmanship 4 course:

> Maybe we can have like the special courses, like maybe the installation rules and all that stuff so … I think I need that. For example, when we are working with practical, it's not like we are exposed like in everything so that we can be able to help the students with their practical (Hennie).

Bertus, who participated in curriculum development for the QCTO, saw the benefits of collaboration in order to enhance the quality of the curriculum and of provision:

> I'm just going to make an example with QCTO since that's the one that is currently running. … There are modules that are being set basically and then you find that, okay, some of them they are not actually in line with the curriculum. So you will find that,

> okay, at some point you will have to let's say, I would say, like a restructure … the question papers or maybe restructure, maybe the whole module whereby so that it can be in line directly with the cost or maybe the particular module that you'll be doing on the practical or maybe theory. And then definitely we use like different types of NATED books or electrical books from different aspects. Then we also engage actually with the varsity, maybe just to check maybe some guys if necessary, in terms of like let me say, if you'll find that I will be – let me say the technicians actually, technicians that are already finished there by varsity like working already, they're in the industry. So we engage with them that they can update this actually like with the new technology that have been implemented, like in terms of like the new variable components that they will be using … Ja. So we use all that information, we get it together, see compile and build maybe a fully question paper that will be according to the standard and the level of the students, and ja.

5.7 Semantic analysis of pedagogy

In this sub-section, the lecturers' interviews are analysed in terms for the four types of knowledge identified by the literature and their relative strengths of semantic gravity (or degree of practicality and contextuality) and semantic density (or degree of abstraction and complexity) (Maton, 2014). In this study, semantic gravity is represented by procedural and practical knowledge, while semantic density is represented by scientific and engineering knowledge) (see Table 2.1). What emerges very clearly across the interviews is the importance of both semantic density and semantic gravity in practice.

5.7.1 The engineering signature pedagogy

The engineering "signature pedagogy" has been described as a "lecture-demo" (e.g., Shulman, 1987; Lucas & Hanson, 2016; Abanilla et al., 2018;) in which an engineering lecturer brings tools and components into the lecture for the purpose of demonstrating engineering knowledge. Gcobani describes the classic engineering "signature pedagogy" here in his own words:

> The first things is to teach the theoretical content of the curriculum and then try to link this to the practical knowledge because remember TVET colleges are mostly there to prepare learners for workplace purposes, so when we teach in class, remember there is no practical knowledge that will come without theory, that's why we first we prepare to go with the theory in class (Gcobani).

For Gcobani, the defining pedagogy of the EIC is not simply a lecture-demo but a continual switching between theory and practice to bring theory and practice into a meaningful and mutually reinforcing relationship because, as he puts it, “there is no practical knowledge that will come without theory”. To understand Gcobani’s explanation, we could visualise his pedagogy as a standing wave continuously connecting theory and practice (Figure 5.1):

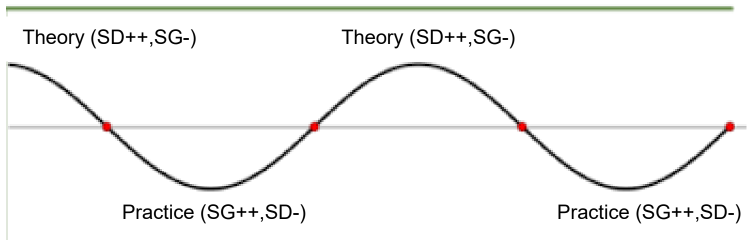


Figure 5.1:
Engineering signature pedagogy as a standing semantic wave

Whether in the lecture room or in the workshop, Gcobani was continually connecting theory and practice in his teaching. If we visualise Gcobani’s practice as connecting a wide range of theory and practice, we could understand that theory and practice could also be connected in a reduced range. For example, Isaac, who also confirmed the need to include both theory and practice in his teaching, describes a way of reducing the semantic density (in this case the engineering knowledge) and simplifying the practice for the purpose of making it easier for students to understand a concept:

> I think important in electrical engineering is to make use of artefacts and be able to demonstrate the different components to the students. So there are no lectures that I present without actual physical components that I can demonstrate and show the students. A lot of the students don’t have exposure to components and hand skills and that type of background, so all these things that we talk about is new to them; they can’t visualise these artefacts and what they look like – all these components. So I have a whole selection of those available and I like to make use of that to demonstrate them. I always say, you can touch it, you and feel it, you can lick it if you want, but get to know the component … so I think that works quite well because the student starts feeling comfortable with the component and starts recognising the component and then when you talk about it in your theory lectures – it’s not an abstract thing to them anymore. They can relate to it. I normally try and first let them identify what the components are all about so that they are familiar with that (Isaac).

In LCT semantic terms, Isaac's practice could be understood as one in which semantic density is reduced and semantic gravity is reduced. In other words, the highly challenging abstract engineering knowledge is simplified by bringing in practical tools and artefacts, but practice is also simplified, as the actual equipment is demonstrated rather than used in a complex practical task. Two waves are used to show Gcobani's practice (represented by the black line) and Isaac's practice (represented by the grey line) (Figure 5.2):

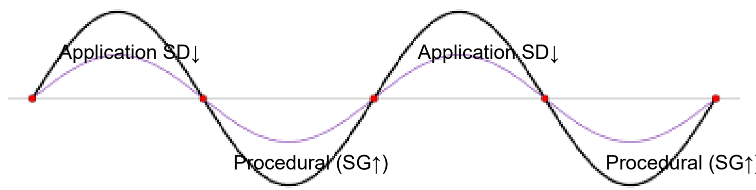


Figure 5.2:
Reducing the semantic range to lighten the cognitive load

Isaac reduced the semantic range by shifting between applied engineering knowledge (SG,SD+) and procedural knowledge (SG+,SD-) to make explanation easier for students; there was no scientific knowledge (SG-,SD++) or practical, contextual activities (SG++,SD-). Isaac's practice did not, however, end with reducing the semantic range to make explanation easier for students to help them grasp the engineering concepts. He understood that, at some point, he would have to increase the range of the semantic wave, slowly strengthening the semantic density and the semantic gravity. In the extract below, he explains how he strengthened semantic gravity. After introducing the tools and components, he stated:

> … and then I start showing them how – how you would physically put the components together, how does it become part of the circuit and its basic operation and so on. And then lastly actually implementing the circuit itself – so they start building the circuit, taking them through the construction phases and then testing and allow them all to do functional testing and commissioning on the circuit that they have constructed. And also introduce a bit of fault finding. So, in many applications I would send them away – create a fault and then let them come back and then have them look at the circuit and see if they can find the fault again, because if they fully understand the circuit they would easily find any of the faults that we can introduce into the circuit in this way. So, and I think that sort of completes the cycle with specific, a piece of practical work (Isaac).

Isaac explains how he built students' practical knowledge, taking them from understanding the tools and components to being able to use these tools to build circuits, and then to engage in fault-finding. In doing so, he replicated electrical technicians' work in his pedagogy, following the logic of practice. In one sense, the practical component of a subject could be understood as a 'tutorial' or as a way of explaining or consolidating theoretical knowledge; but in another sense, the practical must also prepare the student for industry. Weakening semantic gravity (SG↓) was related to also weakening semantic density (SD↓), thereby helping students to develop conceptual knowledge. In contrast, strengthening the semantic gravity (SG↑) was associated with preparation for practice. This need for repeating these iterations between theory and practice (with both a reduced and an expanded semantic range) until competence and proficiency were achieved could elaborate the signature pedagogy of engineering.

> After teaching them the theory then we take the learner into the workshop so that we can show them the things that have been done in theoretical version from the class point of view and then we show them into practical session into the workshops. And from there, after they finish the programme, we can also try to put them … place them into the industry so that they can see also the reality that are taking place into the industry (Gcobani).

5.7.2 The role of theory in practice

Angela was particularly concerned with the importance of theory in engineering practice. She described herself as "pro-textbook". She promoted strengthening semantic density (SD↑) and weakening semantic gravity (SG↓) in her teaching practice:

> I'm teaching more like applying, so I will explain to you the different methods or the different techniques that you can use to get your solution, and then I will give you problems so then you must apply your knowledge on your own. Different types of problems where you, so you can ask a question in different ways, so then I will give you all the different scenarios to practise on your own and see if you can apply the calculation, or if you can apply the theory or the method as I have explained it to you (Angela).

Angela's inclusion of practical activities is not work-directed, but comprises calculations and exercises intended to consolidate conceptual and applied engineering knowledge. Procedural knowledge and contextual knowledge that is orientated to the workplace was largely missing in her teaching. For Angela, the theoretical or what shed called the "academic part" of the programme was very important. In the extract below, she (rather harshly) explained that the lack of theoretical, principled engineering knowledge would be a barrier to students becoming engineering technicians:

> Most of the students perform very well in the workshop … but we found that there are a few that, although they have the hand skills and for that matter even the … how can I say, the soft skills to handle the conditions, the academic part was just too much for them. And unfortunately there is no other route for them to become an electrician and they will most probably remain as a labourer for many, many years to come (Angela).

Because of her understanding of the importance of theory, Angela estimated that she spent "70% of the time on the theory".

Isaac, who was probably the most practically-orientated of all the lecturers interviewed, did not dismiss the importance of theory, but always included practice – even in a lecture using PowerPoint:

> I like to teach using PowerPoint. If we would be discussing an electrical component so that I could use a lot of photographs and video material and so on in the PowerPoint presentations. And then I like to switch to the whiteboard and teach hands-on if it gets to the mathematical problems and so on. And a lot of times I use a combination of the two techniques as well. I would use PowerPoint to like sort of pre-empt the problem and, for the given path of the problem and then, once we go into problem solving I switch to the whiteboard and then I would work on the whiteboard. … So those are the techniques that I like to use (Isaac).

Dumisani was one of the few lecturers who saw theory in two different ways: both in terms of concepts underpinning practice, and as a way of reflecting on practice:

> For theory, I just give a bit of background and use some real-life examples … For practical I have to first show them the components physically. Bring the components to class and show them and explain to them how it works and what is it for and everything and then I go back to theory again and teach them again about the theory behind renewable energy. So that is my approach (Dumisani).

Visualizing Dumisani's semantic wave, the increasing amplitude represents the strengthening of both semantic density (SD↑) and the strengthening of semantic gravity (SG↑) over time (Figure 5.3).

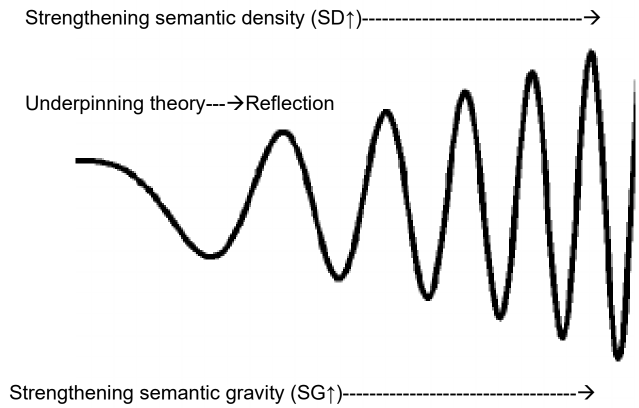


Figure 5.3:
Increasing the semantic range to enable cumulative learning

Reflecting on the EIC programme – and the intellectual and practical challenges that it offers – Hennie felt that not all students would succeed, but while not all students might meet all its demands, there was still scope for students to make meaningful contributions in the world of engineering practice:

> We are as a team well prepared and I've got the background knowledge on saying to a student that, you know, You are scared of getting onto a ladder, how are you going to do this? Or, You're scared to put your hand in somewhere because you got so-called – a fear of short and small spaces. How are you going to crawl into an area where you're going to have to pull a cable with you and do all those kinds of things? No, no, no, no, no – you need to get over this, you know? Because eventually you don't know what that person is going to do. But our attitude isn't that you should only become an electrician. Our attitude is if you have the background knowledge, for instance, to study for the three years right here at the college and you then decide, listen, I don't want to become an electrician per se, maybe you don't have the technical skill … then I would suggest you can move over to a place like Voltex or other supply companies where they supply the parts and stuff and then you are well aware of what the parts look like, you've studied the industry and you have a good idea. So if a person from the street comes in and says I'm looking for wiring for a plug, at least you can provide him with the correct gauge and the break colours and all of those understandings you have, because you've studied the subject and you would be of much more use to a company like that, a supplier, compared to a person just off the street who just made Matric. So, ja, we try and prepare them

for a wider and a broader view than just being an electrician or being an assistant for that matter (Hennie).

5.8 Conclusion: Towards a pedagogy of practice

The findings from the interviews with the Electrical Workmanship 4 lecturers highlight the importance of practical hands-on experience, concerns about curriculum-industry alignment, suggestions for curriculum revision, collaborative teaching approaches, the role of theory, and the need for increased practical training to prepare students for the electrical infrastructure industry. These insights provide valuable perspectives on the challenges and opportunities in teaching Electrical Workmanship 4.

CHAPTER SIX
CONCLUSION: TOWARDS A PEDAGOGY OF PRACTICE

6.1 Introduction

Chapter Six briefly summarises what was achieved in the study (6.2), and how the research sub-questions were addressed (6.3). Section 6.4 outlines the contribution to knowledge made by the study, while Section 6.5 outlines the contribution to practice, in this case, curricular and pedagogical arrangements for practically orientated subjects in TVET colleges. Section 6.6 concludes the study.

6.2 What the study set out to achieve

The aim of this study was to investigate the nature and quality of curricular and pedagogical practices on the NCV EIC in order to understand the effectiveness of lecturers' practices in preparing students for transition to the world of work. The study was guided by the research question and its two sub-questions: 1) How does the NCV EIC curriculum prepare students for industry? and 2) What prior education, training and experience do NCV lecturers draw on in preparing students for industry? The curricular and interview study focused on the practical aspects of Electrical Workmanship 4.

6.3 Addressing the research questions

The two research sub-questions are addressed in sub-sections 6.3.1 and 6.3.2, summarising what was achieved, as set out in Chapters Four and Five of the thesis.

6.3.1 Does the curriculum prepare students for industry?

The course content of the Electrical Workmanship 4 curriculum encompasses topics related to safety, electrical installations, illumination, domestic appliances, and electric machines, focusing on both theoretical and practical aspects. The curriculum does not include basic scientific knowledge but focuses on engineering knowledge, procedural knowledge and practical knowledge, including practical activities. However, many of the practical activities are not work-directed but comprise calculations and exercises intended to consolidate conceptual and applied engineering knowledge. The prescribed textbook for Electrical Workmanship concerns primarily applied engineering knowledge. It focuses on helping students understand circuits involving resistors, inductors, and capacitors. While the textbook enhances students' theoretical understanding of the course content, it lacks work-orientated practical tasks and applications. It includes many calculations intended to reinforce theoretical knowledge and offers quizzes and questions that assess students' theoretical and applied knowledge. Thus there is a need to increase the quality and quantity of practical knowledge. The outcomes tend to be predominately theoretical, and the assessment criteria are poorly formulated, not always showing clearly what is expected or the level of performance required.

The semantic profile of the Electrical Workmanship 4 course shows that the five course topics are not connected. This lack of connection will not support cumulative learning on the programme. Cumulative learning requires topics to build on each other, increasing the semantic gravity and semantic density ranges of the curriculum knowledge. The curriculum thus poses challenges for cumulative learning and for students' work-readiness.

The Electrical Workmanship curriculum provides theoretical and applied engineering knowledge in electrical infrastructure construction. While it offers a mix of theoretical and practical knowledge, these knowledge forms are disconnected. There are gaps in supporting cumulative knowledge building for work-orientated learning. The emphasis on safety and typical electrical installations is clear; further development in procedural and practical knowledge, as well as the inclusion of reporting, debriefing and reflection, would enhance the effectiveness of the curriculum in preparing students for real-world electrical workmanship, as would clear linkages between the different knowledge forms.

6.3.2 Do lecturers have the education, training and experience to prepare students for industry?

The lecturers had a wide range of qualifications and experience. All lecturers had qualifications in relevant engineering fields, and some were (or had been) certified electricians. Many had formal teaching qualifications (e.g., PGDip); others had non-formal certificates in assessment and moderation. All the research participants had some form of industry experience which was extensive and wide ranging in the case of some lecturers, and less so in the case of others. Some had many years of teaching experience; others were relatively new lecturers; and some had experience of teaching electrical engineering in different contexts (e.g., at a comprehensive university). This diversity in backgrounds influenced the lecturers' teaching approaches, and place different burdens on the lecturers. Acknowledging their different strengths, some lecturers chose to work collaboratively, with one lecturer responsible for theory and another for practical work. This approach ensured that students were well-prepared for practical tasks and allowed for some adjustments in the curriculum, based on student needs. All lecturers emphasized the importance of practical hands-on experience for students as it provided them with opportunities to work with actual electrical components, circuit breakers, and other equipment. All lecturers valued practical work and saw this as crucial for students' understanding and preparation for the industry. While practical work was emphasized, all lecturers also recognized the importance of theory, understanding that a strong theoretical foundation was essential for students to understand the principles behind electrical workmanship.

Many lecturers found it challenging to implement the practical requirements of Electrical Workmanship 4, mainly because of the large amount of theoretical knowledge that had to be covered, even in a practically-orientated subject like Electrical Workmanship, but also because, in some cases, there were challenges with equipment and resources, or the availability of a workshop. These constraints limited their ability to prepare students for the world of work in electrical infrastructure construction. However, they felt that students who had mastered the challenging academic level of the course would be well prepared for further study, for example, at a university of technology.

Lecturers stressed the need for colleges to provide more practical experience to students. They believed that colleges should allocate more time to practical training to prepare students better for the industry.

The lecturers felt that some curriculum components were unnecessary and did not align with what students needed to know and do in the electrical infrastructure construction field. Several lecturers believed that the curriculum needed revision. They suggested reducing the emphasis on theory and increasing the practical component to ensure better engagement of students. A more balanced approach was seen as beneficial, especially for students who might struggle with theory. Lecturers who had extensive industry experience or electrician qualifications expressed concerns about the mismatch between the curriculum outcomes and industry requirements. They believed that specialized courses within the EIC programme could help address this issue.

6.4 The contribution to knowledge: a theoretical understanding of practically-orientated subjects in TVET colleges

This thesis contributes a theorised understanding of the knowledge basis and pedagogical arrangements for practically-orientated TVET college subjects. Drawing on the literature and educational theory, the thesis explains combinations of stronger and weaker semantic gravity and stronger and weaker semantic density are required in practically-orientated, technical contexts. The knowledge forms found to be necessary included: 1) basic scientific knowledge (SG-,SD++) that is related to the field of practice, 2) applied knowledge (in this case, engineering knowledge) that underpins the field of practice (SG+,SD+), 3) procedural knowledge (SG+,SD-) and 4) practical knowledge (SG++,SD-). These forms of knowledge are related to one another and can be conceptualised as a V-model (Figure 2.1). Their dynamic relation to one another is represented by the semantic wave. It would be expected that both the semantic range would increase over the course of the curriculum.

The study also shows how pedagogies that draw on "conceptual integration" (Jawahar & Mukeredzi, 2015), in this case those that can shift between the conceptual and the concrete, can both contribute to students' conceptual development and can also increase their work readiness. Such pedagogies were identified as shifts between weakening semantic density (SD↓) and weakening semantic gravity (SG↓), thereby lightening the cognitive load on students, followed by strengthening semantic density (SD↑) and strengthening semantic gravity (SG↑), thereby increasing the level of intellectual and practical challenge. Reducing and increasing the semantic range (represented by rises in the amplitude of the wave) is the key pedagogy to enable both cumulative learning and work-readiness.

6.5 Contribution to practice: curricular and pedagogical arrangements for practically orientated subjects in TVET colleges

The contribution to practice in this thesis addresses the contribution to curriculum development and renewal (Section 6.5.1) and to a pedagogy of practice (Section 6.5.2).

6.5.1 Implications for curriculum development

The study of the Electrical Workmanship (Level 4) Study and Assessment Guidelines and the comparison of these guides with international best practice in the literature review, along with the QCTO occupational standard and industry needs for installation electricians (as evident in recent job advertisements), pointed to several gaps between the outcomes of the practical course and the competencies expected in employment. The following recommendations are offered with the intention to improve Electrical Workmanship 4 and better align it with the occupational standard. These recommendations have implications for similar technical subjects that are practically orientated.

6.5.1.1. Focus and purpose of the subject

The practical subject needs a stronger practical focus; and it needs to be more aligned to the qualification purpose of electrical infrastructure construction. In this case, the Health, Safety, Environment, and Quality (HSEQ) standards that are specific to electrical infrastructure construction should be considered for inclusion in Topic 1. The reintroduction of "Low voltage transformers and switchgear" could also be considered. The 2007 topic, "Low voltage transformers and switchgear", is particularly appropriate to the NCV EIC qualification, and its return (or adding a similar, more up to date module) to the Electrical Workmanship (Level 4) curriculum should be considered. In his study of the NCV-EIC, Mesuwini found “a disconnection between lecturers, graduates, employers and the curriculum policy [that] impacts on all the role-players as there should be an interconnection amongst all the stakeholders” (2015:64). Mesuwini’s study is supported by the findings of this thesis.

6.5.1.2 Simulated electrical infrastructure environments

Through the inclusion of simulation and the introduction of specialized equipment into the laboratories for electrical infrastructure, technical, practical subjects would develop a stronger practical focus that would be better aligned with the purpose of the qualification. In this case, for example, it would be possible for TVET colleges to collaborate with the SAIEE Training Academy to offer jointly a SAIEE-accredited HV/MV switching course for the purpose of ensuring that appropriate practical skills are developed in support of TVET students’ employability. Because electrical infrastructure is generally not available in a TVET college laboratory, simulation should be considered. Site visits and industry-training, such as that offered by SAIEE’s Training Academy, should also be considered for inclusion.

6.5.1.3 Assessing practical training

The inclusion of more practical assessment tasks that are aligned with the key occupational standards should be considered. Assessment criteria should similarly focus on the occupational competences of “installing, monitoring, testing, repairing” electrical infrastructure. Using the “translation device” (Maton & Chen, 2016) adapted for this study (see Table 6.1) would enable curriculum developers to ensure that the semantic profiles of the subject outcomes supports students’ development of practical competence.

6.5.1.4 South African Institute of Electrical Engineers (SAIEE) accreditation

Course accreditation by the South African Institute of Electrical Engineers (SAIEE) would enhance the creditability of the NCV EIC qualification for potential employers. Seeking input from the Training Academy of SAIEE would strengthen the practically orientated subjects and provide them with considerable status in the perceptions of employers. For example, the SAIEE Training Academy offers a short HV/MV switching course which would be highly appropriate for NCV-EIC students.

6.5.1.5 Collaboration with partners

Practically orientated subjects benefit from strong partnerships with industry, private enterprises, and governmental and professional bodies. The training division of ECA(SA) provides specific training for Construction Electricians, refresher courses to prepare students for their trade tests, as well as a two-day practical evaluation of candidates to attain artisan status. It offers registration of apprenticeship contracts with the Sector Education Training Authorities and free practical apprenticeship under the CETA Training Contract. In addition, ECA(SA) offers training courses at its national and regional offices. These courses include: Certificate of Compliance (Unit Standards), Certificate of Compliance Refresher course, SANS 10142-1, Earthing and Bonding, Specialised electrical installation codes (P1 and P2), Electric Fence System Installer course, Management of the Construction Site and Safety Files, amongst many others. Inviting collaboration with ECA(SA) and introducing students to the Association would greatly enhance students' employment prospects.

6.5.1.6 Moderation of practical training

External moderation is conducted by the Department of Education, Umalusi and, where relevant, an Education and Training Quality Assurance (ETQA). The ICASS is "moderated internally and externally quality assured by Umalusi" (EWAG, 2007:3). For practical vocational subjects, it might be more appropriate to draw on the expertise of the SAIEE and the QCTO for external moderation.

6.5.1.7 Nomenclature of Electrical Workmanship (Level 4)

It might be appropriate to change the course title from 'Electrical Workmanship' to one that is more gender-neutral and so more inclusive of female students. This is particularly important in light of the gender imbalances in the field.

6.5.2 Implications for lecturers: discovering a pedagogy of practice

While it was important to ground the study on an established theory of knowledge development and learning, the V-model (Figure 2.4) and the ideal semantic wave (Figure 2.5) can be translated into a more straightforward framework for lecturers to use when planning or reflecting on teaching and learning of practical subjects (Table 6.1).

Table 6.1: A framework for practically-orientated engineering subjects in TVET colleges

Key actions	**Evaluative questions**	***Examples***
Conceptualise	Do the students have the relevant underpinning scientific knowledge for the practical task?	*Lecturers explain/recap key underpinning concepts.*
Apply	Do students have the applied engineering knowledge to plan the practical task?	*Lecturers provide and require the students to work through examples, case studies or calculations, in the field of practice.*
Proceduralise	Do students have procedural knowledge for planning a practical task?	*Students are given time to discuss how they will tackle the task. Students set out their own workstations, including equipment – practise skills.*
Implement	Do students engage in practical activities that are close to, or prepare them for, the industry equivalent?	*Students undertake a practical task that approximates the industry standard.*

Report	Do students write a report on the practice tasks?	*Students write a brief (industry-standard) report on the task (or make an oral report).*
Debrief	Do students debrief and/or receive feedback on practical work?	*Students receive feedback (from lecturer or peers), against criteria, on a practical task.*
Reflect	Do students reflect on the practical task, including drawing on relevant theoretical knowledge to explain errors/enhance future practice?	*Students engage in critical (theoretical) reflection on the practical task.*

6.6 Conclusion and way forward

The guiding question for this research study was, "How do NCV EIC lecturers prepare students for industry?" The question is a complex one which was addressed through an examination of the curriculum and of the lecturers' pedagogical practices. The study found that there were barriers to the lecturers' preparation of students for industry; but these challenges were not caused by poorly prepared lecturers or a lack of student-centred methodologies. Instead, lecturers were constrained by curricular challenges that included a theory-heavy curriculum in a largely practical subject, an exam-focused curriculum, poorly written subject and learning outcomes and assessment criteria and, in some cases, by inadequate training equipment or heavy usage of workshops, leaving insufficient time for their students to access the workshop facilities. Exacerbating these difficulties were that there were few opportunities for students to undertake internships, site visits, or other forms of work-integrated learning, and a TVET college culture that lacked strong forms of industry collaboration.

The study raised many areas for further investigation, such as how the curriculum might be enhanced, whether there might be a need for 100% practical subjects that are strongly aligned with industry requirements and partly facilitated by industry partners, whether more advanced post NQF Level 4 qualifications might be necessary, how the curriculum might need to change to support more entrepreneurial thinking, and how more systemic approaches to collaborations with industry partners and potential employers might be implemented – amongst others.

In conclusion, the study has shown that, far from being 'the problem', the TVET lecturers draw on their engineering knowledge, their engineering practice, and their external networks to support students' learning of engineering theory and acquisition of engineering practice. They work collaboratively, drawing on each other's strengths, to ensure that tools and practices are appropriate and up to date – and often have to mitigate the shortcomings of the curriculum. The TVET lecturers need to be commended for these efforts and supported by their colleagues in keeping their engineering knowledge, skills and practices current.

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APPENDIX/APPENDICES

APPENDIX A: INFORMED CONSENT AND INTERVIEW QUESTIONS

CAPE PENINSULA UNIVERSITY OF TECHNOLOGY

<u>Informed Consent to participate in a Research Study (Lecturers at the TVET college)</u>

How TVET lecturers prepare Electrical Infrastructure Construction students for industry

M Ed Candidate:	Mr Sibusiso Mdletshe, Faculty of Education, Cape Peninsula University of Technology
M Ed Supervisor:	Professor Christine Winberg, Professional Education Research Institute, Cape Peninsula University of Technology.

Dear [Name]

Overview and purpose
I am inviting you to be part of my research study on how TVET lecturers in EIC prepare students for industry. I am trying to find ways to enhance TVET provision, including curricular and pedagogical provision. This study is supported by the Department of Higher Education and Training's Technical and Vocational Education and Training Directorate and is part of the larger 'Evaluating TVET' project that has the purpose to improve provision at TVET more generally.

Description of your involvement
If you agree to be part of this study, I will ask you to tell me about your experiences as a EIC lecturer. The interview will take roughly 45 minutes – one hour. The interview can take place in your office, or on MS Teams. I'd prefer to audio record the interview to ensure that our talk is accurately captured, but if you don't want to be recorded, you can still participate in the study.

Voluntary nature of the study
It is entirely up to you whether or not you choose to participate in this study. You have the right to change to withdraw from the study at any time. You have the option of not responding to a question for whatever reason.

Benefits
You will benefit from the study by having the opportunity to reflect on your approach to teaching and learning, as well as to identify training needs. Your participation will help the college and the TVET sector to enhance the EIC curriculum, which is crucial for the economic development of our country. Even if you do not receive a direct benefit from participating, other lecturers who teach EIC as a beginner may benefit from the knowledge obtained in this study.

Risks and discomforts

If answering questions makes you feel uneasy you have the option of not answering a question or stopping at any point. Simply inform the interviewer that you wish to terminate the interview.

Compensation

There is no payment for participating in the study. The interview will either be held in your own office, or will be held via MS Teams, depending on your preference.

Confidentiality

My supervisor and I plan to publish the findings of this research, but we will not include any information that could be used to identify you. To protect your privacy, the audio recording of your interview will be stored on the CPUT website in a protected area where only I and my supervisor will be able to listen to it. The audio files will be destroyed once a written word-for-word record of the interview has been made. The data will be entered onto a secure university server by the researchers. Your real name will not be used in the written copy of the discussion to preserve your privacy.

We may utilize or share the results of your research in future studies. If we share your data with other researchers, it will be anonymized, which means it will not include your name or any other identifying information.

Contact information

If you have questions about this research, please contact me, Ms Andrea Anita October, at this email address: andreaoctober09@gmail.com, or telephone: (021) 930 3305

With thanks,

Sibusiso Mdletshe

Consent

You consent to participate in the study by signing this paper. I'll send you a copy of this document and keep a copy for my studies. Make sure we've addressed any of your concerns regarding the study and that you understand what you're being asked to undertake. If you have any further questions, please do not hesitate to contact me.

I agree to participate in this study.

______________________________________ ______________________

Signature Date

____

Printed Name

I agree to have my interviews audiotaped.

______________________________________ ______________________

Signature Date

Cape Peninsula University of Technology

Faculty of Education
Ethics informed consent form

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Category of Participants (tick as appropriate):

Principals		*Teachers*		*Parents*		*Lecturers*	✓	*Students*	
Other (specify)									

You are kindly invited to participate in a research study being conducted by *Sibusiso Mdletshe* from the Cape Peninsula University of Technology. The findings of this study will contribute towards (tick as appropriate):

An undergraduate project		*A conference paper*	
An Honours project		*A published journal article*	
A Masters/doctoral thesis	✓	*A published report*	

Selection criteria
You were selected as a possible participant in this study because (give reason why candidate has been chosen):
To assist with the improvising of electrical infrastructure construction education in the TVET sector. Based on your qualifications and experience I would like to gain your perspective and more insight of teaching electrical infrastructure construction subjects in vocational and technical education.

The information below gives details about the study to help you decide whether you would want to participate.

Title of the research:
How TVET lecturers prepare Electrical Infrastructure Construction students for industry

A brief explanation of what the research involves:
In the light of the key role that electrical infrastructure construction plays in work and in education, it is important that the curriculum is of high quality, and that lecturers are well-prepared to facilitate students' learning (Martin & Dunsworth, 2007). Badenhorst and Radile (2018) have shown that TVET lecturers are the most ill-prepared for their work of all educational sectors. While some lecturers might have academic qualifications, they lack the necessary industry experience for effective technical teaching. Lecturers clearly cannot prepare students for the world of work if they have no experience of it. Lecturers who do not

possess the required skills for facilitating learning in a particular subject have a negative impact on students' academic achievements (McConney & Price, 2009). Therefore, the objective of the study is to describe TVET electrical infrastructure construction lecturers' journeys, experiences and practices. As well as to discover how TVET electrical infrastructure construction lecturers' teaching practice could be enhanced.

Why is this research important?

The particular focus and problem of this study, because of the lecturers' lack of formal qualifications and industry experience to teach electrical infrastructure construction subjects. Therefore, in this study my aim is to help EIC lecturers find better ways in training their students for the world of work.

Benefits of research

(Researcher please briefly describe any foreseeable benefits of the study)

This study will contribute to the body of knowledge about supporting lecturers who teach EIC subjects in technical and vocational education, without necessarily have all the required qualifications and/or industry experience. The study thus intends to contribute to the enhancement of TVET educational provision.

Incentives

(Research please describe what if any, incentives will be offered to the participants)

There will be no incentives for participating in the research.

Procedures (duration)

(Researcher please describe the procedures and the duration of the procedures)

Because it is critical to protect the lecturers privacy and dignity, thus I will be doing individual interviews in the lecturers own offices, if possible, or via MS Teams, depending on the restrictions in place. I will follow best practices for the use of video-conferencing software in semi-structured interviews (Archibald, Ambagtsheer, Casey, & Lawless, 2019). The interviews will be done during working hours (lunch breaks) to make sure that participants have access to WiFi. The participants will respond to questions that I have prepared to address the research sub-questions (see Appendix A). The semi-structured interviews will be audio-recorded and transcribed by a professional transcriber.

Right to withdraw/ voluntary

(Researcher please describe how you will explain to the participants how the study is voluntary and that they have the right to withdraw from the study at any time)

The researcher is going to address ethical issues by firstly explaining the purpose of the study to all participants. I will explain that my research is conducted for the purpose of obtaining my Master's degree and my interest in enhancing TVET educational provision. In addition, I will give each participant a consent form to be signed and explain the participation of this study is entirely voluntarily based and elaborate that each participant has the freedom to withdraw at any given point during the interview.

Confidentiality and anonymity

(Researcher please describe how you will explain to the participant that their identity and the data will remain confidential and anonymous)

I will inform the interviewers that I'll be using pseudonyms for each of them, and that the names of the department and the selected TVET College will be replaced with a pseudonym as well. I'll also explain that I will all interview recordings will be stored on the CPUT Library website, where they will only be accessible for transcription and destroyed on completion of the thesis. Hard copies of transcriptions, my notes, as well as contact information will be kept in a locked filing cabinet at my home, with only I having the key and access. Electronic copies of the transcriptions will be stored on my personal laptop and password-protected. No one else is permitted to use my laptop as I will follow the recommendations stated by the Protection of Personal Information Act (July, 2021).

Potential risks, discomforts or inconveniences
(Researcher please briefly describe any foreseeable risks, discomforts or inconveniences likely to affect research participants)
I will explain that if they feel uncomfortable answering any interview questions they do not have to answer. I will try to minimise any inconvenience, e.g., with regard to their preference for the interview time and or place of interview. I will assume them of confidentiality at all the interviews.

What will happen to the data when the study is completed?
The data will be stored on the CPUT Library's secure storage. When my thesis is complete this data will be destroyed, following the recommendations stated by the Protection of Personal Information Act (July 2021). I will only use the anonymised transcriptions in which all identifying information will be removed. These transcriptions will stored on my personal laptop with encrypted passwords.

Kindly complete the table below before participating in the research.

	Tick the appropriate column	
Statement	Yes	No
1. I understand the purpose of the research.		
2. I understand what the research requires of me.		
3. I volunteer to take part in the research.		
4. I know that I can withdraw at any time.		
5. I understand that there will not be any form of discrimination against me as a result of my participation or non-participation.		
6. Comment:		

Please sign the consent form. You will be given a copy of this form on request.

Signature of participant	Date

Researchers

	Name:	Surname:	Contact details:
1.	Sibusiso	Mdletshe	Contact number: 071 786 4623 Email: isibusisosabadletshe@gmail.com

Contact person: Professor Christine Winberg	
Contact number: 079 039 4931	Email: winbergc@cput.ac.za

Semi-structured interviews

Introduction

At the first interview, I will explain the purpose of the study and the participant will sign a consent form. I will welcome the participant and thank him/her for participating.

1. What is your teaching role on NCV EIC?
- *Prompt: theory subject? Practical subject – e.g., Electrical Workmanship?*

2. Please tell me about your journey as a NCV EIC lecturer.
- *Prompt: what was your prior occupation (if applicable?)*

3. Could you tell me more about EIC Modules that you teach?
- *Prompt: access to resources? Facilities? Partnerships? Computers?*

4. Could you describe how you teach different sections?
- *Prompt: what approach for theory? What approach for practice?*

5. What assessment exercises have you set?
- *Prompt: how to you develop assessment question? Do you consult with industry partners?*

6. Could you describe how you prepare your students with regard to practical learning?
- *Prompt: Is the equipment industry-standard? Do you include industry visits?*

7. Have there been sections of the module that you have found difficult to teach?
- *Prompt: Why? Resources? Skills issues?*

8. Do you have any electrical work experience?
    - *Prompt: If yes what were your duties at the time?*

9. Based on your experience in teaching EIC do you think the curriculum is in line with what the work force is currently doing?
    - Prompt: What are the reasons? Why do you think this is the case?

10. Is there anything you would like to be added or removed from the curriculum?

11. Do you have a teaching qualification?
    - *Prompt: If yes, what is your specialization? If not what qualification(s) do you have?*

12. What professional development would you value as a lecturer of EIC?
    - *Prompt: any suggestions? Have you attended any useful short courses, etc.?*

APPENDIX B: ETHICS LETTER

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FACULTY OF EDUCATION

On the **28 August 2023**, the Chairperson of the Faculty Research Ethics Committee of the Cape Peninsula University of Technology granted ethics approval **(EFEC 1-08/2023)** to S. Mdletshe for a **MEd**.

Title:	**How TVET lecturers prepare Electrical Infrastructure Construction students for industry**

Comments:

The Faculty Research Ethics Committee unconditionally grants ethical clearance for this study. This clearance is valid until **31st December 2026**. Permission is granted to conduct research in the **Faculty of Education**. Research activities are restricted to those details in the research project as outlined by the Ethics application. Any changes wrought to the described study must be reported to the Ethics committee immediately.

______________________________ Date: 21 June 2023

Prof. Zayd Waghid

Chair of the Faculty Research Ethics committee

Faculty of Education

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