IMPLEMENTING LESSON STUDY TO INFLUENCE THE TEACHING AND LEARNING OF ELECTRICAL WIRING DIAGRAMS IN A SOUTH AFRICAN TVET COLLEGE.

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DECLARATION

I, Mark Sanjeevy, declare that:

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Date: 14 May 2025

DEDICATION

This dissertation is dedicated to my Lord and Saviour, Christ Jesus.

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LIST OF ACRONYMS

Acronym	Description
AR	Action Research
CLT	Cognitive Load Theory
CoP	Communities of Practice
DCT	Dual Coding Theory
DHET	Department of Higher Education and Training
FET	Further Education and Training
HOD	Head of Department
IMD	Instructional Material Design
KUT	Korea University of Technology
LS	Lesson Study
MLT	Multimedia Learning Theory
NATED	National Accredited Technical Education Diploma
NCV	National Certificate Vocational
NSF	National Skills Fund
PLC	Professional Learning Communities
SETA	Sector Education and Training Authorities
SP	Signalling Principle
SRR	Standards Referencing Reporting
STEM	Science, Technology, Engineering and Mathematics
TAFE	Technical and Further Education
TVET	Technical and Vocational Education and Training
UNESCO	United Nations Educational, Scientific and Cultural Organisation
VET	Vocational Education and Training
WIL	Work Integrated Learning

ABSTRACT

This study investigated how adopting Lesson Study (LS) inside a Professional Learning Community (PLC) at a South African TVET college influenced students' ability to read, understand and interpret electrical wiring diagrams. LS, a collaborative professional development model, fostered necessary thinking and problem-solving skills. As defined by Ono and Ferreira (2010), LS is "classroom-situated, context-based, learner-focused, improvement-oriented, and teacher-owned" (p. 64).

Using an inductive action research approach within a critical paradigm, this study employed focus group discussions, interviews, rating scale questionnaires, and structured observations to collect qualitative data from twenty-six students and seven lecturers. The conceptual framework integrated Dual Coding Theory, Multimedia Learning Theory, and PLCs to examine the role of instructional design in enhancing diagram comprehension.

LS improved teaching and learning, yet its impact was limited by time, workload, and uneven PLC participation. Effective LS implementation requires team members' deep subject knowledge, trust, administrative support, and strong leadership. Furthermore, successful LS necessitates substantial expertise, balancing collegiality with decisive direction. Additionally, tensions emerged between abstraction and granularity in content delivery, as lecturers often underestimated the importance of foundational knowledge. Dual-coding and multimedia boosted engagement but exposed a relevance gap created by teachers' assumptions. Despite the many positive classroom experiences and sufficient evidence of the effectiveness of LS from numerous research studies, there is still a lack of evidence on the successful implementation in a technical vocational context. It can be implemented successfully if the challenges raised are adequately

addressed. The paradoxes suggest that LS is most valuable when balanced with opportunities for teachers to develop their adaptive expertise and professional judgment rather than being treated as a complete solution for instructional design.

CHAPTER ONE: INTRODUCTION AND ORIENTATION OF THE STUDY

1.1 Introduction

Technological change is rapidly changing society and making it more complex. Global educational shifts and rapid social change require flexible teaching that helps students grasp complex ideas and correct misconceptions. The focus has moved from expert-driven directives to collaborative, continuous professional development centred on student learning. This study researches a LS undertaken by a professional learning community at a Technical Vocational Education and Training (TVET) campus. It examines how LS can improve students' ability to read, interpret and understand electrical wiring diagrams.

This chapter commences with the purpose and background. The rationale clarified the need, intentions, significance, novelty and justification for this study. The research questions and methods followed. The synthesis of concepts, trends, and challenges involved in this research are briefly explained in the literature. The conceptual frameworks underpinning this study were Dual Coding Theory (DCT), Multimedia Learning Theory (MLT) and Professional Learning Communities (PLC). These frameworks are introduced in this chapter. Action research, the methodological approach used, is then outlined. The chapter concludes with an overview of the dissertation, together with the content structure of subsequent chapters.

1.2 Purpose of the Study

This study examined how LS improved students' capacity to read and understand wiring diagrams at a TVET college. Through a collaborative inquiry approach, engineering lecturers systematically investigated how this method fosters professional learning by making teacher discourse explicit, facilitating joint lesson planning, enabling structured lesson observations, and promoting collaborative evaluation of instructional practices and student learning outcomes. Furthermore, the study evaluates how it shifts the pedagogical focus from traditional teacher-centred instruction to a student-centred learning paradigm. Data were gathered from multiple sources, capturing the perspectives of twenty-six students and seven lecturers to analyse their impact comprehensively. This research advances effective teaching methodologies in vocational education by offering an alternative instructional approach. As an action research study, its findings inform best practices and serve as a valuable resource for educators seeking to enhance teaching and learning in technical disciplines.

1.3 Background to the Study

The ability to read and interpret electrical schematics is a fundamental skill for aspiring electricians; however, many students struggle with this competency. Industry standards demand that electrical artisans possess proficiency in schematic interpretation to perform their roles effectively (King et al., 2007). Within the Report 191 electrical syllabus, students must engage with various electrical diagrams, from basic to complex circuit schematics, as part of their final examinations.

Despite the centrality of this skill, the curriculum does not explicitly support conceptual development, nor does it provide well-defined pedagogical strategies to facilitate students' understanding. As a result, many students resort to rote memorisation of electrical diagrams for examination purposes rather than developing a deep conceptual understanding. This pedagogical gap necessitates innovative instructional approaches that actively support knowledge acquisition and skill development in schematic interpretation.

By exploring how LS fosters a deeper engagement with schematic reading through structured lesson planning, observation, and evaluation, this research aims to contribute to more effective teaching methodologies in vocational education.

1.4 Rationale

The abstract nature of electricity, compounded by the complexity of circuit diagrams, presents a significant challenge in electrical education. Core concepts such as potential difference, current, and resistance are often misunderstood and misused interchangeably, making effective instruction imperative. Traditional TVET instruction stresses drawing schematics for examination, yet pays scant attention to how circuits work (Adams, 2017). Bridging this gap requires teaching methods that couple drawing with conceptual reasoning about electrical function.

This study explores an alternative pedagogical strategy to enhance students' comprehension of electrical schematics. Within this framework, a cohort of engineering lecturers re-examined the Circuit Diagrams of Electrical Sub-circuits module in the Report 191 N4 Electrotechnics syllabus to explore more effective teaching methodologies. The study evaluated how collaborative lesson planning, structured observations, and reflective discussions influenced students' ability to read, interpret, and understand electrical schematics.

Given the scarcity of empirical research on instructional improvement within TVET settings, particularly in electrical education, this study addresses a key gap in the literature. Most existing research on schematic interpretation has been conducted at the school level, leaving vocational education largely unexplored. By leveraging the cyclical nature of action research, which aligns with iterative teaching refinement, this study examined a structured approach to improving instructional practices. Its findings contribute to developing evidence-based teaching strategies that enhance conceptual learning in electrical engineering education.

1.5 Research Questions

The following research questions guided this study:

1. How does the implementation of lesson study influence the teaching and learning of electrical wiring diagrams in a South African TVET college?

2. How can cognitive load theory and instructional design theories specific to diagrams and illustrations be integrated to improve the effectiveness of lesson study for teaching electrical wiring diagrams?

3. How do learners perceive and respond to electrical wiring diagrams that employ principles of dual coding theory and multimedia elements?

1.6 Research Objectives

Grounded in cognitive learning theory, DCT, MLT, and PLC, this action research investigated the efficacy of an LS intervention in refining pedagogical approaches within Report 191 N4 Electrotechnics. Rather than focusing solely on the production of drawings, this study prioritised the development of cognitive schema and conceptual mastery as demonstrated through accurate schematic interpretation.

1.7 Key Concepts from the Literature Review

The literature review analysed existing research relevant to this study, identifying gaps, extending prior studies, and establishing the necessity for this investigation. It also delineated the study’s scope and delimitations.

The discussion began by examining the global significance of TVET and its impact on economic growth, poverty alleviation, and modernisation, particularly in first- and third-world countries (Pavlova, 2014). It then explored the complex nature of TVET in South Africa, emphasising its role in promoting social equity and equipping individuals with the necessary knowledge and skills. The review further addressed the formulation of knowledge into theory and practice, linking theoretical learning to practical application through active learning. It deconstructed the concept of a profession, categorising it into academic, educational, and professional practice to illustrate how theory transitions from curriculum design (academia) into pedagogy (education) and ultimately into vocational expertise (professional practice).

A core emphasis was the role of drawing as a teaching strategy, highlighting its effectiveness in fostering explicit thinking, analytical skills, and problem-solving. The review then examined the significance of circuit diagrams in TVET, positioning visual literacy as a necessary cognitive tool that enhances conceptual understanding. It emphasised how drawings facilitate practical tasks, support collaborative communication, and structure relationships between system components (Fan, 2015). The pedagogical application of patterns was reviewed, assessing the benefits of pattern recognition in improving comprehension and retention. The review then explored approaches to learning, contrasting deep and surface learning and identifying the conditions necessary for meaningful knowledge acquisition.

Implementing LS in TVET was examined as a sustainable practice for continuous improvement. The literature discussed LS's principles, essential aspects, benefits, and challenges, demonstrating its potential to enhance teacher collaboration and equip students with industry-relevant skills. Finally, the review concluded by exploring reflexive self-study, a qualitative research approach that enables educators and researchers to examine their experiences, beliefs, and pedagogical practices. Reflexive self-study fosters deeper insights into professional decision-making and instructional effectiveness by acknowledging subjectivity and positionality. This comprehensive review provided a strong theoretical foundation for the study, supporting its aim to improve conceptual learning in electrical schematics through LS.

Comprehension of the terminology and purpose of various categories of electrical diagrams is essential for effective communication, design, installation, and troubleshooting within electrical engineering and cognate disciplines. Whilst terms such as 'electrical wiring diagrams', 'electrical schematics', 'circuit diagrams', and 'schematic interpretation' are occasionally employed interchangeably in informal contexts, they denote distinct conceptual frameworks characterised by specific functions and attributes (Jaakkola et al., 2017).

Wiring diagrams principally illustrate the physical configuration and interconnections of an electrical system's components as they would materialise in actual installations. They specify precise wiring routes, terminal connections, and physical positioning of devices, thereby facilitating practical assembly and maintenance operations. Wiring diagrams frequently employ simplified pictorial representations and tend to emphasise the manner in which equipment is connected, rather than underlying functional relationships. Such diagrams are indispensable for electricians during installation, repair, and inspection phases (Jaakkola et al., 2017).

Conversely, schematic diagrams represent the logical and functional relationships within an electrical circuit whilst abstracting the physical layout. They utilise standardised symbolic representations to illustrate components and their connections, focusing on circuit operation rather than the physical location of components. Schematics facilitate analysis of circuit behaviour, comprehension of signal and power flow, and design or modification of systems by engineers and technicians (Jaakkola et al., 2017; Liévin et al., 2024).

The term 'circuit diagram' is often employed broadly; however, it can be distinguished as a graphical representation that emphasises the flow of electrical current through components, utilising standardised symbols to demonstrate connectivity and interactions within the system. Circuit diagrams share numerous characteristics with schematics but may exhibit reduced abstraction and occasionally present greater detail regarding component specifications and pathways. They serve multiple functions, including documentation, fault diagnosis, and pedagogical purposes (Jaakkola et al., 2017).

Schematic interpretation is not a category of diagram but rather the competency or process of reading and comprehending electrical schematics or circuit diagrams. This proficiency encompasses the recognition of conventional symbols, tracing connections, discerning circuit function, and applying such insights to tasks such as troubleshooting, design verification, and system modification. Practical schematic interpretation underpins professional electrical practice and education (Jaakkola et al., 2017; Liévin et al., 2024).

Academic and practical literature consistently reinforces these distinctions. Empirical investigations within educational contexts reveal that learners frequently encounter difficulties in interpreting circuit diagrams when spatial organisation obscures anticipated relationships, such as voltage gradients or component function (Jaakkola et al., 2017; Urban-Woldron, 2023). This observation highlights the importance of schematic clarity and adherence to standard conventions for facilitating functional comprehension, rather than merely physical representation.

Industry practices further substantiate the proposition that wiring diagrams and schematics serve complementary yet distinct functions. Wiring diagrams support implementation and maintenance by detailing physical connections, whilst schematics facilitate analysis, design, and problem-solving by depicting logical circuit operation (Jaakkola et al., 2017; Liévin et al., 2024). This dual functionality underscores the rationale for professionals maintaining rigorous terminology and diagrammatic standards.

1.8 Conceptual Framework

This study employed a conceptual framework to establish a structured representation of necessary concepts, variables, and relationships that guided the investigation. Conceptual frameworks operationalise theories within particular empirical investigations, mapping relationships across key concepts, structures, and variables to guide methodological choices and interpretations of findings (Kivunja, 2018). Desjardins (2010) emphasised that a conceptual framework serves as a logical blueprint, shaping the research process by defining connections between important ideas and aligning them with the research questions and problem statement. In educational research contexts, conceptual frameworks provide researchers with a lens through which to identify gaps in the literature, operationalise constructs, hypothesise relationships, and design appropriate methodology (Varpio et al., 2020).

The conceptual framework enables researchers to clearly articulate their emergent ideas, making connections among ideas in the study and the study's significance apparent to readers (Schwarz et al., 2021). Furthermore, conceptual frameworks enhance research rigour by establishing the logical orientation and associations that form the underlying thinking, structures, plans, and practices of the entire research project (Kivunja, 2018). Within qualitative research traditions, conceptual frameworks play a critical role in conducting and teaching research whilst maintaining deep engagement with data (Tavory & Timmermans, 2025). This structured approach ensures that empirical investigations remain theoretically grounded whilst allowing for flexibility in exploring emergent themes and patterns. By explicitly articulating the relationships between constructs, conceptual frameworks facilitate scholarly discourse, enable the replication of studies, and contribute to the cumulative development of knowledge within specific research domains (Varpio et al., 2020).

This study integrated three interconnected theoretical frameworks: DCT, MLT, and PLCs. Together, these frameworks provided a comprehensive lens for understanding learning processes and the role of professional development in enhancing instructional effectiveness within VET.

DCT informed the study by explaining how the brain processes verbal and visual information, offering insights into designing instructional materials that promote deeper learning. MLT expanded on this by demonstrating how multimedia elements engage multiple cognitive processes, optimising knowledge retention and comprehension. PLCs provided a collaborative framework for educators, emphasising continuous professional development, reflective teaching practices, and the collective improvement of instructional strategies.

By integrating these frameworks, the study established a robust theoretical foundation for examining the intersection of instructional design, cognitive processing, and educator collaboration in TVET. The following sections further explore how each framework contributed to the broader research context.

1.9 Methodological Approach

This study was grounded in the critical paradigm, which extends beyond understanding phenomena to actively driving change. As Cohen et al. (2007, p.26) assert, the critical paradigm “is not merely to understand situations and phenomena but to change them. It seeks to emancipate the disempowered, redress inequality, and promote individual freedoms within a democratic society." Guided by this perspective, the study implemented an alternative teaching strategy in an N4 class to assess its impact on students' interpretation and comprehension of electrical schematics.

A qualitative approach was adopted to explore participants' lived experiences and perspectives (Stolz, 2013). This approach enabled an in-depth examination of how LS functioned as an instructional strategy within the TVET context. As Dunn, Lyman, and Marx (2003) described, qualitative research generates detailed findings through diverse data collection methods, which are coded, analysed, and interpreted to identify emerging themes. The study employed multiple data collection instruments, including focus group discussions, interviews, Likert questionnaires, structured observation schedules, and a researcher-reflective journal to ensure a comprehensive exploration of the research phenomenon.

Action research was the selected methodology, aligning with the iterative nature of LS. This approach enabled continuous reflection and refinement of instructional strategies to enhance teaching and learning in electrical education. Convenience sampling was utilised to recruit participants, ensuring accessibility and willingness to engage in the study. By selecting available and cooperative individuals, the research effectively captured rich qualitative data essential for evaluating the impact of LS as an alternative teaching method.

1.10 Overview of the Dissertation

This dissertation comprised six chapters, each systematically addressing the research objectives and guiding the study's trajectory.

Chapter One established the foundation of the study by outlining the background, purpose, rationale, research questions, and literature concepts. It provided a concise discussion of the conceptual framework and methodological approach before concluding with an overview of the dissertation structure.

Chapter Two presented the literature review, examining VET from global and local perspectives and discussed active learning to acquire practical knowledge. The chapter further analysed the' pedagogical role of drawings, diagrams and illustrations in VET, and the conceptual application of patterns to enhance metacognition. It also reviewed deep and surface learning, the LS approach, and reflexive self-study as vital components in educational research.

Chapter Three focused on the conceptual framework, illustrating how theoretical constructs are interconnected within this study. It defined the variables, structured the empirical investigation, and set the stage for addressing the research questions and problem statement. The study drew upon DCT, MLT, and PLCs to examine instructional design, cognitive processing, and collaborative professional development.

Chapter Four detailed the methodological approach, explaining the critical paradigm and the qualitative action research design. It justified the use of action research and described its cyclical nature, detailing its integration with the LS stages of implementation. The chapter also addressed data generation methods, sampling strategies, data analysis procedures, and ethical considerations.

Chapter Five presented and analysed the research findings. Data was systematically examined in relation to the three research questions, using thematic analysis to identify important insights. Findings were interpreted within the context of the study's objectives and theoretical foundations.

Chapter Six synthesised the study's findings, offering conclusions and recommendations. It assessed how the research questions were addressed, discussed implications for further research, and acknowledged study limitations. Finally, the chapter proposed recommendations to enhance pedagogical practices, share best practices, and identify potential avenues for future research in TVET education.

1.11 Conclusion

This chapter established the foundation of the study by outlining its purpose, background, and rationale, highlighting the significance and justification for the research. It presented the research questions that guided the investigation and defined the objectives that shaped its direction. Key concepts were introduced to contextualise the study within the broader academic discourse, distinguishing it from existing research. A brief literature overview synthesised ideas, trends, and challenges relevant to the study. The conceptual framework was introduced to illustrate the theoretical lens through which the research was conducted. The methodological approach was outlined to justify the study's empirical process. The chapter concluded with an overview of the dissertation structure, providing a roadmap for subsequent chapters. Chapter Two presents an in-depth review of the relevant literature, drawing on existing research to position this study within the broader educational landscape.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This literature review systematically examined accredited academic sources and electronic publications relevant to the study. Rather than merely compiling existing research, it analysed, synthesised, and integrated findings to establish a foundation for new perspectives. The review engaged with multiple theoretical and empirical sources, conducted appraisals and theory-generating syntheses to interpret the subject matter comprehensively. The literature was researched, analysed, and organised to address the study's core objective: implementing LS to enhance the teaching and learning of electrical wiring diagrams in a South African TVET college. Concepts and insights from existing studies were integrated into a scholarly framework, positioning this research within broader academic discourse. Creswell and Creswell (2014, p.60) assert that scholarly inquiry must compare findings with existing literature to justify and situate the study within the field. This comparative analysis extracted themes, patterns, and conceptual definitions relevant to the research.

This chapter begins by examining vocational education and training (VET), followed by discussions on practical knowledge, the role of diagrams and illustrations in VET, learning approaches, pedagogical patterns, and LS as a sustainable teaching practice. The chapter explores reflexive self-study, reinforcing the study's theoretical and methodological grounding.

2.2 Vocational Education and Training

2.2.1 Globalisation and Its Impact on Education

Globalisation has positioned skills development as a cornerstone of sustained economic growth. Economic success depends on a nation's ability to cultivate, attract, and effectively utilise “human capital,” a point emphasised by McGrath and Akoojee (2009, p.149). However, as Moloi, Gravett, and Petersen (2009) noted, the globalisation of knowledge has also emerged alongside economic globalisation. One of the fundamental objectives of this phenomenon has been the enhancement of education levels (Meyer, Bushney & Ukpere, 2011; Moloi, Gravett & Petersen, 2009; Price, 2010), with anticipated benefits such as greater employability, improved incomes, lower crime rates, and reduced social delinquency.

Beyond economic imperatives, globalisation has political dimensions, aiming to foster social cohesion through economic viability and competitiveness. Education has thus become a policy tool to achieve these objectives. Rasool (2006) underscores how policymakers recognised the role of knowledge and skills in enhancing international prosperity through competitiveness and job creation. While initially entrenched in first-world economies, this perspective has also permeated developing nations, bridging the gap between industrialised and emerging economies. Given its economic and geopolitical standing, South Africa wields considerable regional influence. Its success or failure is not only a domestic concern but is important to the broader sustainability of the African continent in terms of “African Viability” (McGrath & Akoojee, 2009, p.150).

Meyer, Bushney, and Ukpere (2011) argue that higher education has become increasingly commercialised, propelled by technological advancements, the internet, and scientific innovation. Globalisation has produced positive and negative effects on education, requiring careful consideration in shaping educational policies. Meyer, Bushney, and Ukpere (2011) propose several strategies for addressing the challenges and opportunities globalisation presents. Firstly, constructive global trends must be systematically integrated into curriculum development and planning. Establishing alliances with international institutions—particularly in emerging markets such as Africa and Asia—can reduce over-reliance on Western curriculum models while maintaining a balanced global and local approach.

Moreover, strong and visionary leadership is necessary for effective governance within local educational institutions. The recruitment and retention of international academic talent should be prioritised to enhance knowledge exchange and institutional capacity. Encouraging empirical research on the impact of globalisation on education is equally important in shaping data-driven policy decisions. Additionally, fostering a global mindset among students will enable them to navigate and contribute to an interconnected world.

To assess progress, South Africa's higher education sector must implement a measurement system that evaluates the extent and effectiveness of globalisation at the post-school level. Vocational education is one of the most effective vehicles for achieving this, as it directly links skills development with economic and social transformation. By leveraging the potential of vocational education, South Africa can better position itself within the global economy while simultaneously addressing local socio-economic challenges.

2.2.2 Vocational Education: A Catalyst for Economic and Social Development

Vocational Education and Training (VET) has evolved into a globally recognised education-work policy framework, as noted by McGrath (2011). Its significance extends beyond education, playing a pivotal role in economic growth and social upliftment. Historically, the nature of education has been a subject of philosophical debate, dating back to Aristotle. Education was deeply intertwined with colonial legacies in many regions, shaping its structure and purpose.

In Africa, post-colonial reforms sought to redress the limitations of inherited education systems (McGrath, 2004; Chisholm & Leyendecker, 2008). Governments initiated efforts to establish industrial schools, yet these were met with resistance from missionaries and Pan-Africanists, who favoured academic education over vocational training. A compromise between vocational and academic education eventually emerged. In the early 20th century, the World Bank strongly advocated for an American-style education model, integrating vocational and general education. However, by the 1970s, the Bank shifted its stance, arguing that primary education was a more effective tool for poverty reduction than secondary or vocational training. The long-standing decline in prioritising vocational education in Africa has recently begun to shift. King, McGrath, and Rose (2007) highlight that African governments increasingly recognise VET as a viable alternative educational pathway beyond traditional schooling. According to McGrath (2011, p.38), this momentum accelerated in 2009 when the "UNESCO General Assembly ratified VET as one of the three thematic priorities." Furthermore, skills development became the central focus of the 2012 Global Monitoring Report. McGrath and Akoojee (2009) argue that the current global perspective on VET positions it as a powerful tool for poverty alleviation and integration into the modern economy, fostering growth and competitiveness. The demand for highly skilled artisans is now necessary to enhance the competitiveness of regions, nations, industries, and institutions.

McGrath (2011, p.41) outlines areas of focus for enhancing the quality and effectiveness of VET in Africa, including a "quality assurance framework, a qualifications framework, a system for credit transfer, systematic identification of skills demands, improved guidance systems and a network of VET experts producing annual reports." A shift from job security to employability has occurred as economies transition to service and knowledge-based industries. With the collapse of welfare-based economic models, the emphasis has turned to education-driven employability as a solution to social exclusion and poverty. Policymakers now advocate for boundaryless careers, lifelong learning, and continuous skills development to enhance workforce adaptability.

Hillage and Pollard (1998, p.2) define employability as the capability of “getting and keeping fulfilling work”. An individual's employability depends on their knowledge, skills, and attitudes and how they apply and present these attributes to potential employers. Their employability assets comprise their knowledge (what they know), skills (how they apply their knowledge) and attitudes (how they perform tasks and interact in professional settings). These principles are integral to technical and vocational education and training, reinforcing VET’s role in developing a workforce equipped for modern economic challenges. By fostering employability and practical expertise, VET continues to shape the future of education, industry, and economic resilience.

2.2.3 Technical Vocational Education and Training: A Catalyst for Workforce Development

VET is a specialised education pathway that equips individuals with occupation-specific skills necessary for economic sustainability and workforce development. Despite its important role, VET is often perceived as inferior to academic education (Cedefop, 2017). In most countries, VET primarily targets young learners, offering mid-level qualifications financed through education budgets and coordinated by central governments.

TVET extends beyond basic skills training, fostering lifelong learning and technological proficiency. It integrates scientific principles, practical knowledge, and entrepreneurship, preparing individuals for emerging careers. Lamb (2011, p.60) asserts that

TVET can provide those with minimal schooling, the most disadvantaged, with the training and skills needed. Therefore, it has the potential to not only deliver higher numbers of skilled workers but also to bridge the gap between the poor and the wealthy, between those who have been excluded from the benefits of education and training in the past.

Khalid and Metersad (2016) emphasise TVET's important role in workforce development, particularly in addressing the challenges posed by rapid technological advancements. TVET programs are designed to deliver practical skills, relevant knowledge, and professional competencies, ensuring individuals are equipped for meaningful employment in specific trades or occupational sectors. As technological progress and economic integration accelerate, skill development remains a cornerstone of national economic growth. The demand for skilled workers spans manufacturing, agriculture, and service industries, positioning TVET as the primary mechanism for aligning labour force competencies with evolving economic demands.

Beyond workforce preparation, TVET plays a pivotal role in poverty reduction and economic growth, particularly for marginalised and disadvantaged communities. However, achieving this potential requires a fundamental shift in TVET pedagogy. Traditional approaches, focused on outdated teaching methods, must evolve into outcomes-based curricula prioritising competency-driven education. This shift ensures that skills, knowledge, and attitudes align with national socio-economic priorities and global technological advancements. Rinos (2014) highlights the intrinsic link between globalisation, skills development, and economic competitiveness, underscoring TVET's relevance in an increasingly interconnected world. Berisso (2016) further argues that while TVET is not the sole driver of human resource development, it remains an important pillar of educational, social, and economic progress. Sustainable economic growth hinges on integrating education and training with viable workforce development strategies.

TVET colleges serve as the principal training institutions for artisans in many countries. Loynes (2016, p.4) underscores their role in national "Human Resource Development strategies," while Mpondomse (2016, p.4) asserts that "The TVET system holds the key to unlocking the human resource development challenge and unemployment, which will ultimately contribute to the broader objective of socio-economic transformation and a more equal society." Governments and donor organisations continue to champion post-school vocational education, recognising its potential to equip individuals with practical expertise and foster economic resilience (McGrath, 2011).

By addressing labour market needs, reducing unemployment, and enhancing economic competitiveness, TVET emerges as a cornerstone of sustainable development. A well-structured and forward-thinking TVET system ensures a skilled, adaptable, and globally competitive workforce, reinforcing its role in shaping the future of education and industry.

2.2.4 Social Injustice and the Struggle for Equitable Education

The Minister of Higher Education and Training, Dr B. Nzimande, has reiterated that from the apartheid era, TVET has been largely marginalised. Ten years into the new democracy, the state justified success in many macroeconomic aims. However, inequality, unemployment and poverty were a stark reality. Between 8 and 10 million people live in extreme abject deprivation, with 18 to 24 million South Africans living in poverty, according to Everatt and Maphai (2003). Woolard (2002, p.2) stated that "one in 10 Blacks were malnourished; one in four Black children were stunted." Poverty was allied with gross inequality and the AIDS pandemic, argued McGrath and Akoojee (2009). Many urban Blacks lived in informal settlements in Townships.

Ngubane (2013, p.8) states, "Township is a South African term that usually refers to the often-underdeveloped urban living areas that, from the late 19th century until the end of apartheid, were reserved for non-whites (Africans, Coloureds and Indians)." As Huchzermeyer (2011) described, these settlements were typically constructed on the fringe of cities and towns. Nongxa (2010) argued that most children living in townships study at deprived, impoverished institutions. Two-thirds of high schools had no sports or recreational facilities, and approximately 50 % of township schools suffered from a lack or shortage of classrooms. Spreen and Vally, cited in Ngubane (2013, p.8), reiterate that “many learners in the township schools are not only heads of households, but faced social problems including hunger, poverty, HIV/AIDS and violence.”

Under these extreme conditions, the South African government had to develop a viable post-school education system. The preferred choice was technical vocational education and training. Although South Africa transitioned to this post-school education system, students faced tremendous obstacles. These socio-economic challenges wreaked havoc and devastatingly influenced the academic achievements of students coming from township schools. Since townships are far from the urban areas, students also travel long distances to the institution, leaving home early and returning late. Attendance was also compromised when they had no money for travelling. For most students, English (the medium of instruction) is not their first language. Many of these students are from quintile one and two schools and have been disadvantaged by not having access to quality education. The latter catered predominantly for the upper and middle classes. The educational disparity continues, with the middle class served by schools that levy high fees yielding better academic results than those serving people experiencing poverty. Faced with these mammoth challenges, the South African government embarked on transforming vocational education.

2.2.5 Core principles of an effective TVET system

A robust TVET system is a cornerstone of economic success, equipping individuals with industry-relevant skills that drive productivity and innovation. The effectiveness of TVET hinges on dynamic teaching and learning strategies that evolve in response to shifting industry demands, particularly in important occupations and trades. MacDonald, Nink, and

Duggan (2010) illustrated this principle through the collaborative model between the Korea University of Technology (KUT) and Samsung Corporation. KUT provided the infrastructure in this partnership, while Samsung funded learning materials, equipment, and instructional technology. Together, they designed a curriculum tailored to Samsung's industrial needs, ensuring graduates were immediately employable and equipped with relevant skills. In Australia, TVET operates under the Technical and Further Education (TAFE) model, which is structured as a dual education system. This approach focuses on producing work-ready graduates by aligning education with real-world industrial requirements. To remain relevant and impactful, successful TVET programs must anticipate and adapt to technological advancements and evolving labour market demands.

In South Africa, strengthening post-school education and training is a strategic imperative for achieving national development goals. A well-structured, task-oriented curriculum that enhances students' practical competencies through rigorous formative and summative assessments is important. (Abrahams et al., 2013; McGrath & Akoojee, 2009; Mesuwini, 2015). However, Mentzer et al. (2015) challenged this perspective, arguing that students often performed tasks mechanically without fully grasping the underlying concepts. This led to a fixation on singular solutions rather than fostering problem-solving abilities and adaptability. To ensure the effectiveness and sustainability of TVET, education systems must incorporate Industry-driven curriculum development, ensuring alignment with market needs; cutting-edge instructional technology, fostering innovation and practical skill development; comprehensive assessments that evaluate both theoretical understanding and applied competencies; and collaborations between educational institutions and industries, enhancing real-world relevance and employment prospects. By embedding these core principles, TVET can bridge the skills gap, empower individuals, and contribute meaningfully to economic growth and social mobility.

2.2.6 Report 191/National Accredited Technical Education Diploma (NATED) N1 to N6

The NATED qualification is a cornerstone of South Africa's technical education system, providing important theoretical knowledge across diverse vocational fields with no integrated practical skills (Umalusi, 2013). This robust program is structured in progressive levels, from N1 to N6, ensuring a comprehensive learning journey. The foundational N1 to N3 levels (NQF Levels 2-4) equip students with fundamental knowledge and skills in their chosen discipline. Building upon this base, the advanced N4 to N6 levels (NQF Levels 5 and 6) delve into more complex concepts, preparing graduates for demanding technical roles. A defining strength of the NATED program is its unwavering commitment to practical, hands-on learning. Students gain invaluable real-world experience through mandatory internships and work placements, guaranteeing they are job-ready upon graduation (McGrath & Akoojee, 2009). This focus on practical application is why NATED qualifications are highly valued by employers and educational institutions, serving as a powerful springboard for career advancement (Mesuwini, 2015).

The NATED qualification is also designed with flexibility, allowing students to pursue their studies full-time, part-time, or through distance learning, making it accessible to a wide range of learners. This adaptability ensures that individuals can balance their education with work commitments or personal responsibilities. Furthermore, the program fosters seamless career progression by enabling graduates to transition into higher education pathways, such as degrees or advanced diplomas, further enhancing their qualifications. This academic mobility empowers students to continuously upgrade their skills and expand their career opportunities in South Africa’s evolving technical and vocational landscape (Akoojee, 2016; Sithole et al., 2022). With a curriculum aligned to industry needs, the NATED program remains a necessary driver of workforce development, equipping graduates with the competencies required to thrive in sectors such as engineering, business management, hospitality, and information technology. By combining rigorous theoretical instruction with real-world application, NATED qualifications continue to shape skilled professionals who contribute meaningfully to the nation's economy (Nundkumar, 2016).

The transition to NCV dramatically transformed colleges. However, its sustainability and impact are yet to be determined. The primary focus of colleges had transitioned to young students coming out of school instead of an industry-fed model. These students had performed moderately after nine years in school, possessing weak numeracy and literacy skills. They enrolled on a three-year vocational programme that parallels the last three years of general schooling. For South Africa to successfully navigate its post-school challenges, it must provide an effective vocational model that aligns with the country's developmental plans. This must include an effectual, task-oriented curriculum that improves learning outcomes. The need for additional empirical research in the TVET sector, especially on the effectiveness of teaching and learning, is vital. In South Africa, TVET must gear toward practical competence assessment, particularly in adequately training and testing artisans. This envisioned goal of the TVET must be realised to address the enormous social challenges confronting this country. One area that needs to be addressed is the role of practical knowledge in VET, which we will focus on next.

2.3 Practical Knowledge

This chapter examines the relationship between knowledge, theory, and practice, exploring how academic learning translates into professional application. Practical knowledge is analysed through active learning, emphasising its role in bridging theoretical foundations with real-world execution. The discussion is structured into three interrelated dimensions: academic knowledge (curriculum), educational application (pedagogy), and professional practice (vocation). This framework illustrates how conceptual understanding evolves within academic spaces, is refined through educational methodologies, and ultimately finds expression in occupational settings.

An important component of this discussion is Work Integrated Learning (WIL), a pedagogical approach that blends formal education with hands-on industry experience. While WIL is often associated with universities, TVET institutions have long embraced this model, integrating experiential learning into their curricula before it gained prominence in higher education. As noted by the Council on Higher Education (South Africa) (2011, p.6), "WIL, in various forms, has always formed an important part of technical, vocational and professional higher education." Through concept engagement, this chapter underscores the fundamental role of practical knowledge in shaping competent professionals, ensuring that learning is theoretically grounded but also applicable and impactful in real-world contexts.

2.3.1 Knowledge

Knowledge is a multifaceted construct, simultaneously personal, contextual, and socially constructed (Guzman, 2009). In academic settings, knowledge is traditionally compartmentalised into distinct disciplines, yet it is acquired and applied in practice in diverse ways. Chilton and Bloodgood (2008) emphasised that much knowledge remains tacit, often developed socially through collaboration, mentorship, and experiential learning.

Every profession incorporates fundamental skills and procedures, such as operating specialised instruments or following standard protocols. While these skills transfer effectively to workplace settings, Raaijmakers et al. (2018) argued that they primarily address routine and habitual tasks. In contrast, higher-order knowledge is necessary for discretionary decision-making, particularly in complex and unpredictable environments (Fukuta & Yamashita, 2021).

This chapter focuses on theory and practical knowledge, recognising their reciprocal relationship. Priede (2017) asserted that theory and practice mutually reinforce each other, a view supported by Rajaratnam and Campbell (2013, p.722), who stated that "greater understanding of theory [is enhanced] through the teaching of practice." This chapter highlights how knowledge is constructed and applied when examining these dimensions, ensuring that learning remains dynamic, relevant, and adaptable to real-world demands.

2.3.2 Applied Practical Knowledge

Practical knowledge manifests as skills and know-how, equipping individuals with specific techniques necessary to their trade (Kilbrink, 2012; Nyíri & Smith, 1988). Unlike theoretical knowledge, which predicts outcomes (Priede, 2017), practical knowledge is acquired through experience and application (Parry, 2003). It is embodied in action, refined through practice, and shaped by real-world challenges.

Greenwood (1957, p. 47) asserted that "preparation for a profession must be an intellectual as well as a practical experience." Professional expertise develops across three interrelated domains: academic, educational, and professional practice (Council on Higher Education South Africa, 2011). The academic field establishes the scientific foundation of a profession. Educators then curate and structure this knowledge to create the educational field where curricula, pedagogy, and assessment strategies are developed. The professional practice field applies this knowledge in real-world settings, ensuring that theory translates into practical skills and competencies. Although these domains differ in emphasis, they operate within an integrated knowledge system (Council on Higher Education South Africa, 2011). Their synergy ensures that learning remains dynamic, relevant, and responsive to the evolving demands of industry and society.

2.3.3 Curriculum Integration for Transferable Skills

In the academic sphere, curricula serve as structured frameworks for learning, comprising lessons, assessments, and academic content designed to cultivate attitudes, competencies, and understanding (Ende & Davidoff, 1992). A curriculum encompasses subject content and the organisation of knowledge, pedagogical approaches, learning processes, and assessment methods (Knight & Yorke, 2006). The growing demand for work-based skills has compelled higher education institutions to incorporate Work-Integrated Learning (WIL) into their curricula, bridging the gap between theoretical knowledge and real-world application (Knight & Yorke, 2006; Patrick, 2009). WIL is a pedagogy that "integrates theory with the practice of work within a purposefully designed curriculum" (Patrick, 2009, p. iv).

Smith (2012) emphasised that curricular alignment in WIL ensures coherence between learning outcomes, pedagogy, internships, and applied experiences. Sachs et al. (2016) highlighted the central role of authentic learning and assessment, where students observe, reflect, conceptualise, and apply knowledge in practice (Dinsmore & Alexander, 2012; Dolmans et al., 2016; Hansen et al., 2018). Khamidov (2019) argued that students must develop theoretical expertise and practical competencies, including teamwork, problem-solving, and effective communication, which are integral to professional success. The primary objective of a curriculum is to prepare students for their professions by blending intellectual and practical learning.

Since the early 1990s, vocational education has actively integrated transferable skills into curricula (Kaider & Hains-Wesson, 2017; Mortaki, 2012). Sebetlene (2016) noted that vocational educators utilised diverse assessment strategies, evaluating students' knowledge, skills, attitudes, and professional values. Effective curriculum implementation requires acknowledging that "theoretical knowledge may be out of step with workplace practices," necessitating integrative learning and creating new knowledge (Council on Higher Education

South Africa, 2011, p.11). By embedding workplace-relevant expertise into teaching methodologies, educators ensure that vocational training remains dynamic, responsive, and aligned with industry needs (Kaider & Hains-Wesson, 2017).

2.4 The Role of Diagrams and Illustrations in VET

Visual representations are important in vocational education and training (VET) by enhancing comprehension, problem-solving, and skill acquisition. Diagrams and illustrations function as cognitive tools that bridge the gap between abstract theory and practical application, enabling learners to visualise complex concepts and translate them into real-world skills. Fan (2015, p.170) underscores the importance of visual literacy, explaining that

> When we understand something, we say that we see it. We solve a problem through 'insight.' To communicate our ideas better, we aim to make them 'clear.' These metaphors equating 'cognitive processes to visual experience' extensively suggest a close connection between 'how we think about and how we see the world.

This perspective highlights how visual learning is deeply intertwined with cognitive development, reinforcing the importance of diagrams and illustrations in educational settings.

In technical and vocational education, diagrams serve as instructional aids that simplify complex machinery, processes, and techniques, making them more accessible to learners. Schematic drawings, flowcharts, blueprints, and 3D models allow students to engage with content spatially and sequentially, facilitating a deeper understanding of industrial and technical skills. These tools also enhance problem-solving abilities, enabling learners to identify patterns, relationships, and solutions in ways that purely textual explanations cannot. Furthermore, illustrations support knowledge retention by providing visual memory cues, reinforcing learning. Studies on DCT (Paivio, 1990) suggest that verbal and visual information is more likely to be retained and recalled than text alone. This is particularly relevant in VET, where practical execution relies on accurate procedural memory and spatial awareness.

In addition, integrating digital technologies has expanded the role of visual learning in VET. Interactive computer-aided design (CAD) models, augmented reality (AR) simulations, and virtual reality (VR) training programs now complement traditional hand-drawn illustrations and textbook diagrams. These advancements increase engagement, improve accuracy, and provide immersive, hands-on experiences, allowing learners to practice skills in a risk-free, controlled environment before applying them in real-world settings. VET institutions create dynamic, effective, and engaging learning environments by incorporating diagrams, illustrations, and digital visualisations. These tools clarify technical content and enhance problem-solving, critical thinking, and knowledge retention, ensuring students develop competence, confidence, and readiness for the workforce.

2.4.1 The Significance of Drawings

Drawings are a powerful cognitive tool in education, particularly in technical and vocational training, where visual representation is important in conceptual understanding and skill acquisition. (Quillin & Thomas, 2015, p. 2) define a drawing as "a learner-generated external visual representation depicting any type of content, whether the structure, relationship, or process, created in static two dimensions in any medium." This definition underscores the interactive nature of drawing, emphasising its role in facilitating knowledge construction, problem-solving, and communication. Ainsworth et al. (2011, p. 1096) reinforce this perspective, arguing that "visualisation is integral to scientific thinking. Scientists do not rely solely on words but use diagrams, graphs, videos, photographs, and other images to make discoveries, explain findings, and engage public interest." Through drawings, scientists conceptualise new relationships, test hypotheses, and refine knowledge, demonstrating the essential function of drawings in cognitive development and applied learning. Similarly, Quillin and Thomas (2015, p.2) describe "visual literacy" as the ability to interpret, analyse, and generate visual representations. This skill is particularly vital in fields requiring technical precision and spatial reasoning.

Enhancing visualisation competencies improves teaching, learning, and student engagement, particularly in disciplines prioritising numerical and linguistic comprehension over visual cognition. Fan (2015) highlights that drawing is a fundamental visualisation skill that integrates with cognitive processes necessary for scientific reasoning. Drawings facilitate observation, analysis, and problem-solving, reinforcing their pedagogical importance in theoretical and applied learning. Despite their importance, Ainsworth et al. (2011) observed that students often focus on interpreting pre-existing classroom drawings rather than actively creating their own. Encouraging students to generate their visual representations fosters deeper engagement, profound thinking, and conceptual clarity, particularly in technical disciplines where practical application is paramount. As Fan (2015) asserts, drawing cultivates cognitive development, enabling students to move beyond surface-level assumptions to a comprehensive qualitative understanding.

Drawings are valuable educational diagnostic tools, offering insights into students' cognitive progress and comprehension gaps. Fan (2015) suggests that analysing students' inclusions and omissions in their drawings can reveal underlying misconceptions or incomplete understanding. Every line, shape, or visual element represents a learning decision, making drawings an effective means of assessing concept mastery. Empirical studies have established a strong correlation between drawing accuracy and test performance in reasoning-based assessments (Gates, 2018; Larkin & Simon, 1987; Wammes et al., 2016). These findings highlight the role of drawing as a metacognitive strategy, enabling students to identify and rectify errors in their comprehension. Van Meter (2001) differentiates between higher-order learning, where students construct mental models through recall and synthesis, and lower-order learning, which relies on rote memorisation and passive recognition. However, to maximise the educational benefits of drawing-based learning interventions, providing clear, structured instructions and incorporating multiple learning resources is essential. Effective implementation requires guidance, iterative practice, and alignment with core learning objectives, ensuring students develop visual literacy and analytical skills.

In conclusion, drawings are pivotal in knowledge construction, conceptual understanding, and skill development, particularly in technical education and vocational training. Educators can enhance comprehension, foster problem-solving abilities, and bridge the gap between theoretical knowledge and practical application by integrating visual representation into learning strategies.

2.4.2 The Role of Visualisation Skills in Learning

Through drawing, learners develop communication, explanation, problem-solving, and observation abilities, making it an important tool for intellectual and practical skill development. Despite the cognitive benefits of visualisation, students primarily engaged with pre-existing classroom drawings rather than creating their own. This passive approach limited their ability to construct knowledge actively, reducing opportunities for deeper conceptual understanding (Ainsworth et al., 2011). Encouraging students to generate their visual representations fostered critical thinking, engagement, and retention, particularly in technical education, where the ability to translate observations into structured visualisations was an important professional skill.

Visualisation transformed observations into structured knowledge in technical studies. Fan (2015) noted that drawing enabled students to surpass assumptions and progress toward a more comprehensive qualitative understanding. This shift from passive recognition to active creation strengthened cognitive processing and conceptual clarity, reinforcing visualisation as an integral component of scientific and vocational education.

2.4.3 Interpreting Drawings as a Cognitive Learning Tool

Drawings are windows into students' cognitive processes, offering valuable insights into their learning progress, misconceptions, and conceptual understanding. Analysing omissions and inclusions in student-generated drawings revealed gaps in knowledge (Fan, 2015). Each line, mark, or visual element reflected a student's ability to comprehend, process, and apply information, making drawing a powerful diagnostic tool in education. Empirical studies further reinforced the connection between drawing accuracy and cognitive performance. Research demonstrated that the quality of student-created visuals correlated with their success in reasoning-based assessments (Larkin & Simon, 1987; Van Meter, 2001; Wammes et al., 2016). This underscored the role of drawing as an active learning strategy rather than a passive exercise in reproduction.

One of the primary objectives of drawing-based interventions was to cultivate self-directed learning, enabling students to identify and correct their misconceptions autonomously. Van Meter (2006) distinguished between higher-order learning, where students constructed mental models through recall and synthesis, and lower-order learning, which relied on rote memorisation and recognition. However, the effectiveness of visual learning strategies depended on structured guidance, explicit instructions, and access to diverse learning resources. Without these elements, students risked reinforcing inaccuracies rather than refining their understanding. Thus, the interpretation of drawings extended beyond artistic representation—it functioned as an important pedagogical tool, fostering conceptual clarity, analytical thinking, and independent learning in vocational and technical education.

2.4.4 Drawing as a Problem-Solving Tool

Understanding the relationships between variables often becomes overwhelming when confronted with complex scenarios, such as the physics problem. The most compelling scientific approach is to visualise the problem through a diagram. Fan (2015, p. 174) defines diagrams as "schematic drawings that convey structured relationships between parts of a system." These simplified representations break down intricate calculations, reducing cognitive overload and enabling more efficient reasoning. By externalising information, diagrams allow the working memory to focus on problem-solving rather than tracking multiple variables.

Larkin and Simon (1987) undertook an empirical investigation to determine the impact of diagrams on the problem-solving process within physics and mathematics. Their research demonstrated that including diagrams enhanced performance in three areas. Firstly, diagrams facilitated inference by rendering relationships between variables explicit, thereby supporting logical deduction. Secondly, they streamlined the search for relevant information, enabling students to identify necessary data points more efficiently. Thirdly, diagrams promoted rapid recognition of fundamental principles, reducing the likelihood of students pursuing unproductive or incorrect solutions. Furthermore, the study indicated that diagrams minimised cognitive errors by constraining flawed perceptions, a phenomenon illustrated by the structured reasoning inherent in Venn diagrams.

Chi et al. (1981) investigated the problem-solving strategies of physics novices (undergraduate students) and experts (PhD physics students). While both groups performed similar mathematical operations, experts demonstrated a deeper structural understanding, whereas novices focused on superficial aspects of the problem. Experts also used multiple pathways to reach a solution, frequently employing drawings to check and refine their reasoning (Chi et al., 1981; Rosengrant et al., 2009). In contrast, novices relied solely on their diagrams without further exploration.

Egan and Schwartz examined how electrical artisans represented circuits through drawings (Fan, 2015). Experts constructed functional schematics that reflected the purpose of each component (e.g., filters, amplifiers, rectifiers), while novices mimicked spatial arrangements without considering underlying functionality. This study concluded that the effectiveness of diagrams depends not only on their presence but on how they are used. Drawings should serve as one of many tools in problem-solving, helping to organise information, prevent errors, and refine interpretation.

Cox and Brna (2016) analysed students' preliminary rough sketches during problem-solving. They found that high-achieving students used multiple diagrams strategically, switching between representations to clarify their understanding. In contrast, low-achieving students only changed their approach when stuck (Cox & Brna, 2016). This suggested that expert problem-solvers actively refine their visual representations to align with the problem's demands rather than passively relying on a single schematic. The researchers concluded that problem-solving skills improve not through rote memorisation but through continuous practice in diagram creation and refinement.

Integrating verbal, graphical, and symbolic representations in engineering and technical curricula enhances students' ability to think flexibly and solve problems more effectively. Encouraging students to develop advanced visualisation skills fosters deeper understanding, reduces cognitive errors, and strengthens logical reasoning in complex problem-solving environments.

2.4.5 Drawings as External Models Shaping Internal Cognitive Structures

Under specific conditions, visual explanations proved to be more effective than written descriptions. Bobek and Tversky (2016) compared verbal and visual explanations, examining the efficacy of writing a paragraph versus drawing a diagram. Their findings demonstrated that while both approaches enhanced understanding, students who created drawings outperformed their counterparts in post-test assessments. This suggests that visual representations provide a distinct cognitive advantage, reinforcing comprehension and retention more effectively than text alone.

Chun, Jiang, Guida, and Lavielle-Guida (Quillin & Thomas, 2015) highlighted that the brain naturally encodes spatial information, enhancing memory and learning capacity. Drawings are external representations, making abstract ideas tangible and accessible beyond the designer's mind. Johnson-Laird (Quillin & Thomas, 2015, p. 2) further argued that learning involves a dynamic interaction between external models (drawings) and internal models (mental representations in the mind's eye). This interplay fosters deeper cognitive engagement, enhancing students' ability to integrate, organise, and apply new knowledge.

Mayer (2016) advanced the notion of multimedia learning through his cognitive theory, which posited that students constructed mental models via three interconnected cognitive processes. Initially, students extracted knowledge from learning materials and their existing prior experiences. Subsequently, they structured visual and verbal information into coherent frameworks. Finally, they integrated these distinct sources into a unified mental pattern, forming a comprehensive mental representation of the subject matter. Quillin and Thomas (2015) concurred, asserting that conceptual visualisations emerge only after mental models are established, aligning with processes of selection, organisation, and integration of information. However, contradictions within the literature must be acknowledged.

Students who constructed mental models without relying solely on drawing exhibited significant learning gains (Leutner et al., 2009). Their study suggested that drawing might be ineffective when not accompanied by internal model development. They posited that many students lacked the necessary skills or confidence in drawing and often allocated their time inefficiently. This finding stands as a significant counterpoint in the literature. However, Koba and Tweed (2009) opposed this perspective, arguing that drawings reduce cognitive load by offloading information from working memory. Their assertion aligns with broader research advocating for integrating visual and verbal learning strategies, reinforcing the importance of drawing as both a cognitive tool and a means of externalising thought processes (Koba & Tweed, 2009). Ultimately, the relationship between external representations and internal cognitive models underscores the indispensable role of drawings in learning. When effectively employed, drawings do more than illustrate concepts—they facilitate problem-solving, deepen understanding, and enhance long-term retention.

2.4.6 Drawings can be representational or abstract

The realm of drawing, once perceived as a singular domain, revealed its inherent duality: it encompassed representational and abstract forms. Representational drawings, traditionally lauded as mirroring reality, were often privileged, with some scholars exclusively ascribing 'drawing' to this mode. However, this narrow definition proved insufficient. Quillin and Thomas (2015, p.3) noted that a more comprehensive perspective emerged, acknowledging "any learner-generated visualisations, including those with quantitative information, such as graphs," as valid forms of drawing. This inclusive approach, central to the drawing-to-learn teaching strategy, embraced the entire spectrum from abstract to representational.

Further categorised as analogical or analytical, abstract drawings found resonance within engineering disciplines. Conversely, the sciences manifested a dynamic interplay between abstract and representational modes. Students immersed in a pedagogy that fostered proficiency across multiple knowledge generation and construction modes. Ainsworth, Prain and Tytler (2011, p.1096) underscored the pivotal role of these visual modalities, alongside traditional linguistic forms like talking, reading, and writing, in constructing knowledge.

Their research demonstrated that students' perceptions were broadened and deepened through engagement with visual representations, notably graphs. Students acquired a nuanced understanding of line graphs as conveyors of "continuous quantitative information." Furthermore, they discerned the efficacy of condensed, compact, and coherent drawings in conveying complex scientific and engineering concepts. This realisation highlighted the necessity for a versatile approach to drawing that equipped students to navigate the diverse visual languages inherent in scientific and technical domains.

2.4.7 Why are drawings so important?

The pedagogical significance of drawing is not merely ornamental but facilitates learning and assessment. Wiggins and McTighe (2006) posited that the efficacy of drawings in education hinged upon the alignment between desired outcomes, assessment, and activities. This alignment became particularly pronounced in formative assessment, wherein drawings were a dynamic tool for monitoring and enhancing student comprehension.

Formative assessments, designed to provide ongoing feedback, enabled students to discern their strengths and weaknesses in knowledge acquisition. The use of drawings in this context empowered students to identify areas requiring focused attention. Concurrently, faculty leveraged formative drawings to promptly identify struggling students, thus facilitating immediate intervention and support. This proactive approach addressed real-world student challenges, fostering a more responsive and effective learning environment.

Furthermore, information and data derived from drawings functioned formatively, influencing subsequent pedagogical decisions and student efforts. Quillin and Thomas (2015, p.5) highlighted the development and enhancement of observational skills as a primary aim of formative drawings. They asserted that "seeing and communicating are distinct, but aligned, goals with more practice seeing will be better equipped to communicate what has been seen." This emphasis on observation underscored the role of drawing in cultivating visual literacy.

Beyond observation, drawings served as powerful tools for knowledge construction. Students employed graphic models to design and comprehend experiments, solve problems, process data, and integrate concepts into coherent frameworks. These models facilitated the learning and retention of content knowledge. Moreover, drawing and constructing models fostered student motivation and metacognition, promoting self-awareness and agency in the learning process. Conversely, summative assessments evaluated student knowledge against a benchmark after completing a module.

2.4.8 Visual Synergy: Drawing as a Catalyst for Collaborative Cognition

The power of drawing transcended individual expression, functioning as a conduit for collaborative communication and knowledge construction. Ainsworth et al. (2011, p.1097) established that scientists leveraged drawing to clarify ideas for diverse audiences, asserting, "In externalising private knowledge more permanently, visual representation is one way to enable broader dissemination." This principle extended to students, who, through drawing, articulated their thoughts more explicitly, enhancing their ability to communicate, clarify, and exchange concepts with peers. Publicly sharing and critiquing drawings on platforms fostered personal development, allowing students to refine their visual representations based on coherence, content, and clarity. Educators considered these platforms valuable formative, summative, and diagnostic assessment tools.

Fan (2015) further emphasised the public nature of drawings, contrasting them with private perceptual images. The shared observability of drawings facilitated scientific thinking through collaborative engagement. Schwartz (1995) demonstrated that paired secondary school students outperformed individual students in problem-solving tasks involving mesh gears, deriving more accurate numerical equivalences and generating superior conceptual visualisations, such as graphs. This disparity stemmed from the negotiated, mutually derived drawings paired students produced, resulting in greater abstraction. Similarly, Fan (2015) found that real-time interactive drawing, which can modify or erase a partner's work, fostered more generalisable and abstract representations than non-interactive scenarios (Schwartz, 1995).

Fay et al. (2010) observed the evolution of drawings in a Pictionary-like game, where initial detailed drawings gradually transformed into symbolic representations as participants developed synergy. This convergence of thinking and drawing patterns highlighted the impact of interaction history on collaborative visual communication. These studies collectively affirmed that robust social interactions refined graphic representations, a process that Garrod et al. (2007) confirmed was crucial for developing representational complexity.

Hupet and Chantraine (1992) advocated shifting from traditional lecturing to collaborative teaching methodologies, utilising physical or virtual whiteboards to facilitate real-time interaction and knowledge exchange between educators and students. Graphical communication fostered student engagement and addressed uncertainties, promoting innovative teaching practices (Hupet & Chantraine, 1992). Ainsworth et al. (2011, p.1096) echoed this sentiment, noting that passive learning roles in traditional science education diminished student interest. They championed inquiry-based and interactive learning, concluding that “students draw to explore, coordinate, and justify understandings in science. They were more motivated to learn than from conventional teaching methods.” They also emphasised the personalised nature of drawing, stating that “Drawing caters to individual learner differences, as a drawing is shaped by the learner's current or emerging ideas and knowledge of visual convention” (p.1096).

2.4.9 Cultivating Visual Proficiency: Strategic Scaffolding for Drawing Mastery

Cultivating visual proficiency demanded a deliberate and structured approach wherein educators provided strategic scaffolding to empower students to achieve independent mastery. This process necessitated clearly articulating desired learning outcomes, guiding the pedagogical trajectory from inception. Novice learners, often reliant on rote memorisation of models, needed to transition towards flexible, reflective engagement with visual tools characteristic of expert practitioners, as seen in Figure 1.

Figure 1 *Differences between novices and experts in how they draw and use models (Quillin & Thomas, 2015, p.8)*

Aspects of models	Novice learners	Expert learners
Relationship to reality	Think there is a 1:1 correspondence between models and reality	Understand that no model is wholly 'right,' so multiple models should be used
Relationship to other models	Struggle to translate among multiple models at the same scale and between models at different scales	Can easily translate among multiple models
Salient features	Tend to focus on surface features of the models (such as the model organism used or other case study context)	Tend to focus on underlying relationships, processes, functions, and principles in the models
Flexibility	View models as static and fixed	View models as dynamic tools that can be manipulated and changed
Purpose	View models as endpoints that are 'right' and can be memorised as facts	View models as thinking tools
Spontaneous use	They tend not to make their models solve problems unless explicitly instructed to do so	Tend to make models spontaneously to solve problems on their own
Metacognition	When creating models, they tend not to be self-aware of the quality or utility of their models.	When creating models, they can evaluate the quality or utility of their models.

Maries and Singh (2018) highlighted the efficacy of drawing and diagram comprehension in enhancing problem-solving abilities, aligning with cognitive load theory. This perspective underscored the importance of minimising extraneous cognitive load while maximising germane cognitive load, fostering more profound understanding and skill acquisition.

Instructors strategically deployed scaffolding techniques to facilitate this progression, gradually withdrawing support as students demonstrated increasing competence (Maries & Singh, 2017).

Serra and Dunlosky (2010, p. 699) emphasised the important role of “metacognitive judgments” in self-assessment, enabling individuals to gauge their task performance accurately. By integrating metacognitive strategies into drawing instruction, educators empowered students to monitor their progress, identify areas for improvement, and refine their visual representations. This self-regulatory approach fostered autonomy and accelerated the development of drawing expertise (Serra & Dunlosky, 2010).

Furthermore, Adams (2017) asserted that drawing constituted both a process and a product, necessitating a comprehensive evaluation of student capabilities. Complemented by an analysis of student achievements, performance assessments provided a holistic understanding of their visual literacy. Educators provided feedback regarding line quality, perspective, composition, and representational accuracy. They also provided examples of student work that exhibited the desired qualities. This allowed students to observe and internalise the standards of excellence (Adams, 2017).

In addition to direct instruction and feedback, educators facilitated collaborative learning experiences, wherein students engaged in peer critique and shared best practices. These interactions fostered a community of practice, encouraging students to learn from one another and refine their visual communication skills. By strategically scaffolding drawing skills, educators empowered students to transcend novice limitations, cultivating the visual fluency necessary for academic and professional success.

2.4.10 Overcoming Visual Inertia: Confronting Apprehension and Resistance to Drawing

Cognitive engagement plays a pivotal role in student learning. Emotional states, directly influencing motivation and commitment, impacted the efficacy of pedagogical interventions. Consequently, it became imperative to address student apprehension and resistance to drawing. Many students carried anxieties from early childhood experiences, manifesting as a general disinclination towards visual representation. This resistance contributed to negative associations, past failures, or a simple aversion to drawing. Baldwin and Crawford (2010) corroborated this, noting that students often avoided participation due to discomfort with drawing.

Furthermore, a notable misconception persisted: the perception that drawing belonged exclusively to art, not science. As Mohler (2007) argued, even students who enjoyed drawing often compartmentalised it, failing to recognise its value as a scientific tool. This misattribution resulted in the underutilisation of drawing strategies, hindering students' ability to leverage visual representation for knowledge construction (Baldwin & Crawford, 2010; Mohler, 2007).

A pervasive lack of self-confidence further compounded this resistance. Quillin and Thomas (2015, p. 8) captured this sentiment with the typical student refrain, “I am not good at drawing.” This self-perceived inadequacy, anxiety, and fear of evaluation created a barrier to effective learning. Students with low self-esteem exhibited heightened apprehension, fearing the harsh judgment of their visual representations.

Moreover, Uesaka et al. (2007) identified a prevalent misconception: the belief that drawing models was inherently problematic. Paradoxically, research indicated that students who employed drawing were more likely to achieve accurate solutions, demonstrating a disconnect between perceived difficulty and actual performance. Educators implemented strategies that fostered a supportive and non-judgmental learning environment to counteract these apprehensions. This included emphasising the drawing process over the final product, providing constructive feedback, and explicitly demonstrating the utility of drawing across disciplines. Furthermore, integrating collaborative drawing activities helped reduce anxiety and promote peer learning. By addressing these affective and cognitive barriers, educators enabled students to embrace drawing as a powerful tool for learning and communication (Uesaka et al., 2007).

2.4.11 Visualising Expertise: The Indispensable Role of Diagrams and Illustrations in TVET

Diagrams and illustrations functioned as necessary pedagogical tools in TVET, translating complex information into accessible visual representations. This visual approach facilitated learning across diverse fields, including engineering, construction, and design (Seufert, 2003). Evagorou et al. (2015, p. 1) asserted, "The use of visual representations (i.e., photographs, diagrams, models) has been part of science, and their use makes it possible for scientists to interact with and represent complex phenomena, not observable in other ways." This underscored the inherent capacity of visual modalities to render abstract concepts tangible.

Ainsworth (2006) posited that diagrams and illustrations enhanced learning, comprehension, and retention by providing a visual medium for representing concepts, relationships, and processes. Ainsworth (1999) further delineated three primary functions of these visual aids: complementing textual information, constraining interpretation, and facilitating mental model construction. These functions empower learners to grasp abstract concepts, render complex ideas more accessible, and foster problem-solving skills and real-world application of knowledge (Florian & Hegarty, 2004; Mayer, 2001). Seufert (2003) emphasised the relevance of diagrams and illustrations in TVET, recognising their efficacy in accommodating diverse learning styles, notably visual learners who thrived on graphically represented information. Moreover, these visual representations bridged the gap between theoretical and practical aspects of learning, enabling students to connect abstract concepts with concrete applications (Seufert, 2003).

Research within specific technical and vocational domains, such as electrical wiring, validated the importance of diagrams and illustrations. Preston (2019) demonstrated that well-designed diagrams improved students' comprehension of electrical circuits. Mawardi et al. (2020) explored the application of multimedia in teaching electrical wiring diagrams, further enhancing students' understanding and retention. In essence, diagrams and illustrations were indispensable tools in TVET (Ismail & Mohammed, 2015), effectively supporting learning, comprehension, and retention. By offering visual representations of complex information, catering to diverse learning styles, and bridging the theory-practice divide, these visual aids played a vital role in delivering effective vocational education and training.

2.4.12 Electrical Wiring Diagrams as Cornerstones of TVET Mastery

Electrical wiring diagrams stood as indispensable tools within TVET, particularly within disciplines such as electrical engineering, where students confronted the intricate architecture of complex electrical systems. The fundamental imperative of electrical engineering, the communication and transfer of energy, necessitated a robust understanding of circuit design. Alexander and Sadiku (2009, p. 4) articulated this necessity, stating, “requires an interconnection of electrical devices. Such interconnection is called an electric circuit; each component is an element.” The electric circuit, therefore, represented the foundational framework upon which all electrical systems were built.

These diagrams facilitated effective communication, problem-solving, and knowledge application between instructors and students, fostering a comprehensive understanding of electrical circuitry (Martin, 2017). Beyond mere representation, electrical wiring diagrams served as a vital bridge between theoretical concepts and practical application. They provided students with a visual roadmap, enabling them to trace the flow of electricity, identify component interconnections, and troubleshoot potential faults.

Furthermore, electrical wiring diagrams fostered the development of spatial reasoning skills. Students learned to interpret complex visual information, translating abstract symbols into concrete physical layouts. This skill proved essential in real-world applications, where technicians and engineers relied on accurate diagram interpretation to install, maintain, and repair electrical systems.

In addition to traditional two-dimensional diagrams, contemporary TVET programs incorporate interactive digital simulations and three-dimensional modelling. These advanced tools allowed students to visualise circuit behaviour in dynamic environments, enhancing their understanding of complex electrical phenomena. Moreover, integrating augmented reality (AR) and virtual reality (VR) technologies offered immersive learning experiences, enabling students to interact with virtual electrical systems in a safe and controlled environment. The ability to accurately interpret and create electrical wiring diagrams represented a fundamental competency for TVET graduates pursuing careers in electrical engineering and related fields. Proficiency in this area ensured that graduates possessed the necessary skills to contribute effectively to the' design, installation, and maintenance of modern electrical systems. This competency extended to adhering to safety standards and regulations, using diagrams to minimise risk in real-world scenarios.

2.4.13 The Indispensable Role of Electrical Wiring Diagrams in TVET

In the dynamic landscape of TVET, students are confronted with various non-textual instructional materials, including pictures, graphs, diagrams, and symbols, each serving as a vital conduit for knowledge transfer (Yasak & Alias, 2017). Electrical wiring diagrams emerged as indispensable tools, conveying the intricate arrangement of electrical components and operational logic within complex systems. Yasak and Alias (2017, p. 41) asserted, “Trainees in technical vocational education are expected to master symbolic representations concurrently with skills acquisition,” highlighting the interplay between visual literacy and practical proficiency.

Electrical wiring diagrams empowered students to visualise and analyse complex interconnections, enhancing their capacity to design, troubleshoot, and maintain electrical systems in real-world contexts. This visual representation transcended mere depiction as a cognitive scaffold facilitating the transition from abstract theory to concrete application. By engaging with these diagrams, students cultivated important thinking and problem-solving skills, necessary for navigating the complexities of modern electrical systems (Cheng & Gilbert, 2015).

Beyond their role in practical application, electrical wiring diagrams fostered the development of a shared language within the electrical trades. Standardised symbols and conventions ensured clear communication between technicians, engineers, and designers, minimising errors and promoting safety. Furthermore, these diagrams were pivotal documentation, providing a permanent record of electrical installations for future maintenance and modifications.

The integration of digital technologies further amplified the importance of electrical wiring diagrams in TVET. Computer-aided design (CAD) software enabled students to create and precisely manipulate complex diagrams while building information modelling (BIM) platforms, integrating electrical systems into comprehensive building models. These advanced tools fostered collaboration and enhanced the efficiency of electrical design and installation processes.

Moreover, the emphasis on sustainability and energy efficiency in modern electrical systems underscores the importance of accurate diagram interpretation. Students learned to analyse wiring diagrams to identify energy-saving opportunities, optimise circuit performance, and ensure compliance with environmental regulations. The ability to understand and interpret these diagrams allowed students to work with renewable energy systems and modern smart grid technology. Electrical wiring diagrams became a core component in the education of a modern electrician.

2.4.14 Decoding and Designing: Mastering Electrical Wiring Diagrams in TVET

Proficiency in electrical wiring diagrams demanded a dual competency: the ability to accurately interpret pre-existing diagrams and the capacity to create original representations (Ainsworth et al., 2011). This mastery necessitated a multi-faceted cognitive engagement, requiring students to move beyond mere component identification to a comprehensive understanding of system-wide implications. The foundational understanding of symbol relationships, as articulated in the relationship triangle, hinges on meaningful learning. Yasak and Alias (2017) underscored the potential for symbolic representation misinterpretation when instructors fail to employ appropriate teaching methodologies. Therefore, cultivating meaningful learning and enhanced symbolic representation comprehension became paramount.

The interpretation of electrical wiring diagrams demanded a meticulous analysis of symbols, lines, and annotations, enabling students to trace the flow of electricity and discern the functional relationships between components. This process involved the application of spatial reasoning, logical deduction, and pattern recognition, fostering the development of fundamental thinking skills. Students learned to identify potential faults, anticipate system behaviour, and troubleshoot complex electrical problems.

Conversely, creating electrical wiring diagrams required students to translate conceptual designs into precise visual representations. This process involved the application of standardised symbols, adherence to industry conventions, and the ability to organise information logically. Based on the specific application, students learned to select appropriate diagram types, such as schematic diagrams, wiring diagrams, or one-line diagrams.

Integrating digital tools, such as CAD software, further enhanced the creation and interpretation of electrical wiring diagrams. Students learned to utilise these tools to generate accurate and detailed representations, facilitating collaboration and communication among team members. Furthermore, digital simulations allowed students to test and validate their designs in virtual environments, minimising the risk of errors and enhancing system reliability.

Fan (2015) established that a thorough understanding of electrical wiring diagrams improved student performance and cognitive abilities within the TVET sector. Therefore, the ability to decode and design these diagrams represented a fundamental competency for aspiring electricians and electrical engineers. This proficiency ensured that graduates possessed the necessary skills to contribute effectively to designing, installing, and maintaining modern electrical systems while adhering to safety regulations and industry best practices.

2.4.15 Overcoming Obstacles and Optimising Instruction in Electrical Wiring Diagram

Despite their pivotal role in TVET, electrical wiring diagrams presented notable challenges to students, often hindering their comprehension of complex electrical systems. Lombard and Simayi (2019, p. 40) observed, “Many learners experience difficulties in identifying the basic components of an electric circuit,” highlighting novices' foundational hurdles. Schematic representations, replete with meaning-dense symbolism, proved particularly daunting. A seemingly simple circuit diagram encapsulated many intricate electrical concepts, posing a considerable cognitive load. Yasak and Alias (2017) emphasised the difficulty of mastering symbolic representations, noting that miscommunications and compromised job performance often resulted from inadequate comprehension. The challenge intensified when students encountered symbols representing abstract concepts, with the inability to master the "symbols language" (p. 141) impeding subsequent learning. Common obstacles included misconceptions about symbol meanings, difficulties connecting abstract representations to real-world scenarios, and limited spatial reasoning skills (Cheng & Gilbert, 2015; Mawardi et al., 2020).

Educators needed to implement targeted and dynamic instructional strategies to effectively address these challenges and empower students to develop electrical wiring diagram interpretation and creation proficiency. These strategies aimed to cater to diverse learning styles and foster active engagement. Multimedia learning materials, such as interactive diagrams, animations, and simulations, proved invaluable in enhancing comprehension and retention (Mawardi et al., 2020). These tools provided dynamic visual representations, allowing students to explore circuit behaviour in a virtual environment.

Encouraging students to create diagrams reinforced understanding and facilitated active learning (Ainsworth et al., 2011; Lombard & Simayi, 2019). This hands-on approach allowed students to translate theoretical concepts into tangible visual representations.

Clear and comprehensive instruction on diagram interpretation and creation, including detailed explanations of symbols, conventions, and common errors, was necessary (Cheng & Gilbert, 2015). Educators provided explicit guidance, breaking down complex diagrams into manageable components.

Collaborative learning and problem-solving activities fostered engagement and facilitated the application of knowledge in real-world contexts (Leana, 2011; Mewald, 2021). Students worked together to analyse diagrams, troubleshoot problems, and design solutions. Ismail and Mohammed (2015, p. 75) correctly stated, "Interpreting circuit diagrams, sourcing circuit components and constructing circuits, taking measurements, installing, testing, and troubleshooting circuits are important areas of TVET curricula." Therefore, addressing the challenges inherent in learning electrical wiring diagrams and employing effective instructional methods enhanced student cognitive abilities, skill development, and overall success in the TVET sector. Educators must proactively address these challenges to ensure students develop the necessary skills to excel in the electrical trades.

2.5 Approaches to Learning

This chapter examines the foundational theories behind deep and surface learning, tracing their conceptual origins and exploring their profound impact on academic engagement and knowledge retention. Deep learning fosters meaningful understanding through critical thinking, intrinsic motivation, and active cognitive processing, while surface learning relies on rote memorisation and minimal engagement, often leading to fragmented knowledge. By analysing the conditions necessary for meaningful learning, this chapter underscores the significance of cultivating deep learning strategies to enhance intellectual development and long-term comprehension.

2.5.1 Deconstructing the Limitations of Surface Learning

Surface learning, a pedagogical approach characterised by rote memorisation and a singular focus on immediate assessment requirements, represented a transient and ultimately inadequate mode of knowledge acquisition. Learners who adopted this strategy, often exhibiting a marked lack of genuine interest in the subject matter (Townsend, 2010), prioritised the reproduction of information over analysis and conceptual understanding. This reliance on isolated facts and a 'pass-the-test' mentality resulted in a superficial engagement with the material, neglecting the nuanced exploration of underlying principles. Chipamaunga (2015) highlighted the tendency of surface learners to feel overwhelmed by the sheer volume of content, leading them to adopt a broad yet shallow approach to learning. While potentially enabling the coverage of a wide range of material, this strategy precluded the development of deep conceptual understanding and the ability to apply knowledge in meaningful contexts. Entwistle (1988) further illuminated the characteristics of surface learning, emphasising the learner's focus on extrinsic motivation and the avoidance of meaning-making. This approach, often driven by a fear of failure or a desire to minimise effort, resulted in a fragmented and disconnected understanding of the subject matter. Learners operating within this paradigm frequently relied on memorising lists, definitions, and procedures without grasping the interconnectedness of concepts or the broader implications of the material.

Biggs (1999) contributed to this discourse by identifying the ‘serialist’ approach prevalent in surface learning, wherein learners processed information in a linear, sequential manner without integrating it into a coherent framework. This fragmented understanding limited the learner's ability to transfer knowledge to new situations, solve complex problems, or engage in evaluation. The consequences of surface learning extended beyond immediate academic performance. While it might facilitate short-term retention for assessment purposes, it failed to foster the development of enduring knowledge and transferable skills. Learners who relied on this approach struggled to apply their understanding in real-world scenarios, synthesise information from diverse sources, or engage in higher-order thinking. Furthermore, research by Marton and Säljö (1976) demonstrated that surface learning often resulted in a reproductive approach to knowledge, wherein learners regurgitated information without transforming it into personally meaningful insights. This lack of cognitive transformation hindered the development of deep understanding and the ability to apply knowledge creatively.

Therefore, educators must actively discourage surface learning practices and cultivate a learning environment that promotes deep engagement, critical thinking, and conceptual understanding. This necessitates implementing pedagogical strategies that encourage active learning, problem-solving, and the application of knowledge to real-world contexts. By fostering a culture of intellectual curiosity and encouraging learners to seek meaning and connections, educators can empower students to transcend the limitations of surface learning and achieve lasting academic success.

2.5.2 Cognitive Immersion: Cultivating Enduring Understanding Through Deep Learning

Deep learning, a paradigm of cognitive engagement characterised by a profound and meaningful interaction with subject matter, is the antithesis of superficial knowledge acquisition. Learners who embraced this approach were driven by an intrinsic motivation to comprehend underlying principles and conceptual frameworks, transcending the mere memorisation of isolated facts. They actively sought connections and relationships between ideas, concepts, and theories, engaging in rigorous thinking, reflection, and analysis to comprehensively understand the material. These deep learners often ask why questions, explore diverse perspectives and delve into the broader implications of the content, demonstrating a genuine interest in the intrinsic value and long-term retention of knowledge. This cognitive immersion resulted in a more profound understanding of the subject matter, enabling learners to apply their knowledge in diverse contexts and connect it to real-life situations.

However, Dinsmore and Alexander (2012, p. 500) cautioned against a simplistic dichotomy, arguing that "there seems to be tension in the assumption by some that deep processing promotes better learning outcomes, while surface processing promotes weaker learning outcomes; however, this assumption only holds in some studies of the relation between depth of processing and performance." They highlighted the contextual variability of learning outcomes, suggesting that deep and surface learning approaches could be employed strategically, depending on the specific learning objectives and assessment criteria. Nevertheless, the overarching goal of educators remained the cultivation of deep learning, achieved through the design of engaging and meaningful learning experiences that fostered curiosity, thinking, and active engagement. This involved creating opportunities for students to connect concepts, apply knowledge to real-world scenarios, and participate in problem-solving tasks beyond rote memorisation (Marton & Säljö, 1976).

Entwistle (1997, p.21) further emphasised the importance of fostering a "meaning orientation" in learners, characterised by a desire to understand the underlying principles and relationships within the subject matter. This orientation, they argued, was necessary for developing a deep understanding and promoting lifelong learning (Entwistle, 1997). Hansen et al. (2018) reinforced this perspective, emphasising the role of deep learning in cultivating lifelong learners who were equipped with a nuanced understanding of their field of study and prepared to apply their knowledge in meaningful ways. They emphasised that deep learning allows for transferring knowledge to new situations. Biggs and Tang (2011) discussed Constructive Alignment, a method of designing learning that directly encourages deep learning. By aligning intended learning outcomes, teaching and learning activities, and assessment tasks, educators can create a learning environment that encourages students to construct their understanding actively.

By fostering a culture of intellectual curiosity and promoting active engagement with the subject matter, educators empower students to transcend the limitations of surface learning and embrace the transformative power of deep learning. This cognitive immersion enhanced academic performance and cultivated lifelong learners equipped to navigate the complexities of the modern world.

2.5.3 Understanding the Mechanisms of Student Learning

The attainment of pedagogical insights into student conceptual development necessitated thoroughly examining how students experienced and conceptualised subject matter (van der Merwe & Woollacott, 2017). Reed (2006, p. 1) aptly concluded, "Research into the understanding of technical concepts by students is most meaningful if you specifically look to understand students' interactions with these issues… from their perspective," underscoring the imperative to adopt a student-centred approach to educational research. The seminal work of Marton and Säljö (1976) emerged from this epistemological foundation, delineating the distinct learning approaches of deep and surface learning. These constructs, reflecting the qualitative variations in student engagement with learning materials, provided a framework for understanding the cognitive processes underlying academic achievement. Marton and Säljö (1976) elucidated that learners might employ deep, surface, or strategic learning approaches throughout their academic journey, highlighting learning strategies' dynamic and context-dependent nature.

Dolmans et al. (2016) further emphasised the influence of the learning environment on student approaches, positing that deep and surface learning were adaptive responses to perceived contextual factors. Smith et al. (2019) characterised surface learning as a strategy devoid of meaning-making, wherein students merely regurgitated information deemed acceptable by the educator, mirroring rote memorisation and minimal cognitive effort. Conversely, deep learning, as articulated by Dinsmore and Alexander (2012), involved a proactive pursuit of meaning and understanding, transcending rote memorisation through inquiry and reflective analysis. Hansen et al. (2018) highlighted the role of associative anchoring in deep learning, wherein understanding, comprehension, and application were prioritised over discrete evidence. However, they acknowledged memorisation and discrete evidence could be foundational elements for constructing more complex and integrated conceptual frameworks.

Entwistle (1997) contributed to this understanding by describing how deep learning is characterised by an intention to understand and a search for meaning. He also explained how deep learning is often associated with intrinsic motivation. Dolmans et al. (2016) further emphasised that cultivating deep learning necessitated a deliberate course design that fostered reflection and intentional practice. This approach involved engaging students in metacognitive processes, encouraging them to evaluate their learning experiences and refine their cognitive strategies. Furthermore, the concept of "transfer of learning," as explored by Bransford et al (1999, p. 129). became important in deep learning. This concept demonstrated that deep understanding facilitated the application of knowledge to novel situations, a hallmark of effective learning. Therefore, educators must design learning experiences that promote transfer by encouraging students to connect concepts to real-world applications and solve complex problems.

By adopting a student-centred perspective and implementing pedagogical strategies that fostered deep learning, educators empowered students to transcend the limitations of superficial knowledge acquisition and develop enduring conceptual understanding.

2.5.4 Navigating the Variation in Student Engagement

Student engagement is a dynamic and context-dependent phenomenon. Gleason et al. (2011) astutely observed that a single student could adopt a surface learning approach in one course or with one educator while embracing a deep learning strategy in another, contingent upon the perceived learning environment. This variability underscored the role of educators in shaping student engagement through pedagogical practices. Educators who fostered a deep learning environment provided constructive feedback, enabling students to refine their skills based on a nuanced understanding of their interaction with the course material. Consequently, students operating within such environments demonstrated enhanced learning outcomes and achieved superior academic performance, transcending the limitations of rote memorisation.

To cultivate meaningful learning, Gleason et al. (2011) advocated implementing diverse, active learning techniques, promoting student agency, and fostering a culture of intellectual curiosity.

The efficacy of meaningful learning, as elucidated by Cañas and Novak (2010), hinged upon three pivotal conditions. First, the learner must possess relevant prior knowledge, serving as a cognitive foundation upon which new information could be anchored. Second, the material to be learned must be conceptually explicit and presented in language that resonates with the learner's existing knowledge base, facilitating cognitive integration. Third, and perhaps most importantly, the learner must consciously engage in meaningful learning, demonstrating an intrinsic motivation to understand and apply the subject matter. This volitional aspect of learning emphasised the importance of fostering student autonomy and cultivating a growth mindset. These three conditions, when met, create an environment for deep learning to flourish.

Furthermore, research by Pintrich (2000) highlighted the importance of motivational and self-regulatory factors in student engagement. He suggested that students' beliefs, values, and goals influenced their learning strategies and academic performance. Therefore, educators must create learning environments that foster a sense of competence, autonomy, and relatedness and promote intrinsic motivation and self-directed learning (Pintrich, 2000). Additionally, the concept of “situated cognition,” as explored by Brown et al. (1989, p.32), emphasised the importance of learning within authentic contexts. This perspective suggested that knowledge was best acquired and applied when embedded in real-world situations, promoting transfer and enhancing meaningful learning (Brown et al., 1989). Therefore, educators must design learning experiences that connect classroom activities to practical applications, enabling students to see the relevance and value of their studies.

2.6 Pedagogical Patterns

The assertion that students built robust memory retention frameworks by exploring and identifying patterns is central to pedagogical discourse. The ability to discern, generate, and recognise patterns is a vital cognitive tool, allowing individuals to make predictions based on observed phenomena (Alexander et al., 1977; Mor et al., 2014). Early childhood education exemplified this principle, as kindergarten curricula utilised patterns to introduce complex numerical concepts, facilitating the assimilation of abstract knowledge through concrete experiences. Patterns extended beyond mathematics, permeating disciplines such as art, literature, music, and nature, reinforcing their significance in human cognition.

Chi (2009) highlighted the role of pattern recognition in expert performance, arguing that experts developed refined abilities to identify and apply patterns, enabling efficient problem-solving and decision-making. Schema theory (Rumelhart, 1980) further explained how patterns contributed to knowledge organisation and retrieval, as schemata provided structured mental frameworks for processing information (Chi, 2009). Bergin and Eckstein (2004) demonstrated the application of pedagogical patterns in software engineering education, showing their effectiveness in designing and implementing teaching strategies. The deliberate integration of pattern recognition in pedagogy thus emerged as a powerful approach to enhancing learning, equipping students with the necessary cognitive tools to navigate complex information and construct enduring knowledge frameworks.

2.6.1 Defining and Deciphering the Impact of Patterns

Far from mere repetitions, patterns represented cognitive frameworks illuminating recurring problems and providing adaptable solutions. A pattern is a descriptor of “a problem which occurs over and over again in our environment and then describes the core of the solution to that problem in such a way that you can use this solution a million times over without ever doing it the same way twice"(Jones, 1999, p. 5) Fernández (1998, p. 1) further distilled this concept, stating, "A pattern is a recurring combination of meaningful units that occurs in some context." These recurring combinations functioned as cognitive anchors, facilitating the identification of regularities and the perception of relationships, thereby enabling the formulation of generalisations (Fernández, 1998; Lockyer et al., 2008). Empirical investigations consistently demonstrated that identifying and comprehending recurring patterns empowered individuals to formulate informed deductions, hypotheses, and predictions (Dehaene et al., 2015; Jones, 1999; Mor et al., 2014). Patterns imposed a sense of order upon perceived chaos, fostering the development of logical and critical thinking skills. The inherent transferability of pattern comprehension across diverse curricula underscores its pedagogical significance.

Dehaene et al. (2015, p. 2) posed the pertinent question: "How does the brain encode temporal sequences of items such that this knowledge can be used to retrieve a sequence from memory, recognise it, anticipate forthcoming items, and generalise this knowledge to novel sequences with a similar structure?" The answer, they implied, lay in the brain's capacity to recognise and utilise patterns. Jones et al. (1999, p. 2) further emphasised the pragmatic value of patterns, asserting that "patterns are a way of recording the knowledge of experienced practitioners, best practice and lessons learned." This highlighted the role of patterns in codifying expertise and facilitating knowledge transfer. Beyond mere recognition, patterns provide a lens for understanding the world, allowing for the construction of mental models that are both flexible and robust.

2.6.2 Architecting Effective Pedagogy Through Pattern Utilisation

The genesis of pattern identification and utilisation, rooted in architectural design, expanded to encompass diverse domains, including teaching and pedagogy. Despite its recognised potential, the widespread adoption of pedagogical patterns remained limited. Alexander et al. (1977, p.

13) emphasised the interconnectedness of patterns, stating, "In short, no pattern is an isolated entity. Each pattern can exist in the world only to the extent supported by other patterns: the larger patterns in which it is embedded, the patterns of the same size that surround it, and the smaller patterns which are embedded in it." Fernández (1998) reinforced this concept, highlighting the significance of pattern reuse, particularly with sub-patterns, which facilitated the clarification and simplification of complex structures. Christopher Alexander and his colleagues, pioneers in town planning and architecture, established the foundation for pattern utilisation. Analysing 'built form' enabled the construction of compelling patterns, synthesising social, mathematical, aesthetic, and moral assessment methods derived from extensive practical experience and professional training (Lockyer et al., 2008). They excelled at refining language and representations to deconstruct built form, laying the groundwork for the systematic application of patterns.

Recurring patterns served as potent tools for resolving explicit design problems and fostering the development of reusable, elegant, and flexible solutions. They also provided a structured approach to authenticate and reuse expertise and experience. Furthermore, patterns established a common language for practitioners to share and discuss ideas, thereby streamlining the process of discovering and implementing practical solutions. Jones et al. (1999) asserted that patterns documented abstract solutions to common problems, which could be implemented in diverse ways. Gamma et al. (1993) added that designers familiar with these patterns could readily apply them to address design challenges, accelerating the design process and enhancing its efficacy. This application of patterns in pedagogy, like in architecture, creates a framework for repeatable and effective teaching methodologies (Gamma et al., 1993).

2.6.3 The Certainty and Structure of Pattern Application

Characterised by their inherent recognizability and predictability, patterns were systematically documented and identified through standardised formats. These formats, designed to elucidate the rationale behind each pattern, facilitated the learning, comparison, and application of patterns (Dehaene et al., 2015; Jones, 1999; Mor et al., 2014). Gamma et al. (1993, p. 13) delineated four components of a pattern: “the pattern name, the problem, the solution and the consequences.” The pattern name, a concise descriptor, encapsulated the design problem, its solution, and its consequences, enhancing design vocabulary and fostering improved design abstraction. Developing and utilising a standardised pattern vocabulary enabled efficient communication of design concepts among colleagues and through documentation.

The “problem” component articulated the specific challenge the pattern addressed, clarifying the context and obstacles inherent in the design or pedagogical issue (Gamma et al., 1993, p. 13). It also addressed structural complexities and delineated the requirements to be met before pattern application. The “solution” component defined the design elements, collaborations, and relationships constituting the pattern's core (Gamma et al., 1993, p. 13). Notably, the solution remained abstract, functioning as a template adaptable to diverse scenarios, thereby providing a framework for resolving design problems through multiple arrangements of elements. The “consequences” component delineated the outcomes of applying the pattern, serving as a tool for evaluating design alternatives and assessing the costs, advantages, and benefits of pattern implementation (Gamma et al., 1993, p. 13). It also addressed language considerations, implementation challenges, and potential pitfalls. Given the iterative nature of pattern application, the consequences explicitly acknowledged the impact on system portability, flexibility, and extensibility. The explicit tabulation of consequences facilitated comprehension and evaluation, providing valuable insights into potential challenges and best practices. These consequences guide how to utilise the pattern best and anticipate potential issues.

2.6.4 Decoding the Language of Pattern Learning

Knowledge acquisition through pattern recognition represents a fundamental cognitive process pervasive across decision-making domains (Konovalov & Krajbich, 2018). By engaging with patterns, students grasped scientific relationships by manipulating, learning, and documenting visual representations, such as graphs, charts, tables, and drawings, while simultaneously analysing data and resolving complex scientific problems. Konovalov and Krajbich (2018, p. 1289) posited that "the brain divides all possible patterns into specific groups (structures, or pattern types), assigns beliefs to each group, and updates them during the learning process," highlighting the brain's inherent capacity for pattern categorisation and belief refinement. Dehaene et al. (2015, p. 2) further elaborated on the hierarchical organisation of sequence knowledge, identifying at least five distinct categories that represented increasing levels of abstraction. These categories included

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

This hierarchical structure underscored the complexity of pattern learning, encompassing both concrete and abstract representations of sequential information. By mastering these diverse categories, students developed a sophisticated understanding of pattern recognition, enabling them to navigate complex information landscapes and make informed decisions.

2.6.5 Recognising the Nuances of Pattern Identification

Pattern articulation and development exhibited variability, with some patterns derived from expert insights and others from rigorous research, as Mor et al. (2014) noted. Additionally, patterns were constructed from knowledge gleaned through the "mining" of existing practices and literature. This approach addressed the complexities of teaching environments, facilitated the broad adoption of innovation, and bridged the "field gap," as articulated by Jones (1999, p. 7). Pattern detection served as a fundamental mechanism of human learning and decision-making. Researchers accessed the neural processes underlying pattern identification (Bennedsen, 2006). Konovalov and Krajbich (2018) concluded that the brain processed pattern learning differently from probabilistic learning, highlighting the continuous engagement of pattern detection in daily life. However, the precise mechanisms by which humans decipher patterns and the rules guiding pattern engagement remained largely unknown (de Hevia & Spelke, 2010). When patterns were successfully identified, the ventromedial prefrontal cortex, a brain region associated with reward, was activated, suggesting the release of dopamine and serotonin, neurotransmitters linked to learning and memory.

However, the human propensity for pattern recognition also carries inherent risks. Gilovich (1991) observed that humans, uncomfortable with chaos and chance, readily perceived patterns where none existed. This tendency, termed pareidolia (Kahneman, 2011; Stanovich & West, 2007) or patternicity (Shermer, 2008, p. 48), involves the identification of recognisable patterns in unrelated phenomena. Stanovich and West (2007, p. 169) referred to this as "illusory correlation," while Dobelli (2014, p. 17) termed it "an illusion of control," highlighting the brain's inclination to invent patterns when none were apparent. Shermer (2008) argued that the human brain evolved into a pattern-recognising machine, generating perceived patterns daily, which often represented chance occurrences (Dobelli, 2014; Gilovich, 1991; Shermer, 2008). Pattern utilisation, originating in architecture, expanded to encompass diverse disciplines, including teaching and pedagogy. Despite its recognised value, the widespread adoption of pedagogical patterns remained limited. Studies on pattern application were virtually nonexistent in the TVET sector, particularly within the South African context. This research endeavour aimed to address this gap, paving the way for exploring LS as a sustainable pedagogical practice.

2.7 Lesson Study to Create a Sustainable Practice

2.7.1 Origins of Lesson Study

The origins of LS can be traced back to Japan in the late 19th and early 20th centuries. LS was developed by the pioneering educator and mathematician Jiro Tanaka in the early 20th century. Tanaka introduced the idea of "jugyokenkyu" as a formalised process of collaborative lesson planning, implementation, observation, and reflection (Fernandez & Yoshida, 2004, p. 22). He believed teachers could improve their instructional techniques by observing and learning from each other's lessons.

The initial concept of LS emerged in the Meiji era (1868-1912), a period of modernisation and educational reform in Japan. During this time, the Japanese government and educators sought to improve the quality of teaching in schools. They were inspired by educational systems in the United States and Europe, but adapted these ideas to suit their cultural and educational context. "When American teachers retire, almost all the lesson plans and practices they developed also retire. When Japanese teachers retire, they leave a legacy" (Isoda & Olfos, 2021, p. v11).

In the following decades, LS gained popularity and became an integral part of the Japanese education system. It was embraced by educators and school administrators across the country as a powerful method for teacher professional development and enhancing the quality of education (Makinae, 2019). Over time, LS has spread to other countries and has been adapted and incorporated into various educational systems worldwide. Its success can be attributed to its focus on teacher collaboration, reflective practice, and continuous improvement of instruction based on real classroom experiences (Skott & Møller, 2020).

LS's effectiveness in Japan garnered attention from educators and researchers worldwide. In the 1990s, LS began to gain popularity in the United States and other countries as educators sought new approaches to improve teaching practices and student learning outcomes (Fernandez & Yoshida, 2004).

LS has continued to evolve and expand and "is spreading worldwide" (Uffen et al., 2022, p. 1). Countries and regions have integrated LS into professional development programs and teacher training initiatives. Each adaptation incorporates local educational needs and priorities while preserving the core elements of collaboration, reflection, and continuous improvement (Morrison, 2019). One of the strengths of LS is its adaptability to diverse educational contexts. Whether implemented in Japan, the United States, or any other country, the core principles remain consistent: a commitment to improving teaching practices through collaborative lesson planning, observation, and reflective feedback (Cerbin, 2011; Safik et al., 2021; Uffen et al., 2022). Over time, research on LS has shown positive impacts on teacher efficacy, instructional quality, and student learning outcomes (Abdelhalim & Elnagar, 2021; Benedict et al., 2024). As a result, it has become an influential approach in education, and many educators continue to explore and adopt this method as part of their ongoing professional development efforts and classroom "instruction" (Cerbin, 2011, p. xv).

2.7.2 Principles of Lesson Study

The practice of LS is guided by several principles fundamental to its success. These principles, often embraced by educators, promote collaborative professional development to improve teaching practice. The following are the main principles of LS.

Educators collaborate in teams in LS to plan, implement, and reflect on a research lesson (Isoda & Olfos, 2021). The emphasis on teamwork fosters a sense of collective responsibility for student learning. It encourages sharing ideas and expertise to "develop a high level of professional capital and help their schools outperform institutions where teachers work in isolation" (Mewald, 2021, p. 2). LS thrives in an environment of trust and mutual respect among teachers. Teachers feel comfortable sharing their ideas, experiences, and challenges, knowing their contributions are valued and will be used constructively to improve instructional practices (Gómez-Gómez & Pozo-Llorente, 2021). The central focus of LS is to improve student learning outcomes. Teachers design research lessons with specific learning goals and carefully consider how to facilitate student understanding and engagement best (Safik et al., 2021). LS is iterative and cyclical and is not a one-time event. Teachers continually revise and refine their research lessons based on observation, feedback, and reflection. Each iteration builds upon the insights gained from previous attempts (Widjaja et al., 2017).

LS is rooted in evidence-based practice. Teachers use observations, data, and student assessments to inform instructional decisions. The emphasis on evidence helps ensure that teaching strategies are practical and responsive to student needs (Schipper et al., 2020). The LS team engages in reflective discussions and debriefing sessions after each research lesson. They analyse the lesson's strengths, weaknesses, and the impact on student learning. These reflective conversations lead to actionable insights for improvement (Cerbin, 2011). LS respects teachers' diverse perspectives and experiences and recognises that each educator brings unique insights and collaborative inquiry benefits from various ideas and approaches (Sekao & Engelbrecht, 2022).

LS encourages experimentation with new teaching strategies and innovations, providing a safe and supportive environment for trying novel instruction approaches and learning from successes and challenges (Norwich et al., 2021). LS empowers teachers to take ownership of their professional growth. "The LS approach pursues a bottom-up development, where CPD is created by and with teachers in job-embedded processes in authentic teaching and learning scenarios" (Mewald, 2021, p. 2). Through collaborative inquiry and reflective practice, educators develop a deeper understanding of their teaching methods and gain confidence in their abilities (Khaled et al., 2021). LS offers a sustainable model of professional development (Darling-Hammond et al., 2017). It builds a culture of continuous improvement within schools and districts, promoting ongoing learning and growth among teachers. LS promotes the sharing of findings and insights with other educators. Teachers often present their research lessons and outcomes to colleagues, encouraging wider dissemination of effective teaching practices (Fernandez & Yoshida, 2004).

LS values teacher autonomy and professional expertise, allowing "teachers to adapt and interpret it within their specific context" (Uffen et al., 2022, p. 2). Teachers can design research lessons that align with their students' needs, curriculum requirements, and teaching styles with the "support of knowledgeable others" (Mewald, 2021, p. 2). This autonomy fosters a sense of ownership and investment in the teaching process. LS takes a long-term perspective on teacher development and has been instrumental "in helping to transform elementary-level teaching in Japan from a didactic approach based on drill and practice to a problem-based learning pedagogy" (Cerbin, 2011, p. 7). It recognises that meaningful change in instructional practices requires time, effort, and multiple iterations. Rather than seeking quick fixes, LS encourages sustained and gradual improvement (Kandaga et al., 2021). LS thrives in a supportive school culture that values collaboration and professional growth (Opfer & Pedder, 2021). “Schools should provide opportunities for safe conversations in which participants can explore their ideas and assumptions freely and openly” (Uffen et al., 2022, p. 10). Institutional leaders foster an environment where teachers feel encouraged to engage in LS and share their insights with their colleagues.

LS is committed to inclusivity and equity in education. By examining the impact of instructional practices on diverse groups of students, teachers can address potential disparities and create more equitable learning experiences for all learners (Isoda & Olfos, 2021). LS enables TVET teachers to identify and address skill gaps in students effectively. By closely observing students' performance during research lessons, teachers can tailor their instruction to meet specific skill development needs. LS takes a holistic approach to teacher development and encourages a research-oriented mindset among teachers. It recognises that effective teaching involves content delivery, classroom management, student engagement, and socio-emotional support. As educators design and implement research lessons, they should "employ a backwards design process first to identify the goal of instruction and then design lesson activities to support it" (Cerbin, 2011, p. 8). LS is adaptable to different educational contexts and subject areas. Whether applied in early childhood education or higher education, in mathematics or the humanities, the core principles of LS can be tailored to suit various settings. LS is a dynamic approach that continues to evolve. As educators experiment with new teaching strategies, integrate technology, or address emerging educational challenges, LS adapts to remain relevant and effective (Dudley et al., 2019; Larssen et al., 2018).

These principles collectively make LS a powerful and impactful approach to teacher professional development. By engaging in collaborative inquiry and reflective practice, educators can continuously enhance their teaching skills and contribute to improved student learning experiences. By fostering a professional growth and collaboration culture, LS empowers educators to improve their instructional practices, enhancing student learning. As this approach gains recognition and implementation globally, its impact on education continues to grow and evolve.

2.7.3 Key Components of Lesson Study

The LS process typically comprises several important components that promote collaborative inquiry and improve teaching practices. These components provide a structured framework for educators to effectively engage in the LS process.

LS begins with identifying specific learning goals or outcomes that teachers aim to achieve during the research lesson. These goals guide the lesson design and serve as a foundation for the entire process. "In the first formal step of the Japanese lesson study cycle, teachers work together to establish curricular goals" (Bruce & Ladky, 2011, p. 2). Teachers form an LS team and collaboratively plan the research lesson. They share their expertise, explore different teaching strategies, and design lessons to address the identified learning goals. This planning phase often involves in-depth discussions and research on effective instructional methods (Skott & Møller, 2020). Once the research lesson is planned, one of the teachers on the team teaches the lesson to a group of students. The participating teachers in the team observe the lesson closely, taking notes on student engagement, understanding, and teacher practices (Adams, 2013). During the research lesson, the observer teachers carefully observe students' reactions and interactions and the teaching strategies employed by the demonstration teacher. They collect qualitative and quantitative data to comprehensively understand the lesson's effectiveness (Kanellopoulou & Darra, 2019). After the research lesson, the LS team engages in a post-lesson reflection and debriefing session. They share their observations, discuss the strengths and weaknesses of the lesson, and analyse the impact on student learning. "The goal of the analysis is to better understand how students learned or did not learn from the lesson" (Cerbin, 2011, p. 9). This reflection allows the team to gain insights and identify areas for improvement (Cheung & Wong, 2014). In TVET, this contributes to quality assurance and programme evaluation. The LS team revises the research lesson based on the observations and reflections. They integrate the feedback and adjust to enhance the lesson's effectiveness and alignment with the learning goals. LS is an iterative process, and the revised research lesson may undergo additional cycles of implementation, observation, and reflection. Each iteration builds upon the insights gained from previous ones, leading to continuous improvement (Cerbin, 2011).

LS encourages sharing findings and insights with other educators and contributes "to teaching in one's field of instructors document and disseminate their work effectively" (Cerbin, 2011, p.

9). The LS team may present their research lesson and its outcomes to a broader audience, contributing to the professional development of other teachers (Wæge & Fauskanger, 2023). LS fosters a professional learning community within schools or districts. Teachers collaborate, share experiences, and support each other's growth as they engage in the LS process (Longhitano, 2021). Effective LS implementation often requires support from institutional leaders and administrators. They can facilitate the formation of LS teams, provide resources, and create a culture that values collaborative professional development (Fernandez & Yoshida, 2004). LS emphasises the importance of teachers' expertise in the subject matter. A deep understanding of the taught content allows educators to design effective, engaging lessons that facilitate student learning and conceptual understanding (Isoda & Olfos, 2021).

LS ensures that the research lessons align with the "curriculum sequence", standards and learning objectives (Isoda & Olfos, 2021, p. 99). Teachers support students' academic progress and achievement by addressing the prescribed content and skills. LS encourages the use of interactive "subject-centred and student-centred" instructional methods (Isoda & Olfos, 2021, p. 15). Teachers actively engage students in the learning process using "formative assessments to gauge students' understanding and progress" during the research lesson, fostering higher-order thinking skills and a love for learning. However, formative assessments tend "to focus on what students learn from an instructional experience rather than the process of learning" (Cerbin, 2011, p. 68). These feedback assessments enable TVET lecturers to make necessary adjustments to their instruction (Black & Wiliam, 2018).

LS can incorporate educational technology as part of the research lesson. Digital platforms and online collaboration tools can facilitate LS processes, allowing teachers to explore technology to enhance learning experiences and differentiate instruction for various student needs. However, "excessive use of technology may negate the thinking process, even though the aim is to design appropriate integration between learning and technology" (Kandaga et al., 2021, p.

1). Engaging in LS requires teachers to reflect on their own professional development needs. By identifying areas for growth, educators can focus on specific aspects of their teaching practice during the LS process (Abdella & Reddy, 2021). LS provides a supportive environment for novice teachers to learn from experienced colleagues. "Imagine being a novice in the subject and what it would be like to encounter the subject matter and instructional activities?" (Cerbin, 2011, p. 15). Novice teachers can gain valuable insights and mentoring from more experienced educators, accelerating their professional growth. Institutional managers, such as principals or instructional coaches, can actively participate in LS teams to understand the methodology and support teachers in LS endeavours (Mewald, 2021). Their involvement reinforces the importance of professional development and provides valuable guidance and resources.

These important components of LS ensure a systematic and evidence-based approach to teacher development, empowering educators to refine their instructional practices and positively impact student learning outcomes by focusing on collaborative inquiry, reflective practice, and continuous improvement.

2.7.4 Benefits of Lesson Study in TVET

Although there are few peer-reviewed studies, LS offers several significant benefits in the context of TVET. Vocational programs provide students with the practical skills and knowledge required for specific industries and occupations. The implementation of LS can enhance the quality of instruction and improve students' readiness for the workforce. LS's benefits are LS allows TVET educators to collaboratively design and refine lessons directly aligned with industry standards and practices. These programs aim to prepare students for the workforce. LS helps teachers develop employability skills, such as communication, problem-solving, teamwork, and adaptability, which employers highly value. When vocational lecturers engage in "industry developments", lessons become more relevant and responsive to current workforce needs by incorporating input from industry experts and employers (Mewald, 2021, p. 8). LS promotes the use of interactive and hands-on teaching methods. Vocational students benefit from engaging lessons that emphasise the practical application of their skills, preparing them for real-world challenges in their future careers (Gamire & Pearson, 2023). LS encourages lecturers to engage in reflective practice. Regular reflections on research lessons allow teachers to assess their instructional choices, leading to continuous growth and improvement. LS enables lecturers to differentiate instruction effectively (Khaled et al., 2021). By observing how students respond to different teaching strategies, teachers can tailor their approaches to accommodate individual learning styles and abilities. LS holds immense potential to transform Technical and Vocational Education and Training. LS empowers lecturers to provide high-quality education that equips students with the necessary skills for successful careers by fostering collaboration, reflection, relevance to industry needs, and a student-centred approach. Moreover, by building partnerships with industry stakeholders, LS bridges the gap between education and the workforce, contributing to a stronger and more responsive TVET system overall.

2.7.5 Challenges for Lesson Study in TVET

Implementing LS in vocational settings comes with challenges. While LS offers numerous benefits, overcoming these challenges ensures its integration and sustainability.

TVET programs often have tightly packed schedules, leaving limited time for teachers to engage in collaborative planning and LS activities. Finding dedicated time for LS may require adjustments to existing timetables. Institutions may face resource constraints, making allocating funds and materials for LS implementation challenging. In some countries, the state and businesses collaborate to provide, administer and fund vocational education (Maltitz & Lindsay, 2018). Adequate funding and resources are necessary for conducting research lessons effectively. Key programs must align with rapidly evolving industry demands and workforce needs and provide "portable, certified occupational skills that are standardised and fully recognised on national labour markets" (Maltitz & Lindsay, 2018, p. 12). Ensuring LS addresses current industry practices can be challenging, requiring ongoing employer collaboration (Cedefop, 2020). Colleges cover a wide range of vocational areas, each with its unique challenges and requirements. Tailoring LS approaches to suit the specific needs of different program areas can be complex. "Developing new learning materials for TVET courses is quite a challenge as the field of study is often associated with the use of technology" (Yasak & Alias, 2017, p. 180). The programmes aim to bridge the gap between theoretical knowledge and practical skills. Designing research lessons that balance theory and hands-on application can be demanding. Lecturers are subject matter experts with diverse backgrounds and experiences. Balancing the expertise of instructors from various vocational fields during collaborative planning can be a delicate task. The curriculum often involves work-based learning, such as internships and on-the-job training. Coordinating LS activities with students' placements and industry partners can be logistically challenging. Student perception is typically low. "Young people and their parents perceive a broad academic background as far more desirable and valuable than a narrow vocational education that trains young people for specific jobs with limited career growth opportunities" (Maltitz & Lindsay, 2018, p. 14). TVET programs typically have specific assessment and certification requirements. Integrating LS with these requirements while maintaining its focus on instructional improvement may require careful planning. Lecturers may be resistant to adopting new teaching practices or collaborative approaches. Overcoming resistance and fostering a culture of openness to change is necessary for successful LS implementation. Ensuring the long-term sustainability of LS in these institutions may be a challenge. Sustained commitment from teachers, administrators, and stakeholders is necessary to keep LS a regular part of the educational process. "The education and training system should not only provide knowledge and skills required by the economy. It should also contribute to developing thinking citizens who can function effectively, creatively and ethically" (Akoojee, 2016, p. 9).

TVET institutions often comprise multiple campuses or training centres. Effective communication and collaboration among instructors from different locations can be challenging, requiring technology and regular meetings. Evaluating the impact of LS on students' learning outcomes can be complex. Measuring the direct influence of LS on students' skills and employability may require developing appropriate evaluation methods. "Longer time and missing goals can increase the learning cost, which must be strongly avoided in TVET as the cost of providing TVET is already higher compared to other sectors of education" (Yasak & Alias, 2017, p. 184). Integrating technology into LS can be daunting for instructors with varying levels of technological proficiency. Providing support and training for teachers in utilising educational technology effectively is important and "includes the study of technology and related sciences, as well as the learning of real-world competencies" (Saif, 2023, p. 2). Aligning the schedules of employers, instructors, and students for research lessons and industry input can be challenging. Vocational institutions may experience instructor turnover due to retirements or job opportunities in the industry. This turnover can disrupt LS teams and require continuous efforts to sustain the collaborative culture. Cultural and language diversity among instructors and students may impact LS dynamics in international vocational settings. Sensitivity to cultural differences and language barriers is necessary for effective collaboration. TVET institutions may vary in their commitment to supporting LS initiatives. Strong institutional support, including policies and resources, is vital to facilitate LS integration. Monitoring the progress and impact of LS "by senior lecturers and HODs" over time can be demanding. Regular assessments of LS outcomes are necessary to identify areas of success and areas that require further attention (Sithole et al., 2022, p. 97).

Addressing these challenges requires thoughtful planning, strong leadership support, and ongoing professional development for lecturers. Despite the challenges, LS in vocational education holds immense potential to enhance the quality of vocational education, better prepare students for the workforce, and strengthen the connection between education and industry demands. By recognising and working through these challenges, TVET institutions can harness the power of LS to continuously improve instructional practices and ultimately benefit students and the broader community.

2.7.6 Opportunities for Lesson Study in TVET

Opportunities for LS in TVET are vast and hold the potential to transform vocational education to better meet the needs of students, industries, and society. LS brings faculty together to exchange ideas and collaborate on instructional design and classroom practice in ways that make a difference (Ono & Ferreira, 2010) by tailoring the LS approach to the unique challenges and contexts of TVET, LS endeavours to develop educator instructional strategies, knowledge and skills that will improve student outcomes and foster a continuous improvement and innovation culture within this community (Khaled et al., 2021; Mewald, 2021). LS provides a platform for institutions to collaborate closely with industries and employers. By involving industry partners in LS activities, educators can ensure that their instructional practices align with current industry demands, fostering well-prepared graduates for the workforce (Goldshaft, 2016). A collaborative environment is created where educators can reflect on their practices, exchange ideas, and develop innovative instructional methods (Khaled et al., 2021). TVET strives to enhance quality teaching and learning through sustainable collaborative professionalism in institutions (Khaled et al., 2021). LS provides close work with others who share their goals for students, a chance to see and examine alternative teaching approaches and practice new ways to capture the student learning experience (Cheung & Wong, 2014). Second, LS builds on the shift in focus from teaching to learning that has commenced in higher education over the past two decades (Schipper et al., 2022).

LS is a powerful reminder that knowing what students learn, or even how much, is insufficient; teachers need to understand more about how students learn to improve educational outcomes (Hattie, 2023). "Cognitive empathy" (Cerbin, 2011, p. 54) is a term Cerbin coined to capture the importance of imagining how novice learners experience innovative ideas. Doing so is an element of good teaching and a prodigious challenge. Unlike some forms of education research, which aim for generalised knowledge about learning and teaching, LS stakes its claim on the grounds of teaching this lesson to these students in this context (Sekao & Engelbrecht, 2022). Unlike institutional and program assessment, which generates a more cumulative picture of effectiveness, LS looks not for proof but for understanding. In this sense, LS also reflects the growing shift to a more scholarly view of teaching and a recognition of the complexity of pedagogical work (Schipper et al., 2022). Contrastingly, LS makes the otherwise mostly private classroom domain a site for systematic research and knowledge building. It does so not so much because teaching deserves to be seen as crucial intellectual work (which it is) but because there is no alternative. LS takes this to another level, recognising that getting an accurate sense of what and how students learn concepts, skills, and dispositions is no simple matter. Engaging and hands-on research lessons can boost student interest and motivation in their chosen vocational fields. After all, students learn in diverse ways and bring different interests and motivations to the task at hand, and most are not eager to reveal what they do not understand. With these challenges, LS calls on faculty to undertake what Cerbin describes as "deliberate practice" (Cerbin, 2011, p. 137). A necessary element in developing expertise is to adopt a research-oriented mindset. Teachers can actively engage in research activities, drawing upon evidence to make informed instructional decisions. More than casual observation and the trading of impressions, LS brings to teaching a collaborative process that is structured, inquiry-oriented, and, yes, scholarly (Isoda & Olfos, 2021).

2.8 Reflexive Self-Study

"Reflexivity is a set of continuous, collaborative, and multifaceted practices through which researchers self-consciously critique, appraise, and evaluate how their subjectivity and context influence the research processes" (Olmos-Vega et al., 2023, p. 242). Reflexive self-study is a form of self-inquiry and self-reflection that aims to gain insights into one's practice, understand the underlying assumptions that influence one's behaviour, and explore the complexities of one's professional identity (Kirk, 2009). This introspective process involves examining personal thoughts, emotions, and decision-making processes within one's professional role. By adopting a reflexive stance, researchers acknowledge their subjectivity and positionality, recognising that their background, values, and beliefs shape their perceptions and interpretations (Scott, 2014).

2.8.1 Key features of reflexive self-study

Reflexive self-study is context-specific, where researchers openly acknowledge their subjectivity and the influence of their personal experiences and perspectives on the research process (Scoppetta, 2015). The process involves deep self-reflection, where researchers analyse their experiences, motivations, and actions. This self-study process is iterative and often involves narrative inquiry, where researchers write reflective narratives about their experiences and learning journeys and is often utilised as a professional learning and development tool, enabling practitioners to improve their practice (Probst, 2015). The insights gained from reflexive self-study contribute to the existing body of knowledge in the field, offering a unique perspective on practice.

2.8.2 Applications of reflexive self-study

(Bright et al., 2024, p. 408) argue for a reconceptualisation of reflexivity in qualitative research, moving beyond the limitations of the traditional "insider/outsider" perspective. Reflexivity is not merely acknowledging one's socio-historical position but rather a dynamic and ongoing process of self-formation. In the context of doctoral research, writing becomes not just a means of communication but a transformative intellectual and existential practice. By challenging the static insider/outsider dichotomy, the research highlights the researcher identities' fluid and ever-evolving nature. The paper contributed to the discourse on reflexivity by offering a more nuanced and dynamic understanding of its role in the doctoral process and qualitative research. The transformative practice of "care of the self" includes academic writing, continually shaping our existence. (Bright et al., 2024, p. 418). This dynamic self-creation renders traditional insider/outsider reflexivity insufficient. Moving beyond the discovery of pre-existing identities, the study argues that reflexivity, particularly in doctoral work, is a profound intellectual and existential undertaking, transforming the researcher's being. This reconceptualisation offers a new framework for understanding academic identity formation and opens fresh possibilities for reflexive research practices.

2.8.3 Challenges of reflexive self-study

Reflexivity presented several challenges for researchers. The demands of qualitative research often led to prioritising data collection and analysis over reflexive practices. However, effective reflexivity was integral to the research process and should have been allocated dedicated time. Self-reflection could be uncomfortable, requiring researchers to confront their biases and assumptions (Agustin, 2019). Fostering a supportive research environment that encouraged open dialogue and self-examination overcame this resistance. Research evokes strong emotions in researchers. Reflexivity provided a valuable framework for acknowledging and managing these emotions, enabling researchers to maintain objectivity while remaining sensitive to the human dimension of their research (Mortari, 2015).

The human mind operates unreflectively, with most cognitive processes outside conscious awareness. This is a constructivist challenge. "Constructivism maintains that knowledge is a construction of the world," and mental constructs (opinions, beliefs, theories) profoundly influence our actions and decisions (Mortari, 2015, p. 2). These constructs shape our understanding of reality and guide our choices. Remaining in a state of unreflectiveness means allowing these mental constructs to operate unconsciously, potentially leading to unintended consequences and limiting our ability to examine our assumptions and biases. Given the role of reflection in research and that it is not an innate skill but rather one that requires cultivation, it becomes necessary to investigate how researcher training can be designed to foster a reflective mindset. This approach aims to equip researchers with the awareness and ethical grounding necessary to conduct a meaningful and responsible inquiry (Shimizu & Kang, 2022).

In conclusion, reflexive self-study is qualitatively valuable and empowers practitioners to gain deeper insights into their professional experiences, actions, and beliefs. The process of self-inquiry promotes self-awareness, personal growth, and transformative learning, ultimately leading to improved professional practice. Despite its challenges, the benefits of reflexive self-study make it a powerful tool for enhancing individual practice and contributing to the broader knowledge base in various fields of study. Through rigorous self-reflection and examination of experiences, researchers can uncover valuable insights that have the potential to enrich both their professional journeys and the field.

2.9 Conclusion

This literature review systematically synthesised, searched and referenced multiple sources relevant to this study. The structure of the review endeavoured to create a foundation for new perspectives on the subject. The review involved analyses, appraisals and theory-generating syntheses that remained faithful to the interpretive rendering from multiple sources. The review researched, analysed, synthesised and organised the literature that addressed this research project, Implementing Lesson Study to Influence the Teaching and Learning of Electrical Wiring Diagrams in a South African TVET College. While analysing scholarly literature for concepts and definitions, themes and patterns relating to this topic were extracted. The goal was to justify and situate this research, showing how it differed yet aligned with similar empirical studies from important sources and authors. The literature review commenced by discussing VET, followed by practical knowledge, the role of diagrams and illustrations in VET, approaches to learning, pedagogical patterns, and LS to create a sustainable practice and concluded with reflexive self-study. The next chapter will explain the conceptual framework used for this research.

CHAPTER THREE: CONCEPTUAL FRAMEWORK

3.1 Introduction

This conceptual framework incorporates several interconnected concepts, clarifies the research questions and organises the researcher's thoughts to ensure this study is coherent and focused. It bridges the existing literature and the research, guiding the entire research process. The theories used to support and frame this research are DCT, MLT, and PLC, which provide a conceptual basis to help make sense of the findings. Although cognitive load theory is not mentioned as a stand-alone, it is the cornerstone of DCT and Multimedia Learning. Ideas and thoughts were integrated into a scholarly framework that addressed this research project, Implementing Lesson Study to Influence the Teaching and Learning of Electrical Wiring Diagrams in a South African TVET College.

3.2 Dual Coding Theory

DCT is a fascinating concept proposed by Allan Paivio, a Canadian psychologist, in the 1970s. Paivio developed this theory based on his research and observations on how people process and represent information in their minds. DCT contends that human cognition operates with two distinct systems for processing and representing information: the verbal system, which deals with linguistic information, and the nonverbal (visual) system, which processes sensory imagery (Paivio, 2014). The origins of DCT can be traced back to Paivio's earlier work on memory and cognition. In the 1960s, he conducted experiments on memory and found that presenting information visually and verbally improved memory recall compared to using either mode of presentation alone. Paivio strongly believes that using "two systems is more effective than one," (Liu et al., 2020, p. 1). These findings led him to explore the idea that the human mind can use two distinct mental codes for processing and representing information. DCT is a precursor of cognitive load theory and the cognitive theory of multimedia learning (Caviglioli, 2019).

3.2.1 History of DCT

In 1971, Paivio published a seminal book titled Imagery and Verbal Processes, where he introduced DCT. The book argues Mezei (1972, p. 359) It is invaluable because it presents a "systematically structured review of the major research in the psychology of thought, memory and language." In this book, he proposed that the human mind processes information through two separate but interconnected channels: the "verbal" channel, which deals with linguistic and symbolic representations, and the non-verbal or "visual" channel, which involves mental images and spatial representations (Paivio, 2013, p. 150). According to this theory, the brain forms separate mental representations for information processed through each channel, and integrating both types of stimuli can facilitate learning and memory.

Paivio argued that verbal and non-verbal representations can be used to "encode and retrieve" information independently, and having multiple ways to represent information enhances memory and learning (Paivio, 2013, p. 129). This theory was based on a large body of experimental evidence and became influential in cognitive psychology, education, and neuroscience (Sadoski & Paivio, 2012). Since its introduction, DCT has been widely studied and applied in various domains, including education, multimedia learning, and cognitive neuroscience (Sadoski & Paivio, 2012). It continues to be a framework for understanding how the human mind processes and organises information through different mental codes. This theory also explains why providing concrete things (e.g., examples, information, concepts) is important as they are easier to process because they are more "appealing to the imagination" (Caviglioli, 2019, p. 4); they evoke images more quickly and more efficiently than abstract ones. Looking at teaching and learning through this dual coding lens helps us make the learning process more effective, efficient, and enjoyable.

3.2.2 The Linguistic and Imagery Codes

When reading and writing, our sensory-motor experiences allow us to develop a remarkable ability to retain, manipulate, and transform the world around us mentally using a nonverbal code of mental images (Stålne et al., 2016; Voss et al., 2011). The verbal code or system is referred to as the linguistic coding system. In contrast, the nonverbal coding system is often called the imagery code because it is responsible for analysing external scenes and generating internal mental images, according to DCT (Wong & Samudra, 2019). DCT highlights the significance of separate mental codes and the connections between various mental representations to convey meaning and knowledge (Paivio, 2013). It is intriguing to contemplate how we can effortlessly switch between these representations, from language to imagery or speech to writing. DCT suggests that all structuring and monitoring functions occur within and between these systems, rendering abstract schemata or central executives unnecessary. We can even control our cognitive behaviour through inner speech or envisioning alternate scenarios (Sadoski & Paivio, 2012). Furthermore, it is fascinating to consider the continuity between perception and memory as we actively initiate experiential activity through our sense modalities. Our cognitive representations are genuinely sensorimotor, as they store patterns of motor actions such as eye movements, speech articulation, or writing. The correlation between our sensory experiences and cognition is remarkable (Palmiero et al., 2009; Sadoski & Paivio, 2012).

3.2.3 Mental Codes and Mental Sensorimotor Modalities

Our mental representations retain some of the original qualities of external experiences from which they derive, making them modality-specific rather than amodal. This means that our mental encodings are concrete and can deal with abstract information such as language symbols or schematic diagrams (Belardinelli et al., 2009). For example, Visual sensory modality can have verbal and nonverbal encodings. Auditory modalities can have auditory verbal encoding, such as phonemes or word pronunciation, and nonverbal auditory encoding, such as environmental sounds (Dunkelberger et al., 2021). Haptic encoding can be verbal and nonverbal, where the sensation arising from actively touching raised dots in Braille or handwriting is a haptic verbal encoding, and the heft, smoothness, and warmth of a hot cup of coffee is a haptic nonverbal encoding. Chemical sensory modalities, such as olfactory and gustatory, have no verbal representations, but we can experience smells and tastes and encode them as olfactory and gustatory images. Similarly, emotions can be evoked or recalled, but language is not constructed directly from them (Lench et al., 2011; Sadoski & Paivio, 2012).

Figure 2 *Orthogonal relationship between mental codes and mental sensorimotor modalities as theorised by DCT (Sadoski & Paivio, 2012, p. 41).*

	Mental Codes	
Sense Modality	*Verbal*	*Nonverbal*
Visual	Visual language (writing)	Visual objects
Auditory	Auditory language (speech)	Environmental sounds
Haptic	Braille, handwriting	"Feel" of objects
Gustatory	—	Taste memories
Olfactory	—	Smell memories
Emotion	—	Felt emotions

The human brain's information processing is intriguing as it utilises separate subsystems for distinct mental codes and modes that function independently. This means we can visualise a cup of coffee without recalling its aroma or flavour. Modality specificity is equally fascinating, where performing two different tasks in one modality causes disruption, but performing tasks in separate modalities does not interfere. This explains why listening to two conversations simultaneously is difficult, but we can listen to music while exercising without interference. These form part of the brain's wondrous workings (Gyselinck et al., 2007; Holmes & Langford, 1976; Mega et al., 2014).

3.2.4 Basic Units: Logogens and Imagens

It is interesting how cognitive theories break down cognition into basic units or "building blocks"(Sadoski & Paivio, 2012, p. 44). According to DCT, these units are not just abstract concepts without physical form but are assumed to have some physical form in our neural structures and pathways. Morton (1979) describes them as logogens in the verbal system, while in the nonverbal system, they are known as imagens. These are just theoretical terms that distinguish between the underlying neurological representations and their conscious expression in language and imagery. Logogens are also known as verbal representations, verbal encodings, mental language, or inner speech, while images are known as nonverbal representations, nonverbal encodings, mental images, or imagery. The morpheme 'logo' means word, speech, or discourse in Greek, while 'imago' means imitation, copy, or image. 'Gen' means that which generates. Therefore, logogens are neurological language generators, and images are neurological image generators. Mental imagery has its limitations, as well. Eisenhauer et al. explain that sometimes, visual images seem like grainy photos with much out of focus, and detail is lost with imagined distance. They also fade rapidly, needing to be refreshed or reactivated frequently. Mental representations in other modalities are similarly imperfect, and our re-fabrications and rejuvenations can introduce elaboration, distortion, and interpolation. It is interesting to note that one does not need to be literate or even know how to speak to develop a large store of images. Nonverbal representations in all modalities are a part of memory that is not necessarily connected to language, although language commonly evokes imagery and vice-versa in speakers, signers, and literates (Galantucci et al., 2006). Presumably, infants rapidly accumulate large stores of nonverbal representations to which language is later meaningfully associated. As with logogens, imagens are assumed to derive from sensory experience in various modalities.

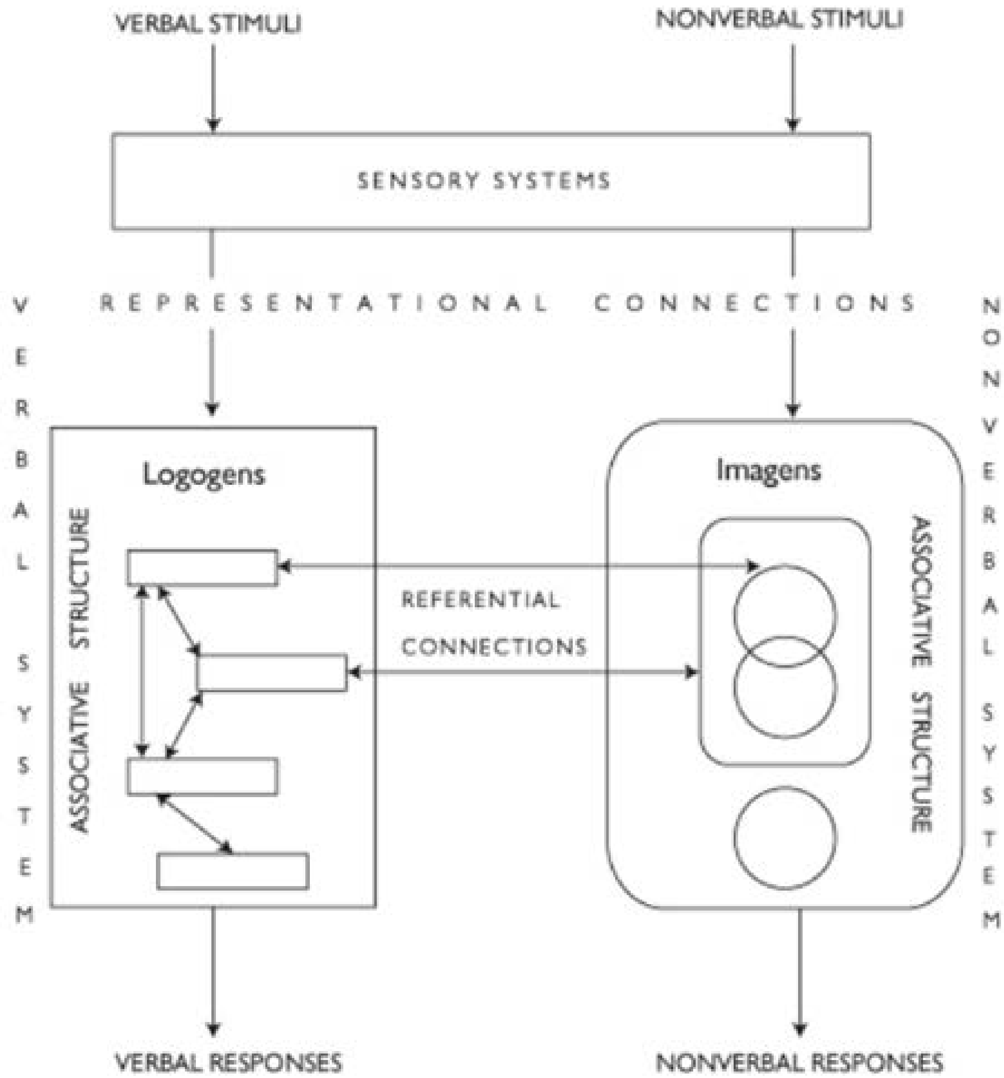
3.2.5 Intra-Unit Organisation and Processing Constraints

Interestingly, how we process information in our minds is determined by the internal structure of logogens and imagens, which are formed based on our experiences (Sadoski & Paivio, 2012). Logogens have a sequential hierarchy, while imagens have a synchronous hierarchy, meaning all information is available simultaneously. This is particularly true in the case of visual imagens. These imagens take the form of nested sets, with each nested part being separately imaged as a set, and the whole set may be nested in a more extensive imaginal set. However, the availability of this information does not imply that all of it can be accessed and processed simultaneously. Unlike verbal structures, information processing in synchronous nonverbal structures is relatively free from sequential constraints (Koenderink, 1984). We can mentally scan a familiar face or room with equal dexterity from one side to the other, from top to bottom or around about.

3.2.6 Organisation and Interconnections of the Verbal and Imagery Systems

Figure 3 presents a general model of DCT, including the internal organisations of the two systems, connections within and between the systems, and their input and output structures. Three levels of processing are implied in the model: representational processing, referential processing, and associative processing. These are organisations and processes of visual and verbal stimuli.

Figure 3 *Verbal and nonverbal responses (Sadoski & Paivio, 2012, p. 48)*



The general model of DCT shows the verbal and nonverbal systems, including representational units and their referential and associative interconnections, as well as connections to sensory input and response output systems.

Recognising how our mental systems can function independently or interconnect is important. We can read without forming mental images or have images without reading

(Arcangeli, 2014). Sometimes, our minds wander, and we experience unrelated images while reading a boring textbook. Our personal history and contextual factors influence the outcomes of our mental processes. Associative processing spreads activation within a system, while referential processing spreads activation between systems (Aminoff & Tarr, 2015). All mental representations are specific to a sense modality, so spreading activation can occur across modes and codes. Understanding these concepts helps to understand how our minds work (Sadoski & Paivio, 2012).

It is interesting to consider how our nonverbal experiences with the world are organised in our minds. Mental images are nested within other mental images in a hierarchy of associations, which allows us to imagine complex environments and scenarios (Pearson et al., 2015; Schifferstein, 2008). While some images remain static, others can shift abruptly, allowing us to imagine completely different scenes. We can also imagine sequences of events, such as entering a building, walking down a corridor, and entering a room, or a continuous event like a fireworks display (Cochrane & Milliken, 2019). Imagery can take many forms and can be associated with other modalities such as sound, taste, touch, and smell. These associations can be hierarchical and blend into a multimodal experience reflecting physical reality. All of this allows for great force and creativity in our imaginative processes. (Sadoski & Paivio, 2012)

3.2.7 Levels of Processing and Meaning

When it comes to understanding, it is not so much about levels as it is about the depth of elaboration. That said, levels can still be valuable, especially regarding reading comprehension. For instance, there is a difference between understanding something literally versus inferentially. It is worth noting, however, that not all conceptualisations of levels are the same. That is why in DCT, we talk about three different levels of processing in both verbal and nonverbal coding systems (Kanellopoulou et al., 2019). "The representational level." (The initial activation of one or both systems). "The referential level." (Activating connections between systems). "The associative level." (Activating connections within a system).(Sadoski & Paivio, 2012, p. 63) The explanation of the representational level of meaning is intriguing. It appears that comprehension at this level depends on the activation of modality-specific neural structures in memory by linguistic or non-linguistic stimuli. Representation familiarity improves understanding at this level. However, it does not necessarily entail a deep semantic understanding or the ability to elaborate on the meaning differently. The continuous merging of the levels of meaning in a bottom-up, top-down manner and the experimental demonstration of the representational level with restricted reading times are equally fascinating. Your point regarding the disparity between familiarity and meaningful comprehension is thought-provoking, particularly in light of something like the formula $E=mc^2$, which may be familiar to many but is only truly meaningful to those with a profound knowledge of physics and mathematics (Gernsbacher, 1984; Marschark & Cornoldi, 1991; Strain et al., 1995).

3.2.8 Semantic Memory

Referential connections run back and forth between logogens in the verbal system and imagens in the nonverbal system. The underlying structure here is the set of connections between known language units and the mental images that have come to be associated with them through world experience (Kumar, 2021). In DCT, this is part of semantic memory. The way our brains process language and imagery is fascinating. Andrews et al. (2009) clarify how our brain connects known language units and mental images associated with them through our experiences. These connections are not always symmetrical or obligatory, meaning language units can evoke different or no images. In reading, we typically progress from language to imagery, but sometimes, the images we imagine can introduce an intense anticipation of the upcoming language, making it easier to comprehend. Imagery and language work together to form a strong internal context that gives meaning to what we read (Vigliocco et al., 2005). Without the ability to form mental images, our understanding of text would be incomplete. Concrete language, meaning language more likely to evoke imagery, has more referential connections than abstract language. For instance, “royal wedding” evokes images of a regal ceremony, a bride and groom, and perhaps a cathedral (Sadoski & Paivio, 2012, p. 63). This example illustrates the power of referential processing, which adds another level of meaning to what we read.

3.2.9 Split Attention Effect

Students often experienced the split-attention effect when required to shift between graphics and accompanying text, which strained cognitive resources and reduced learning efficiency. According to Schroeder and Cenkci (2018, p.680), “split-attention has negative effects,” so it is important to design materials to eliminate this effect. Poorly aligned visual aids can hinder understanding and lead to superficial information processing. Flashy visuals may capture attention but often distract from core content, causing learners to focus more on aesthetics than instructional value. Complex visuals or poorly chosen images can lead to misinterpretation, particularly when they lack clear labels or alignment with the subject. Increased visual complexity can elevate cognitive load, making it necessary to use design techniques that mitigate this impact (Schroeder & Cenkci). Overly abstract or overwhelming visuals often cause misconceptions rather than aid understanding, diverting attention from higher-order thinking tasks like synthesis or analysis. Visuals should clarify concepts rather than create confusion, as they can hinder learning if not used effectively.

3.2.10 Relevance of Dual Coding Theory in Vocational Education and Training

In the context of TVET, DCT significantly influences designing and delivering instructional materials. By incorporating verbal and visual elements, educators can enhance students' understanding of complex concepts, improve information retention, and foster cognitive skills development. Caviglioli (2019), in his book Dual Coding for Teachers, clarifies his aims to introduce teachers, developers, and leaders to the multifaceted aspects of dual coding practice. "When information is transmitted through verbal (speech) and nonverbal (visual) channels, it is represented more fully, leading to stronger comprehension and greater recall" (Wong & Samudra, 2019, p. 2). However, knowing about the psychology and research behind dual coding is only half the story, as the execution skills cannot be ignored. The best-planned graphic, if executed poorly or laid out haphazardly, will fail to realise the potential of that graphic to enhance learning.

Dual coding is a practical approach to meeting vocational students' diverse learning styles and preferences. Incorporating visual elements into the learning material can greatly benefit graphicacy, while auditory learners can benefit from verbal explanations and discussions that complement the visual cognition. With dual coding, teachers can establish a more comprehensive learning environment that caters to the unique needs of vocational students. Recognising and addressing each student's requirements ensures they receive an exceptional learning experience.

Hayikaleng (2019) explains that incorporating visual aids in teaching English reading comprehension at Narathiwat Technical College had numerous positive effects. It boosted understanding, enhanced memory retention, increased engagement and motivation, and catered to diverse learning styles. When teachers combined visual elements with verbal explanations and discussions, they created a more comprehensive and effective learning environment for vocational students.

3.2.11 Practical Applications of Dual Coding Theory in TVET

There are several practical applications of DCT in TVET, including Instructional Material Design. Teachers can develop instructional materials that effectively combine text, diagrams, and illustrations, promoting better understanding and retention of information. For example, in electrical wiring courses, teachers can use diagrams alongside verbal explanations to communicate complex circuit designs (Saunders & Wong, 2020).

The incorporation of multimedia presentations. With the introduction and usage of multimedia presentations, the restructured engineering educational system has been made more interesting, creative, and impressive (Malhotra & Verma, 2020). When delivering content through multimedia presentations, educators can ensure that both verbal and visual information is included. Teachers can create engaging and effective learning experiences catering to various learning styles by combining text, images, audio, and video.

DCT is also demonstrated in student assignments and projects. Instructors can encourage students to incorporate dual coding principles in their assignments and projects. This could involve creating visual representations of concepts alongside written explanations or incorporating multimedia elements in presentations. Ainsworth et al. (2011) explain that visual modes play an important role in knowledge construction in addition to talking, reading, and writing. Students realised science and engineering diagrams were better when condensed, compact and coherent.

Assessments can be designed to evaluate students' understanding of both verbal and visual information. Quillin and Thomas (2015, p. 2) state that “visual literacy” is the ability and aptitude of students to explain ideas presented by educators and, likewise, to craft, construct and create “visual representations” in class work or assessments. Improving visualisation competencies [through diagrams] enhances learning and engagement in the classroom, especially in environments where visual comprehension methods have traditionally been sidelined in favour of numeric and linguistic ones. Educators can better understand student learning by incorporating various assessment formats, such as multiple-choice questions, short-answer responses, and diagram interpretation.

3.2.12 Challenges and Strategies for Implementing Dual Coding Theory in TVET

Implementing dual coding principles in TVET settings may present some challenges, such as balancing the amount of verbal and visual information, ensuring that visual elements do not overwhelm or distract from the core content, and tailoring instructional materials to diverse learners' needs (Clark & Lyons, 2010). To address these challenges in this study, the following strategies will be employed:

The cohort of lecturers engaged in this LS will collaborate and discuss instructional design to create a well-balanced and engaging lesson (Brown et al., 2013). The feedback from students and peers will aid in refining and adapting instructional materials. We will discuss scaffolding methods to support student understanding of complex visual representations (wiring diagrams). The collective work done will promote professional development and collaboration amongst us by sharing best practices (Kitchen et al., 2019) through the implementation of DCT. We will integrate dual coding principles into instructional materials and teaching practices to create more effective learning experiences and promote deeper understanding and cognitive growth for our students.

3.2.13 The Visual Argument and the Importance of Diagrams

Larkin and Simon (1987) expanded on Paivio's theory by distinguishing between sequential and synchronous information structures, creating ‘The Visual Argument’ (Robinson & Schraw, 1994, p. 401). Their research found that well-constructed diagrams were more efficiently modelled than text alone, corroborating that visual information has a pivotal role in learning. The visual impact contends Gates (2018) improves retention and understanding of information, emphasising the value of combining visual material and diagrams into instructional materials.

Visual communication conveys ideas effectively (Kjeldsen, 2015). Diagrams are compelling, as they can distil complex concepts into easily digestible visual representations. However, Winn (1991, p. 212) contends, “Learning… diagrams can only be understood once relationships between symbol systems and psychological processes have been determined.” By incorporating diagrams into our presentations, we can deliver our message with clarity and concision, leaving a lasting impression on our audience. It is remarkable how something as simple as a diagram or chart enhances the impact of our communication (Kjeldsen, 2015; Winn, 1991).

Diagrams enhance clarity and are effective visual aids in conveying complex ideas (Munneke et al., 2003). They are more effective than written explanations for learning and retention by incorporating diagrams into our presentations, we can simplify intricate concepts and illustrate relationships, hierarchies, and data clearly and concisely (Winn, 1982). This enhanced clarity ensures that our audience understands the information without any confusion. Visual information is undoubtedly better retained in memory than textual information, and diagrams can create mental associations that aid in recalling complex concepts. Diagrams are effective tools that enhance communication. Using diagrams to present arguments can help reach a wider audience, especially those who may have difficulty understanding written explanations due to language barriers or personal learning preferences (Peppler & Glosson, 2013). By utilising visual aids, information can be communicated effectively to a diverse range of individuals, promoting inclusivity and accessibility. Therefore, it is imperative to utilise diagrams as valuable tools for learning and reference. Using diagrams is an excellent way to convey information concisely and efficiently. As the saying goes, 'A picture is worth a thousand words,' especially for diagrams. They can condense a vast amount of information into a single visual, making it easier for people to understand complex concepts quickly. You can communicate a wealth of information effectively and efficiently by utilising diagrams.(Ates, 2005; Lombard & Simayi, 2019; C. Preston et al., 2020; Ruiz et al., 2018)

It is important to note that diagrams can encourage active viewer engagement when using diagrams to present arguments (Winn, 1983). By analysing the visual elements and deciphering the message, individuals become more deeply involved in the content, increasing the likelihood of comprehension and retention. Winn (1983, p. 760) explains that visual elements "like diagrams present information using a syntax of spatial organisation." This can be particularly helpful for reaching a wider audience and promoting inclusivity and accessibility, especially for those who may have difficulty understanding written explanations due to language barriers or personal learning preferences (Preston, 2019).

When presenting a sequence of events or outlining a process, diagrams are an effective tool for guiding your audience through a logical sequence. They provide a clear structure for your argument and help support the narrative by visually representing each process step (Winn, 1988). Using diagrams, you can effectively communicate complex ideas and help your audience understand the presented information better. Data-driven arguments are best explained using diagrams like charts and graphs. They provide a clear visual representation of trends, comparisons, and statistical information, making it easier to identify patterns and draw conclusions from the data. However, it is crucial to possess the "ability to learn information in the diagram that is relevant to that task"(Winn, 1988, p. 375). This can help your audience better understand the presented information and make informed decisions based on the insights provided (Prain & Tytler, 2012).

It is important to remember the power of well-designed diagrams when presenting information. They can be influential in shaping opinions and helping to make informed decisions (Carstensen, 2013). Diagrams can support claims and highlight important trends and patterns by presenting data clearly and visually appealingly. Pule (2012) concurs, stating that this can lead to more effective communication and better outcomes for all involved. Diagrams can be used to communicate information across different cultures and languages. Prain and Tytler (2012, p. 2755) define "student-generated representations to include oral and written language." They make it possible to convey complex concepts without translating, which is incredibly helpful for global audiences. The visual nature of diagrams makes them a powerful tool for effective cross-cultural communication, enabling people from different parts of the world to understand and engage with the same information (Billett, 2013).

When facing complex issues, diagrams are beneficial for breaking down and finding solutions. By providing a visual framework, Gates (2018) affirms that they encourage a systematic problem-solving and critical analysis approach. This can be especially useful for global audiences, as diagrams can convey complex concepts without translating (Prain & Tytler, 2012). Overall, the visual nature of diagrams makes them a powerful tool for effective cross-cultural communication. When it comes to fields with specialised knowledge, diagrams can be a helpful bridge between experts and non-experts (Billett, 2013). They provide a way for experts to share their insights with a broader audience while making it easier for non-experts to understand concepts. Using diagrams, experts can communicate complex ideas in a way that is easy to follow and comprehend. At the same time, non-experts can better understand the subject matter without having the same expertise as the specialists. However, Gates (2018, p. 18) clarifies that specific "strategies that experts use may not be accessible to the novice." Overall, diagrams are an effective tool for facilitating communication between people with different levels of knowledge and expertise.

Interactive diagrams can be incredibly valuable tools in educational settings (Buncick et al., 2001; Chang, 2011). They allow learners to "promote active engagement"(Buncick et al., 2001, p. 1237) with the material, encouraging exploration, experimentation, and manipulation of variables. By doing so, learners can better understand concepts and principles. Interactive diagrams can be particularly beneficial for those who struggle with more traditional teaching methods or who learn best through hands-on activities. Using interactive diagrams can help foster a more engaging and effective learning experience. Diagrams are documentation tools in technical fields like engineering and architecture. They provide a standardised way to communicate designs, plans, and instructions to colleagues, contractors, and stakeholders (Cañas & Novak, 2010). Interactive diagrams can take this to the next level, allowing for more engagement and collaboration. By enabling users to manipulate variables and explore different scenarios, interactive diagrams can help teams identify potential issues, test solutions, and make more informed decisions. When combined with traditional diagrams, interactive diagrams can enhance the clarity and effectiveness of technical documentation.

Visualising abstract and theoretical concepts can be challenging to achieve through text alone. However, diagrams offer a tangible representation that helps to aid in conceptual understanding (Chang & Shieh, 2018). When creating diagrams, it is important to remember that they are a powerful tool for persuasion. By using visual elements to simplify complex arguments, highlight important points, and emphasise relationships, diagrams can help enhance your message's overall persuasive impact. Whether you are trying to persuade an audience or illustrate a complex idea, diagrams are an effective way to visualise abstract and theoretical concepts (Prain & Tytler, 2012).

It is important to keep the audience engaged and convey information effectively when creating presentations. Winn (1988, p. 384) contends, "requiring students to remember the names of the elements may have made them more memorable." One way to achieve this is by using diagrams. Diagrams can break the monotony of text-filled slides and help to emphasise important points and relationships. Using visuals to simplify complex arguments and illustrate abstract concepts, diagrams can leave a lasting impression on audiences (Gates, 2018).

When collaborating with experts from different fields, diagrams can be a valuable tool for facilitating communication. By providing a common visual language, diagrams can help to break down barriers and allow for the exchange of ideas more efficiently. This can lead to more effective collaboration and better outcomes (Prain & Tytler, 2012). Diagrams can powerfully connect with people on a personal level. It is incredible how a single image can evoke so much emotion and truly bring a concept to life. They connect with people, convey complex concepts, evoke emotions and make ideas more tangible (Gates, 2018). Diagrams are used in various contexts, from scientific research to marketing campaigns, and they consistently prove to be effective tools for engaging, informing, and persuading audiences. Using diagrams in various fields, including science, engineering, education, marketing, and journalism, creates visual arguments that inform, educate, persuade, and engage audiences. Diagrams are powerful tools for presenting complex information clearly and visually appealingly, highlighting important trends and patterns, supporting claims and shaping opinions (Yasak & Alias, 2017). This can ultimately lead to better outcomes for all involved. The ability of diagrams to bridge the gap between complex information and audience comprehension makes them necessary for effective communication. (Macdonald-Ross, 1979; Munneke et al., 2003; W. Winn, 1982)

3.2.14 Concluding thoughts

Paivio's DCT, developed in the 1970s, is a human cognition model. It posits two interconnected processing channels: verbal and non-verbal. Cognitive processing involves activating both language-based units (logogens) and image-based units (imagens, including visual and auditory). DCT emphasises the superiority of dual coding over single-channel processing, giving equal importance to visual and verbal cognition. It suggests that balanced use of both systems, engaging both brain hemispheres, can enhance learning. DCT is a unique, comprehensive theory of literacy, supported historically, empirically, and practically, aligning with scientific practices and contemporary theoretical perspectives. It has been categorised as a scientific, cognitive, connectivist, embodied, constructivist, and literacy theory, sharing characteristics with other scientific theories.

3.3 Using Multimedia Learning Theory to Engage Multiple Cognitive Processes in TVET

3.3.1 Overview of Multimedia Learning Theory

Building on the DCT, Mayer (2001) developed a cognitive theory of multimedia learning. Richard Mayer pioneered the MLT. This theory focuses on how information processing is influenced by the design of instructional materials. Learning encompasses dual channels. One is visual/pictorial, and the other is auditory/verbal cognitive processing (Jiang et al., 2017). Mayer (2001, p. 43) identifies five primary cognitive processes in multimedia learning, "selecting relevant words and images, organising them into coherent verbal and pictorial representations, and integrating these representations with prior knowledge."

3.3.2 Multimedia Learning

"People learn better from words and pictures than from pictures alone" (Clark & Mayer, 2016, p. 69). Learning through multimedia is an incredibly effective way to enhance one's understanding. Combining words and imagery allows information to be presented comprehensibly and is easy to follow. Research has conclusively demonstrated that individuals are far more likely to retain information when it is presented to them in a multimedia format (Abdulrahaman et al., 2020; Mayer, 2009, 2014). This heightened level of retention can be attributed to the fact that it involves engaging multiple senses, including sight and sound. The various formats in which multimedia messages can be presented, such as through a computer screen or amplified speaker, ensure that the goal of multimedia instruction is achieved, which is to help learners retain information in an enjoyable and stimulating manner. The design of multimedia instructional messages can be based on a technology-centred approach that focuses on the capabilities of advanced technologies or on a learner-centred approach that focuses on the nature of the human cognitive system (Mayer, 2014).

Multimedia learning may be viewed as response strengthening (in which multimedia environments are used as drill-and-practice systems), information acquisition (in which multimedia messages serve as information delivery vehicles), or knowledge construction (in which multimedia messages include aids to sense-making) (Gebre & Polman, 2016; Jiang et al., 2017). When creating multimedia instructional messages, there are two main approaches to consider: a technology-centred approach that focuses on the advanced capabilities of the technologies being used and a learner-centred approach that considers the nature of the human cognitive system. Depending on the purpose of the multimedia message, it can serve as a drill-and-practice system for response strengthening, an information delivery vehicle for information acquisition, or aids to sense-making for knowledge construction through “static graphics such as drawings or photos, or dynamic graphics such as animation or video” (Clark & Mayer, 2016, p. 70)

It is crucial to consider which approach best suits your goals and intended audience. It is important to note three possible learning outcomes: no learning, rote learning, and meaningful learning (Marton & Booth, 1997). Poor retention and poor transfer performance indicate no learning, while good retention and poor transfer performance indicate rote learning. Good retention and transfer performance indicate the ideal outcome of meaningful learning. To achieve this, it is important to focus on the cognitive activity of the learner during the learning process. Basic research aims to contribute to a theory of learning, while applied research aims to derive instructional design principles. By merging these goals, we can conduct basic research on applied situations to derive principles of multimedia design that are both grounded in cognitive theory and supported by empirical evidence. "Selecting words, selecting images, organising words, organising images, and integrating are the cognitive processes needed for meaningful learning"(Clark & Mayer, 2016, p. 48). The utilisation of visual aids is vital for successful learning. Multimedia learning is captivating, as it can enhance our learning experience by incorporating compelling graphics into verbal material (Vagg et al., 2020).

3.3.3 Multimedia Instruction

"Digital technologies enable facts, concepts, and skills to be represented across a range of disciplines using multimodal and interactive techniques", enhancing the learning experience (Bower, 2017, p. 94). The amalgamation of visual and verbal cues can aid in better information retention and promote engagement. It is intriguing to contemplate the components that make a graphic effective and its potential to enrich the learning experience. Instruction integration "relies on the ability of social cues in multimedia instruction to prime a social response in learners that increases attention, motivation, and deeper cognitive processing" (Bower, 2017, p. 75).

Multimedia instruction means different things to different people (Ozcelik et al., 2010). For some people, multimedia instruction means a person sits at a terminal and receives a presentation of on-screen text, graphics or animation, and sounds from the computer's speakers. For others, multimedia instruction means a "live" presentation in which a group of people in a room views images on one or more screens and hears music or other sounds presented via speakers (Mayer, 2009, p. 4). A PowerPoint presentation can present slides while someone talks about each one. Even in low-tech environments, instructors can use a 'chalk and talk' approach by writing or drawing on a blackboard or using an overhead projector while giving a lecture. A textbook lesson with printed text and illustrations can also be considered multimedia instruction at the most basic level. Multimedia instruction presents material combining words and pictures to enhance the learning experience. Other individuals perceive multimedia instruction as a live presentation where a group of people in a room views images on one or more screens and hears music or other sounds presented via speakers. Watching a video on a TV screen can also be considered a multimedia experience since it presents images and sounds. Multimedia instruction can mean different things to different people (Mayer, 2014). While there are many different formats and variations, focusing on these two basic presentation formats is helpful for research.

The definition of multimedia learning has been narrowed down to verbal and pictorial formats, deemed the most relevant in cognitive science research. Thus, "multimedia learning" can more accurately be described as dual-mode, dual-format, dual-code, or dual-channel learning (Mayer, 2009, p. 5). The word multimedia can function as both a noun and an adjective. As a noun, it refers to a technology that presents material in visual and verbal forms. Essentially, multimedia denotes multimedia technology - devices utilised to present visual and verbal material (Cavanagh & Kiersch, 2022). On the other hand, as an adjective, multimedia is applicable in various contexts, such as multimedia learning, multimedia message, multimedia presentation, multimedia instruction, multimedia instructional message, or multimedia instructional presentation - all of which involve words and pictures and aim to facilitate learning. In cognitive science research, the definition of multimedia learning has been refined to focus on verbal and pictorial formats, which are considered the most relevant. Therefore, multimedia learning is more accurately described as “dual-mode, dual-format, dual-code, or dual-channel learning” (Mayer, 2009, p. 5). The word multimedia can be used both as a noun and an adjective. As a noun, it refers to technology that presents material in visual and verbal forms. Essentially, multimedia refers to multimedia technology - devices that present visual and verbal material. Conversely, as an adjective, multimedia can be used in many contexts, such as multimedia learning, multimedia messages, multimedia presentations, multimedia instruction, multimedia instructional messages, or multimedia instructional presentations - all of which involve words and pictures to aid learning. However, “An effect in multimedia learning that has been repeatedly validated is the so-called multimedia effect that people learn more effectively from words and pictures than from words alone” (Bower, 2017, p. 71).

3.3.4 The Case for Multimedia Learning

An instructional message is a communication that aims to facilitate learning. Instructional designers have two primary formats when presenting an instructional message to learners: words and pictures. Words can be spoken language or written text, while pictures can be static graphics like illustrations or photos or dynamic graphics like animations or videos. Words have been the primary medium for conveying instructional messages through lectures and books for centuries. In essence, verbal modes of presentation have been the dominant approach to explaining concepts, and verbal learning has been the prevailing method of education. In recent years, verbal learning has become pronounced in educational research. However, “irrelevant words and pictures undermine learning” (Cavanagh & Kiersch, 2022, p. 1037). With the rise of computer technology, there has been a surge in the availability of visual aids for presenting information, such as vast libraries of static images and captivating dynamic images in the form of videos and animations. Considering the immense potential of computer graphics, it is worth considering whether we should expand instructional messages beyond verbal communication. How do pictures enhance the learning experience? What impact does combining verbal and visual modes of learning have on instructional messages? How do people learn from words and pictures, and how can multimedia presentations contribute to meaningful learning? These important questions can help us explore the potential of multimedia as an effective “inseparable teaching aid and tool in the teaching-learning process” (Sarowardy & Halder, 2019, p. 1507).

The argument favouring multimedia learning stems from the understanding that instructional messages should be tailored to the human mind, which can “organise, synthesise and develop an eye-catching experience of visible content” perceived audibly (Sarowardy & Halder, 2019, p. 1508). It is widely accepted that humans possess two distinct information processing systems – one for verbal and one for visual material. The modality effect is a principle that builds upon the multimedia principle. While the multimedia principle focuses on combining images and written text, the modality effect emphasises explicitly the combination of images and auditory information. However, it is important to note that the primary mode of delivering instructional material is through verbal means. Two reasons supporting the use of multimedia presentations are the quantitative and qualitative rationales. (Clark & Mayer, 2016).

Presenting information on multiple channels is based on a quantitative approach. It is believed that presenting material in both written and visual formats allows for greater exposure to the information, similar to how two lanes accommodate more traffic than one (Mayer, 2009). However, this rationale is incomplete due to its assumption that verbal and visual channels are interchangeable. The concern is that words and pictures are qualitatively different and require different approaches to ensure comprehension—instead, a qualitative approach where verbal and visual representations should complement each other. By doing so, learners can mentally integrate these representations and better understand the material.

As demonstrated, the qualitative rationale posits that the two channels are dissimilar in usefulness, with words being better suited for conveying formal, complex ideas that require careful translation, while pictures are better suited for conveying more intuitive, natural representations (Mayer, 2009). Simply put, a picture cannot be equated to a specific number of words. This rationale is fascinating because comprehension is best achieved when learners establish meaningful connections between visual and linguistic representations. However, inconclusive evidence suggests that "educational design models result in better-quality designs. Perhaps we do not have sufficient research data, and they do lead to qualitatively better designs" (Bower, 2017, p. 121).

One of the benefits of multimedia learning is the ability to visualise the connection between words and images, such as understanding how the "forward motion of a piston" (Mayer, 2009, p. 7) in the master cylinder relates to the animation of a car's braking system. By creating these connections, learners can achieve a deeper level of understanding that surpasses what could be achieved by words or images alone. This concept lies at the core of the cognitive theory of multimedia learning (Mayer, 2014).

3.3.5 Three Views of Multimedia Messages

Multimedia can be interpreted in three ways: based on the delivery media used to convey instructional messages, the presentation modes utilised to exhibit the instructional message, or the sensory modalities employed by the learner to receive the instructional message.

3.3.5.1The Delivery-Media View. A commonly held perspective is that multimedia refers to using two or more delivery devices to present information. The emphasis is placed on the physical means of conveying the material, including computer screens, amplified speakers, projectors, video recorders, blackboards, and even human vocal cords. "Thus, the taxonomy and component synthesis for the development of the multimedia application needs to be extensively investigated, as these would affect the teaching delivery" (Abdulrahaman et al., 2020, p. 2). However, according to the strictest definition of multimedia delivery, textbooks do not qualify as multimedia because they are presented solely through ink on paper (Mayer, 2009). While this view is technically accurate regarding media format, it can be confusing from a psychological perspective and may muddy the waters rather than provide clarity. The emphasis is placed more on the technology used to present information than the learning process and the learners themselves (Malhotra & Verma, 2020). This could lead to a disconnect between the presented material and how learners process and absorb information. It is important to balance utilising technology for educational purposes and prioritising the learners' needs and abilities (Mayer, 2014).

3.3.5.2 The Presentation-Modes View. Another perspective is that multimedia uses multiple presentation modes to convey information (Clark & Mayer, 2016). The emphasis is on how the material is portrayed through words or images. Information can be conveyed through on-screen text, narration, static graphics, or animation in computer-based multimedia. In lecture-based multimedia, information can be communicated through speech, projected graphics, or video. In textbooks, information can be conveyed through written text or still images. This approach aligns with a learner-centred philosophy, assuming students can comprehend and express knowledge using diverse systems, including verbal and visual representations. At the same time, it is commonly believed that images can be translated into words and vice versa; studies on cognitive representations that indicate how knowledge is conveyed through language may differ from how it is conveyed through images (Mayer, 2014). In short, the presentation-modes view of multimedia is consistent with a cognitive theory of learning that assumes humans have separate information-processing channels for verbal and pictorial knowledge. Paivio's Dual-Coding Theory presents the most coherent theoretical and empirical evidence for this idea.

3.3.5.3 The Sensory-Modality View. Although aligned with a learner-centric methodology, the third perspective deviates slightly from the norm. The sensory modalities outlook postulates that multimedia involves engaging the learner's two or more sensory systems. Rather than concentrating on the codes utilised to convey knowledge within the learners' information-processing systems, this perspective emphasises the learners' sensory receptors to interpret the material, such as the ears and eyes. Information can be presented computer-based through various channels, such as visual animations and auditory narrations. Similarly, in a lecture, the speaker's voice is processed through the auditory channel while the visual channel processes slides projected on the screen. Textbooks rely on both illustrations and printed text for visual processing. This approach is learner-centred, as it considers the learner's information-processing activities.

The sensory-modalities view differs from the presentation modes view by emphasising the importance of presenting material that engages visual and auditory processing. This view recognises that humans process visual images and sounds in distinct yet complementary ways. The sensory modalities approach aligns with a cognitive theory of learning that posits separate information-processing channels for auditory and visual perception. To support this idea, Baddeley's (1999) model of working memory offers the most robust theoretical and empirical evidence.

According to Mayer (2009), the delivery-media view emphasises technology more than the learner. Instead, both the presentation modes and sensory modalities focus on how humans process information through multiple channels, known as the dual-channel assumption. However, these views differ in their conceptualisation of the two channels. “The presentation-modes view distinguishes between separate systems for processing verbal and pictorial knowledge, while the sensory-modes view distinguishes between separate systems for auditory and visual processing" (Mayer, 2009, p. 7).

3.3.6 Three Metaphors of Multimedia Learning

When it comes to designing multimedia, the underlying conception of learning held by the designer determines how multimedia is used. The three main views of these conceptions include multimedia learning as response strengthening, multimedia learning as information acquisition, and multimedia learning as knowledge construction. Each of these views has its advantages and disadvantages, so it is important for designers to carefully consider which approach is best suited to their project. Ultimately, multimedia learning aims to create an engaging and practical learning experience. Although "multimedia is non-linear, which allows the learner to utilise their skill and select the path of learning independently" (Malhotra & Verma, 2020, p. 71).

3.3.6.1 Multimedia Learning as Response Strengthening. Traditionally, psychology has viewed learning as strengthening or weakening the association between a stimulus and a response. This perspective assumes certain things about what is learned, who is learning, who is teaching, and the objectives of multimedia presentations. It suggests that "learning involves adjusting the strength of the connection between a stimulus and a response, such as recognising that 3+2 equals 5" (Mayer, 2009, p. 15). The learner's responsibility is to provide responses and receive feedback through rewards or punishments to be conditioned through this process. This combination "of two cognitive models: Mayer's Cognitive Theory of Multimedia Learning, which implements using multimedia elements to enhance the learning experience of a child, and a mild implementation of Skinner's Operant Conditioning, which suggests using gentle positive and negative reinforcements to help motivate the child" (Saad et al., 2015, p. 367). The teacher, or multimedia designer, must offer rewards and punishments based on the student's behaviour to strengthen desirable responses and weaken undesirable ones. Finally, multimedia presentations facilitate practice and repetition by prompting responses from the learner and providing reinforcement as needed. This drill-and-practice model relies on multimedia to reward and discourage incorrect responses.

The concept that behaviours are more likely to be repeated when accompanied by feelings of satisfaction is not novel, as it has been established since Thorndike's seminal research conducted in 1911, which involved studying the learning behaviours of cats placed in puzzle boxes. The study's findings gave rise to what is known as the "law of effect," which posits that behaviours that lead to positive outcomes are more likely to be repeated in the future (Mayer, 2009, p. 15). Conversely, behaviours that lead to less satisfying or adverse outcomes are less likely to be repeated. "Thorndike's original idea that transfer is based on some type of similarity between the original learning situation and the subsequent transfer situation" (Mariano, 2014, p. 2). This principle forms the basis of the response-strengthening view, which asserts that associations between stimuli and responses are modified based on the outcomes they lead to. Thorndike's experiment is a classic example of this principle in action, as the cats learned to pull a string to escape the box due to the favourable consequence of freedom, thus reinforcing the association between the behaviour and the outcome. The law of effect has become a cornerstone of learning and psychological theories (Mariano, 2014).

3.3.6.2 Multimedia Learning as Information Acquisition. The concept of learning as an information-acquisition process is intriguing. Under this view, learning is perceived as integrating fresh knowledge into one's memory. This approach presupposes that learning entails collecting and retaining factual data that can be conveyed from a digital display or another medium to the learner's brain. Moreover, it has implications for the teacher's role and the goals of multimedia demonstrations.

The perspective of learning that centres on information acquisition implies that the learner merely absorbs and memorises information. Unfortunately, this approach depicts the learner as a passive recipient rather than an active participant in the learning process. “In its original form, response-strengthening viewed the learner as a passive recipient of rewards or punishments, and the teacher as a dispenser of rewards” (Clark & Mayer, 2016, p. 46). In this approach, the teacher's primary responsibility is to convey knowledge to the student. The focus is on effectively communicating information logically and in a structured manner, hoping the student fully understands and retains the material.

Multimedia presentations need to convey information to the learner efficiently (Srivastava & Arora, 1998). The use of multimedia is seen as a highly effective way to transmit information from the program to the learner. This method allows learners to understand and retain the presented information more easily. The fundamental concept behind this perspective is that multimedia functions as a conduit for information delivery. The analogy is a vehicle carrying information from the sender to the receiver. This view presupposes that the receiver's mind is an empty vessel that requires filling with information (Saad et al., 2015).

Critics of the information-acquisition perspective highlight its limitations, especially in fostering a profound understanding of complex topics (Bransford et al., 1999). While this approach may help learn discrete pieces of information, it falls short when the objective is to encourage genuine comprehension (Marton & Booth, 1997). This viewpoint contradicts research that suggests how people effectively learn intricate subjects. When individuals strive to understand complex material, such as how a car's braking system works, they do not merely record and store every word verbatim. Instead, they engage with the material's meaning and interpret it in the context of their existing knowledge and experiences. The information-acquisition view oversimplifies the intricate processes involved in meaningful learning and understanding. It neglects the active cognitive engagement, thinking, and sense-making learners employ when grappling with complex concepts (Mayer, 2014).

3.3.6.3 Multimedia Learning as Knowledge Construction. In contrast to the information-acquisition view, the knowledge-construction view posits that multimedia learning is an activity focused on making sense of and building coherent mental representations from the presented material. "The active processing assumption holds that individuals actively engage in cognitive processing to construct mental representations of their experiences" (Mariano, 2014, p. 2). Unlike information, which is considered an objective commodity that can be transferred between minds, each learner individually constructs knowledge. It cannot be replicated in the same form in another mind. This is why two learners exposed to the same multimedia content might interpret and retain the information differently (Saad et al., 2015).

When considering the nature of the learner, the learner's role is that of an active sense-maker. They engage with the multimedia presentation to comprehend, organise, and integrate the material into a meaningful mental framework (Fakhrunnisaa & Munadi, 2019). This active engagement allows them to construct personal knowledge based on their unique cognitive processes and existing understanding. However, the role of the teacher is that of a cognitive guide (Clark & Mayer, 2016). They assist the learner's sense-making process by providing guidance and support. Rather than delivering information directly, the teacher facilitates the learner's cognitive processing, helping them navigate the complexities of the material.

The goal of multimedia presentations in the knowledge-construction view extends beyond delivering information. It aims to guide learners in effectively processing the provided information (Mariano, 2014). This involves helping learners discern what to focus on, how to structure the material mentally, and how to connect it with their prior knowledge (Mayer, 2009). The metaphor underlying the knowledge-construction view is that multimedia communicates and guides sense-making. Multimedia is seen as a tool that aids learners in constructing their understanding by facilitating the organisation and integration of information. From a pedagogical perspective, the knowledge-construction view is favoured because it aligns more closely with research findings on effective learning. It also consistently promotes a genuine understanding of the material rather than overwhelming learners with extensive information. This view recognises that the objective of multimedia presentations is not solely to expose learners to vast amounts of data but to help them develop a deep comprehension of necessary concepts (Clark & Mayer, 2016).

The knowledge-construction view provides a more practical and effective understanding of learning, mainly when the aim is to facilitate understanding and practical application of acquired knowledge. It acknowledges the active role of learners in the learning process and emphasises the importance of meaningful sense-making rather than passive absorption of information.

3.3.7 Three Kinds of Multimedia Learning Outcomes

In the context of multimedia learning outcomes, there are three primary categories of achievements: remembering, understanding, and transfer. These categories represent different goals and abilities that learners can demonstrate.

3.3.7.1 Remembering. Remembering is the fundamental ability to reproduce or recognise information presented to the learner. This aspect is evaluated through retention tests, which gauge how well the material has been retained in memory. Two common types of retention tests are recall and recognition. In recall tests, learners are asked to retrieve and reproduce information from memory. For instance, they might be required to write important points from a lesson they have read. In many instances, “attentional effort is being expended on remembering instead of learning” (Bransford et al., 1999, p. 49). Recognition tests assess whether learners can identify correct information from a set of options. Multiple-choice questions are a classic example of recognition tests, where learners select the correct answer from a list of choices. True-false questions also fall into this category, as learners must determine whether a given statement matches the presented material. The primary concern in retention tests is the quantity of learning and how much information has been successfully memorised (Marton & Pang, 2006).

3.3.7.2 Understanding. Understanding goes beyond mere memorisation but addresses “learners’ idiosyncratic understanding of instructional content” (Cavanagh & Kiersch, 2022, p. 1043). It refers to constructing a coherent mental framework from the material presented. This comprehension is evident when learners can apply the presented concepts and information in novel situations when they “construct mental representations of their understanding of texts, using and coordinating both concept-driven (top-down) and sentence and word-level (bottom-up) processes” (Kassen, 1998, p. 4). “Understanding is evaluated through transfer tests” (Clark & Mayer, 2016, p. 71). Transfer tests assess learners' capacity to apply what they have learned to new and unfamiliar scenarios. These tests often involve problem-solving tasks not explicitly covered in the learning materials. For example, an essay question requiring learners to generate solutions for a problem would require them to draw on their understanding and apply it creatively (Mayer, 2014).

3.3.7.3 Transfer. The central focus of transfer tests is the quality of learning and how effectively learners can employ their acquired knowledge in real-world applications.

"Transfer tests can help tell us how well people understand what they have learned" (Mayer, 2014, p. 44). It is worth noting that these three categories—remembering, understanding, and transfer—highlight distinct facets of learning outcomes. Remembering concentrates on the amount of information retained, understanding delves into constructing meaningful mental representations, and transfer assesses the practical usability of learned knowledge in diverse situations. Developing meaningful mental representations promotes meaningful learning. Meaningful learning is distinguished by good transfer and retention performance of organised words and pictures (Clark & Mayer, 2016; Mariano, 2014; Mayer, 2014).

3.3.8 Two Kinds of Active Learning

"Humans engage in active learning by attending to relevant incoming information, organising selected information into coherent mental representations, and integrating mental representations with other knowledge" (Mayer, 2014, p. 47). Active learning is the best way to promote meaningful learning outcomes. This is because meaningful learning outcomes occur when learners actively engage in the learning process. However, there is some debate about what constitutes active learning. Some people believe active learning only refers to physical activity, such as hands-on activities. Others believe active learning also includes cognitive activities like thinking and problem-solving. To foster meaningful learning outcomes, multimedia presentations should be designed to prime behavioural and cognitive activity such as "process, comparison, generalisation, enumeration, and classification" (Mayer, 2014, p. 50). Group discussions and problem-solving exercises can prime behavioural activity. Cognitive activity can be primed by concept mapping and thinking tasks. Ultimately, the best way to prime behavioural and cognitive activity will vary depending on the specific learning objectives. However, by incorporating both types of activity into multimedia presentations, educators can increase the likelihood of promoting meaningful learning outcomes (Saad et al., 2015).

3.3.9 Concluding thoughts

Multimedia learning happens within the learner's mind, which has separate visual and verbal processing channels, each with limited capacity. Active learning requires proper cognitive processing in both channels. This demanding process involves selecting and organising relevant words and images and then integrating these representations and existing knowledge. Information is represented in multiple ways during learning, from the initial presentation (words and pictures) through sensory and working memory, culminating in long-term knowledge. Cognitive resources must be allocated effectively between extraneous, necessary, and generative processing. Therefore, effective instructional design aims to minimise extraneous processing, manage processing, and encourage generative processing. The core idea is that multimedia messages should be designed to align with how the mind works to maximise meaningful learning.

3.4 Professional Learning Community (PLC)

3.4.1 Overview of PLCs

Professional Learning Communities (PLCs) are educators who collaborate regularly to enhance teaching practices and improve student learning. These communities emphasise shared goals, continuous improvement, and data-driven decision-making. A strong PLC fosters a collaborative culture where teachers and staff exchange insights, strategies, and best practices "situated in a theory of authentic dialogue" (Shuilleabhain, 2013, p. 22). The primary focus is always on student learning, with educators using performance data to guide instructional decisions. Reflection and continuous inquiry encourage teachers to engage in professional growth and self-improvement. Leadership within a PLC is often shared, promoting accountability and a collective commitment to success. By participating in a PLC, educators benefit from innovation, reduced isolation, and ongoing professional development, ultimately leading to improved student outcomes. Whether within a school, district, or virtual setting, PLCs are potent tools for fostering meaningful educational change (Feldman, 2020; Fox & Poultney, 2020; Owen, 2014; Ríos, 2019; Willems & Bossche, 2019).

3.4.2 The Five Levels of a PLC

3.4.2.1 A Safe, Supportive, and Collaborative Culture. Professional Learning Communities (PLCs) at level 1 are "foundational because they address basic human needs" and foster teacher growth to improve student outcomes (Eaker & Marzano, 2020a, p. 11). At this foundational level, the focus is on establishing a safe, supportive, and collaborative culture. This begins with creating an environment of trust and respect where members feel comfortable sharing ideas, asking questions, and taking risks without fear of judgment (Feldman, 2020). Open communication is promoted, characterised by honest and respectful dialogue where diverse perspectives are valued. A sense of shared responsibility ensures that all members feel accountable for the PLC's success and student learning. "The collaborative atmosphere needs trust, mutual respect, and confidentiality", and encourages vulnerability (Goldshaft, 2016, p. 19). Building a collaborative culture involves developing a shared vision and goals, clearly understanding the PLC's purpose, and working together towards common objectives. Regular meetings at consistent times allow for ongoing collaboration and progress monitoring (Ono & Ferreira, 2010). Active participation from all members in discussions and decision-making is vital. Shared leadership, where roles are distributed among members, fosters ownership and engagement. An important aspect of Level 1 PLCs is a focus on continuous improvement. This involves data-driven decision-making, using data to inform instruction and identify areas for growth (Fox & Poultney, 2020). Reflective practice, where members regularly consider their teaching and seek ways to enhance their skills, is also important. Sharing resources and expertise among members supports everyone's professional development. Ultimately, the central goal of the PLC is to improve student achievement and well-being. For those establishing Level 1 PLCs, starting small with a group of interested teachers is helpful. Providing training and support on effective collaboration and PLC facilitation is beneficial. Celebrating successes along the way builds momentum and motivation. It is important to remember that building a strong PLC culture requires time and effort. Level 1 PLCs can create a foundation for ongoing growth and development through focused elements, leading to improved teaching practices and student outcomes (Eaker & Marzano, 2020a; Fox & Poultney, 2020).

3.4.2.2 Effective Teaching in Every Classroom. Professional Learning Communities (PLCs) at Level 2, focusing on effective teaching in every classroom, build upon the foundation of a safe and collaborative culture established in Level 1. At this stage, the PLC focuses on the practical application of that culture to improve teaching practices and student learning, where "teachers develop and maintain enhanced levels of pedagogical skill" (Eaker & Marzano, 2020a, p. 13). The core focus is on enhancing instructional strategies. PLC members delve into effective teaching practices, exploring research-based strategies and best practices relevant to their subject areas and student needs. They collaboratively analyse curriculum, assessment data, and student work to identify areas for improvement and develop targeted interventions. An important element is the sharing of teaching strategies and resources. Members openly share successful lesson plans, activities, and materials, creating a collective pool of knowledge and expertise. They also engage in peer observation and feedback, providing constructive criticism and support to refine or change each other's teaching practice "as a result of learning from others through the PLC processes"(Owen, 2014, p. 65).

Data-driven decision-making is crucial at Level 2. The PLC regularly analyses student data, including formative and summative assessments, to monitor student progress and identify areas where students struggle. This gathered "relevant data" informs instructional adjustments and the development of targeted interventions to address specific student needs (Owen, 2014, p. 65). Collaborative lesson planning is a hallmark of Level 2 PLCs. Members work together to design and refine lessons, ensuring alignment with curriculum standards and incorporating effective teaching strategies. This collaborative approach fosters a shared understanding of effective instruction and promotes classroom consistency (Saif, 2023). Level 2 PLCs also emphasise the importance of reflective practice. Members regularly reflect on their teaching practices, analysing their strengths and weaknesses and identifying areas for professional growth. They discuss their teaching, share insights and challenges and seek feedback from their colleagues. This ongoing reflection promotes continuous improvement and helps teachers refine their skills. “Reflective practice allows teachers not only to set instructional goals but also reflect about what worked well, what did not work, and what they might do next” (Eaker & Marzano, 2020a, p. 86). Ultimately, the goal of Level 2 PLCs is to translate the collaborative culture into tangible improvements in teaching practices, leading to increased student engagement, achievement, and well-being in every classroom.

3.4.2.3 A Guaranteed and Viable Curriculum. An inquiry cycle starts by “asking collaborative teams to answer the first critical question of a PLC: What do we want students to learn?” This leads to initiating a “guaranteed and viable curriculum”, which can be a powerful tool for encouraging effective teaching (Eaker & Marzano, 2020a, p. 112). At Level 3, this represents a significant step in the evolution of PLCs. At this level, the PLC moves beyond improving individual teaching practices to ensuring all students access a high-quality, consistent, and challenging curriculum (Shuilleabhain, 2013). The core focus is on curriculum development and alignment. PLC members collaboratively analyse the curriculum, ensuring it is aligned with state standards, learning progressions, and the needs of their students (Brown et al., 2013). They work together to develop a guaranteed and viable curriculum that is rigorous and achievable for all learners. This includes identifying necessary learning outcomes, creating common assessments, and establishing pacing guides to ensure classroom consistency. Another element of Level 3 PLCs is the development of common assessments. “Teachers must understand how their actions, assessment practices, behaviour and task requirements affect what is going on in the minds of their students. In other words, they need insight into the learning processes occurring in their students’ minds” (Chipamaunga, 2015, p. 65). Members collaborate to create formative and summative assessments that measure student learning. These assessments provide valuable data that informs instruction and helps identify areas where students are struggling. The PLC uses this data to adjust the curriculum and provide targeted interventions for students who need extra support.

Another important aspect is the focus on instructional materials and resources. PLC members work together to identify and select high-quality instructional materials that align with the curriculum and support effective teaching practices (Fox & Poultney, 2020). They may also develop their resources, such as lesson plans, activities, and assessments, to ensure they have the materials to teach the curriculum effectively. Level 3 PLCs also emphasise the importance of collaboration and communication (Saif, 2023; Shuilleabhain, 2013). Members work closely to ensure the curriculum is implemented consistently across classrooms. They share their expertise, provide feedback to each other, and work together to solve any challenges that arise. This collaborative approach fosters a sense of shared ownership and ensures that all teachers work towards the same goals. Ultimately, the goal of Level 3 PLCs is to ensure that all students have access to a guaranteed and viable curriculum that prepares them for college, career, and life. By working collaboratively to develop and implement a high-quality curriculum, Level 3 PLCs positively influence students (Eaker & Marzano, 2020).

3.4.2.4. Standards-Referenced Reporting. Professional Learning Communities (PLCs) at Level 4, focusing on Standards-Referenced Reporting, represent the most advanced stage of PLC development. “Developing a standards-referenced reporting system becomes an excellent staff development exercise. What better way to sharpen a guaranteed and viable curriculum than to engage teachers in developing a reporting system that reflects how well individual students are learning that curriculum” (Eaker & Marzano, 2020, p. 189). At this level, the PLC has established a strong foundation of collaboration, effective teaching practices, and a guaranteed curriculum (Owen, 2014). The focus now shifts to how student learning is communicated to parents, students, and other stakeholders. The core focus is on developing and implementing a standards-referenced reporting system. PLC members collaboratively define clear learning targets aligned with curriculum targets. They develop assessments that accurately measure student progress toward these targets (Ríos, 2019). The reporting system provides detailed information about student achievement on each learning target, allowing parents and students to understand exactly what students know and can do.

Another element of Level 4 PLCs is multiple assessment measures. Members work together to identify a variety of assessments, including formative and summative assessments, performance tasks, and student work samples, that provide a comprehensive picture of student learning (DuFour & Reason, 2015). They use this data to inform instruction and to provide feedback to students and parents about their progress. Another important aspect is the focus on communication and collaboration with parents (Saad et al., 2015). PLC members work together to develop clear and concise reports that are easy for parents to understand. They may also hold parent conferences to discuss student progress and answer any questions that parents may have. This collaborative approach ensures that parents are actively involved in their child's education and clearly understand their child's strengths and areas for growth (Bransford et al., 1999). Level 4 PLCs also emphasise using data to inform instruction and improve student learning. Members regularly analyse student data to identify areas where students are struggling and to adjust instruction. They may also use data to track student progress and identify students needing additional support. Ultimately, the goal of Level 4 PLCs is to provide all stakeholders with accurate and meaningful information about student learning (Chipamaunga, 2015). By working collaboratively to develop and implement a standards-referenced reporting system, Level 4 PLCs can help to ensure that all students are successful.

3.4.2.5 Competency-Based Education. Professional Learning Communities (PLCs) at Level 5, focusing on Competency-Based Education, represent the pinnacle of PLC development. The PLC has mastered collaboration, effective teaching, curriculum alignment, and standards-referenced reporting at this stage. The focus now shifts to a student-centred approach where learning is personalised, and progress is measured by demonstrated competency. The core focus is on shifting from a time-based to a competency-based system. "Successfully capturing the full potential of competency-based education requires confronting the question, Which competencies are essential for students in the 21st century and beyond?" (Eaker & Marzano, 2020a, p. 255). PLC members collaboratively define clear competencies that students are expected to master. These competencies are aligned with the curriculum and college and career readiness expectations of students. They develop assessments that measure student progress toward these competencies, allowing students to demonstrate their learning at their own pace (Owen, 2014). Another objective of Level 5 PLCs is personalised learning. Members work together to create flexible "learning pathways" that allow students to progress at their own pace based on their individual needs and learning styles (Stuart et al., 2018, p. 4). They may use various instructional strategies to engage students and support their learning, including project-based, inquiry-based, and technology-integrated learning.

"Student ownership of assessment was a[nother] key element of the system" (Stuart et al., 2018, p. 141). PLC members work together to create a learning environment where students are actively involved in their learning (Eaker & Marzano, 2020). They may use goal setting, self-assessment, and reflection strategies to help students take ownership of their learning and track their progress. Level 5 PLCs also emphasise the importance of collaboration and communication with students and parents (Chipamaunga, 2015). Members work together to provide students and parents with clear and timely feedback on their progress. They may also hold student-led conferences to discuss student goals and progress. This collaborative approach ensures that students and parents are actively involved in learning. Ultimately, the goal of Level 5 PLCs is to create a learning environment where all students can achieve mastery of competencies (Owen, 2014). By working collaboratively to implement a competency-based education system, Level 5 PLCs can help ensure that all students are prepared for college, career, and life success.

3.4.3 Leadership in high-performing PLCs

Leadership is necessary for high-performing PLCs. Effective leaders cultivate a culture of collaboration, trust, and continuous improvement, empowering teachers to work together to enhance their practice and improve student outcomes (Chipamaunga, 2015; Goldshaft, 2016; Owen, 2014). They work collaboratively with PLC members to develop a shared vision and establish clear, measurable goals, ensuring everyone works toward a common purpose. Leaders also distribute leadership responsibilities among PLC members, fostering a sense of ownership and shared accountability. "Leadership is about being not the bossiest person in the group, but rather the one who understands how to be authentic and deliver feedback that helps the team reach its goals" (Stuart et al., 2018, p. 152). Creating a culture of trust and respect is paramount, where members feel comfortable sharing ideas and taking risks. This environment's hallmarks are open communication, active listening, and valuing diverse perspectives.

Facilitating meaningful collaboration is a leadership function achieved through effectively structured meetings and focused discussions (Shuilleabhain, 2013). Leaders guide the PLC using data to inform decisions, helping members analyse student data and develop targeted interventions. Focusing on continuous improvement is crucial, with leaders promoting reflection, providing feedback, and supporting professional growth. Modelling lifelong learning by staying current with research and best practices is also necessary (Brodie & Borko, 2016). Effective leaders recognise and celebrate PLC accomplishments, building morale and reinforcing the value of collaboration. Finally, they connect the PLC's work to the broader school community, sharing successes and advocating for the PLC's needs, ensuring alignment with school-wide goals (Brodie & Borko, 2016). These leadership qualities are vital for creating and sustaining high-performing PLCs that positively impact teaching and learning.

3.4.4 PLCs in TVET

PLCs play an important role in TVET by fostering collaboration among educators, industry professionals, and institutions (Saif, 2023). These communities help improve teaching practices and ensure that students develop the practical skills necessary for the workforce. Given the rapidly evolving nature of vocational education, PLCs allow educators to stay updated with industry trends, integrate new technologies, and enhance competency-based learning. A defining feature of PLCs is strong industry collaboration (Mazhinye, 2018). Educators work closely with employers and training organisations to align teaching with workforce demands and emerging technologies. Unlike general education PLCs, those in TVET emphasise practical skills development, competency-based training, and work-based learning (Mewald, 2021; Sibisi, 2019). Teachers collaborate to refine hands-on instructional methods, assessment strategies, and certification alignment to better prepare students for real-world applications.

Technology and innovation integration are crucial. As industries adopt automation, artificial intelligence, and digital fabrication, PLCs provide a platform for instructors to explore best practices for incorporating these advancements into training programs. "If educators learn to leverage technology tools strategically to support continuous school improvement powered by the PLC process, schools can be transformed for the better" (DuFour & Reason, 2015, p. 14). Work-based learning and apprenticeships are also important elements of PLCs, helping educators design strategies for practical industry placements, mentorship models, and employer engagement (Khaled et al., 2021). Cross-disciplinary collaboration is another important aspect, as many vocational fields require expertise across multiple domains. Instructors from different disciplines work together to create integrated learning experiences that reflect industry realities (Urama & Ndidi, 2012). This approach is particularly relevant in mechatronics, green energy technologies, and advanced manufacturing. Competency-based assessments are a significant focus in TVET PLCs, ensuring that students demonstrate real-world skills rather than theoretical knowledge (Weigel et al., 2007). Educators collaborate to develop standardised assessment rubrics and skill validation techniques. The emphasis on lifelong learning and upskilling is also necessary, as industry standards and technologies constantly evolve (Eklund-Myrskog, 1997). PLCs support continuous professional development through certifications, industry training, and collaborative research projects.

The impact of PLCs in TVET is significant. They enhance industry alignment, improve teaching strategies, and contribute to better student outcomes by increasing employability and job readiness (Makole, 2015; Mortaki, 2012). Educators benefit from faster adaptation to technological changes and more substantial networking opportunities with businesses and policymakers. To implement effective PLCs, institutions should establish regular collaboration meetings, facilitate industry-led workshops, and use digital resource-sharing platforms (Eaker & Marzano, 2020a). Mentorship programs, peer learning, and research initiatives further strengthen the effectiveness of these communities. By fostering collaboration, innovation, and lifelong learning, PLCs ensure that TVET educators effectively prepare students for careers in a rapidly changing job market (DuFour & Reason, 2015). These communities bridge the gap between education and industry, strengthening workforce development and economic growth.

3.4.5 Challenges of PLCs in TVET

While PLCs in TVET offer numerous benefits, they also face challenges that can hinder their effectiveness. "One of the greatest challenges in becoming a highly effective and learning-progressive school is balancing knowledge and skills learning outcomes" (Stuart et al., 2018, p. 13). These challenges stem from industry dynamics, institutional structures, resource limitations, and educator engagement (Nundkumar, 2016). One of the main challenges is limited industry engagement (Mazhinye, 2018). While TVET relies heavily on industry partnerships, many businesses hesitate to collaborate due to time constraints, lack of incentives, or misalignment between educational programs and industry needs. "We have graduates from TVET colleges who do not adapt to industry because they are not skilled in business or the correct behaviour whilst on our property" (Mazhinye, 2018, p. 86). Establishing consistent and meaningful industry involvement requires considerable effort and relationship-building. Another common issue is resistance to change among educators (Fox & Poultney, 2020). Some instructors, especially those with long-standing teaching methods, may be reluctant to adopt new collaborative approaches or integrate emerging technologies. Overcoming this resistance requires strong leadership, professional development, and a culture encouraging innovation.

Time constraints also pose a significant challenge (Owen, 2014). Lecturers often have demanding workloads, including teaching, curriculum development, student mentoring, and administrative duties. Finding dedicated time for PLC meetings, discussions, and professional learning activities can be difficult, leading to inconsistent participation and engagement (Brodie & Borko, 2016). Another obstacle is insufficient funding and resources. Effective PLCs require access to modern technology, industry-standard equipment, and continuous professional development. Many institutions operate on tight budgets, limiting their ability to provide the necessary tools, training, and infrastructure for sustained collaboration and innovation (Maltitz & Lindsay, 2018). A lack of structured leadership and coordination can weaken PLCs (DuFour & Reason, 2015). Without clear roles, objectives, and accountability, these communities may struggle to maintain focus and productivity. Leadership gaps often result in unstructured meetings, inconsistent follow-ups, and minimal impact on teaching and learning (Eaker & Marzano, 2020a).

Fragmented communication and collaboration can also affect PLC success, especially in institutions with multiple departments or campuses (Winch, 2013). TVET programs often cover various technical disciplines, ensuring cohesive collaboration among instructors with diverse specialisations, and challenging (McGrath & Akoojee, 2009). The absence of digital platforms or centralised communication channels further complicates coordination. Another challenge is integrating new technologies into instruction (Akoojee, 2016). While technology is important in technical education, many instructors face barriers such as a lack of training, outdated equipment, or resistance to adopting digital tools. PLCs may struggle to explore and implement innovative teaching methods without proper support (Brodie & Borko, 2016). Inconsistent policy support and administrative backing can limit the sustainability of PLCs (Nundkumar, 2016). If school leaders and policymakers do not prioritise collaborative professional learning, PLCs may lack the institutional support for long-term success. Clear policies, dedicated funding, and structured time allocation are necessary for maintaining active and productive PLCs (Nundkumar, 2016).

Lastly, measuring the impact of PLCs on student learning and workforce readiness can be challenging (Stuart et al., 2018). While collaboration among educators is valuable, demonstrating its direct effect on student outcomes and employability requires systematic evaluation (Eaker & Marzano, 2020a). Institutions need reliable assessment tools and feedback mechanisms to track progress and refine PLC strategies (Bedwin, 2012). Despite these challenges, with strong leadership, industry collaboration, and institutional support, PLCs in TVET can overcome obstacles and become a driving force for improving teaching quality, industry alignment, and student success.

3.4.6 PLCs in Lesson Study

LS is a collaborative professional development approach where educators systematically plan, observe, and refine lessons to improve student learning (Lee, 2008). When integrated into Professional Learning Communities (PLCs), LS becomes a powerful tool for enhancing teaching effectiveness, fostering reflective practice, and promoting a culture of continuous improvement (Willems & Bossche, 2019). PLCs provide a structured environment for teachers to engage in LS by fostering collaboration, shared accountability, and data-driven decision-making (Shuilleabhain, 2013). Educators work together to analyse student learning, develop lesson plans, observe classroom instruction, and refine teaching strategies based on evidence and feedback (Eaker & Marzano, 2020a). Through this iterative process, PLCs help teachers move beyond isolated practice and engage in collective problem-solving. A benefit of integrating LS into PLCs is the focus on student-centred learning (Dunlosky et al., 2013). Rather than simply evaluating teacher performance, LS within PLCs emphasises how students interact with lesson content, identify learning challenges, and refine instructional methods to enhance student engagement and understanding (Mutch-Jones et al., 2012).

The LS process within a PLC typically follows several stages (Schipper et al., 2020; Vrikki, 2019). “LS involves a group of teachers in iterative cycles of lesson planning, teaching/ observation, evaluation and revision to enhance the quality of classroom learning” (Fox & Poultney, 2020, p. 65). It begins with identifying a specific learning goal based on curriculum requirements, student performance data, or observed difficulties in understanding a concept. The team then collaboratively plans a research-based lesson, incorporating best practices and innovative teaching strategies. One group member teaches the lesson while others observe student engagement and learning behaviours, capturing insights into how students interact with the material. After the observation, the PLC reconvenes to analyse findings, discuss student responses, and identify areas for improvement. The lesson is then refined and re-taught, with the cycle of observation, reflection, and adjustment continuing to ensure continuous instructional improvement. Integrating LS into PLCs is “evidence-based teacher collaboration and enquiry” (Fox & Poultney, 2020, p. 64). It helps educators refine their teaching practices through structured reflection and peer feedback while promoting a culture of teamwork and shared responsibility (Ono & Ferreira, 2010). LS also enhances student-centred learning by ensuring instructional methods are tailored to student needs and learning patterns. This approach provides a sustainable professional development model embedded in daily practice rather than relying on isolated training sessions (Shuilleabhain, 2013). Additionally, it encourages data-driven decision-making, using actual classroom observations to guide instructional improvements (Vrikki, 2019). By embedding LS within PLCs, schools create a continuous cycle of learning, reflection, and growth that strengthens teacher effectiveness and student achievement (Lewis et al., 2006). This model enhances teaching quality and fosters a collaborative school culture focused on lifelong learning and professional excellence (Abdella & Reddy, 2021).

3.4.7 Concluding Thoughts

This framework synthesises research on collaborative teacher inquiry, focusing on elements like examining beliefs, identifying problems, using research to drive innovation, understanding context and incremental thinking, and building supportive communities for inquiry, experimentation, and mutual support. While acknowledging the possibility of setbacks, it emphasises the importance of perseverance in teacher collaboration. The research highlights challenges in building community and supporting teacher inquiry, exploring the practical activities and the underlying principles driving these efforts. Effective professional learning communities (PLCs) foster leadership characterised by an outward focus, forward-thinking, openness to collaborative improvement, commitment to trust, and strong communication skills, including offering and seeking constructive feedback.

3.5 Integrating Cognitive Load Theory and Instructional Design Theories into Lesson Study

LS provides a structured framework for improving teaching strategies and student comprehension. When applied to the teaching of electrical wiring diagrams, integrating Cognitive Load Theory (CLT) with instructional design theories specific to diagrams and illustrations can enhance instructional effectiveness. Teaching technical subjects such as electrical wiring diagrams presents unique challenges due to the complexity and abstract nature of the content. Effective instructional strategies are necessary to ensure that learners can comprehend and apply this knowledge. CLT and instructional design theories specific to diagrams and illustrations offer valuable frameworks for improving the effectiveness of LS for teachers. These theories can be integrated to enhance LS, particularly in teaching electrical wiring diagrams.

Cognitive Load Theory, developed by Sweller (1988), posits that the human working memory has limited capacity and that instructional design should optimise its use to enhance learning. Intrinsic load is inherent to the material being learned, the extraneous load is imposed by how the material is presented, and germane load refers to the mental effort used to create schemas or mental models. Applying CLT principles alongside well-established instructional design theories for visual representations enables LS to foster a deeper understanding of electrical wiring diagrams, improving student learning outcomes. Given the complexity of wiring diagrams, the intrinsic load is high. Extraneous load can be minimised through effective instructional design, while germane load can be maximised to facilitate more profound understanding.

Instructional design theories specific to diagrams and illustrations, such as MLT (Mayer, 2005), provide guidelines for reducing extraneous load and enhancing germane load. Mayer's theory emphasises the importance of designing instructional materials that align with the cognitive architecture of learners. Important principles include the coherence principle (eliminating extraneous material), the signalling principle (highlighting important information), and the spatial contiguity principle (placing related information close together). These principles can be applied to electrical wiring diagrams to reduce cognitive load and improve comprehension. For example, the coherence principle suggests removing unnecessary details in wiring diagrams to focus attention on necessary components. The signalling principle can be applied using colour coding or labels highlighting connections and components. In contrast, the spatial contiguity principle can be implemented by placing labels and descriptions near the corresponding parts of the diagram.

Integrating dual-coding theory (Paivio, 2013) CLT provides a robust framework for designing practical electrical wiring diagrams. Dual-coding theory posits that information is processed through verbal and visual channels, and integrating these modalities enhances learning efficiency. Mayer's (2014) cognitive theory of multimedia learning aligns with this perspective, emphasising that well-designed diagrams should support textual explanations rather than compete with them. In LS, instructors should collaboratively refine their use of diagrams by ensuring that textual descriptions complement rather than overload visual representations. To enhance comprehension, the spatial contiguity principle should be applied to instructional materials (Mayer, 2014).

The expertise reversal effect, a concept within CLT, further informs the instructional design of wiring diagrams in LS. As learners gain proficiency, instructional strategies must adapt to prevent redundant information from imposing extraneous cognitive load (Tennyson, 2002). Novice learners benefit from explicit guidance, such as colour-coded wiring diagrams with step-by-step explanations. However, as students develop expertise, LS practitioners should transition toward problem-based learning approaches, encouraging students to analyse and interpret diagrams independently. By adjusting instructional methods based on student expertise, LS can ensure that cognitive resources are directed toward deep learning rather than unnecessary redundancy.

The modality effect, another important tenet of CLT, underscores the importance of presenting information through multiple sensory modalities to optimise learning (Leutner et al., 2009). When teaching electrical wiring diagrams, verbal explanations accompanying diagrammatic representations can reduce cognitive overload by distributing cognitive processing between auditory and visual channels (Sweller et al., 2019). LS practitioners should integrate narrated explanations of wiring diagrams into their instructional approach, particularly during initial learning phases, to facilitate cognitive processing. Empirical research has demonstrated that learners retain information more effectively when textual explanations are replaced with auditory narration while simultaneously processing visual representations (Mayer, 2009, 2014).

Cognitive apprenticeship theory further supports the effectiveness of LS in teaching electrical wiring diagrams (Collins et al., 1991). This theory emphasises modelling, scaffolding, and guided practice, aligning with LS's iterative approach to improving teaching strategies. Students can observe expert strategies before engaging in independent practice by incorporating worked examples, where instructors demonstrate problem-solving processes using annotated wiring diagrams. This approach aligns with CLT's worked example effect, which asserts that step-by-step guidance facilitates learning efficiency by reducing the extraneous cognitive load (Sweller et al., 2011). LS should incorporate collaborative refinement of worked examples, ensuring that instructional diagrams provide clear, sequential guidance.

Schema theory, which aligns with CLT, further informs the structuring of LS activities. As learners develop mental frameworks for interpreting wiring diagrams, instructional strategies should emphasise pattern recognition and the development of schematic knowledge (Anderson, 1990). LS practitioners can scaffold instruction by introducing simplified diagrams that gradually increase complexity. Instructional activities can facilitate the transition from novice to expert performance by progressively challenging students, reinforcing germane cognitive load and the cognitive effort directed toward schema construction and automation.

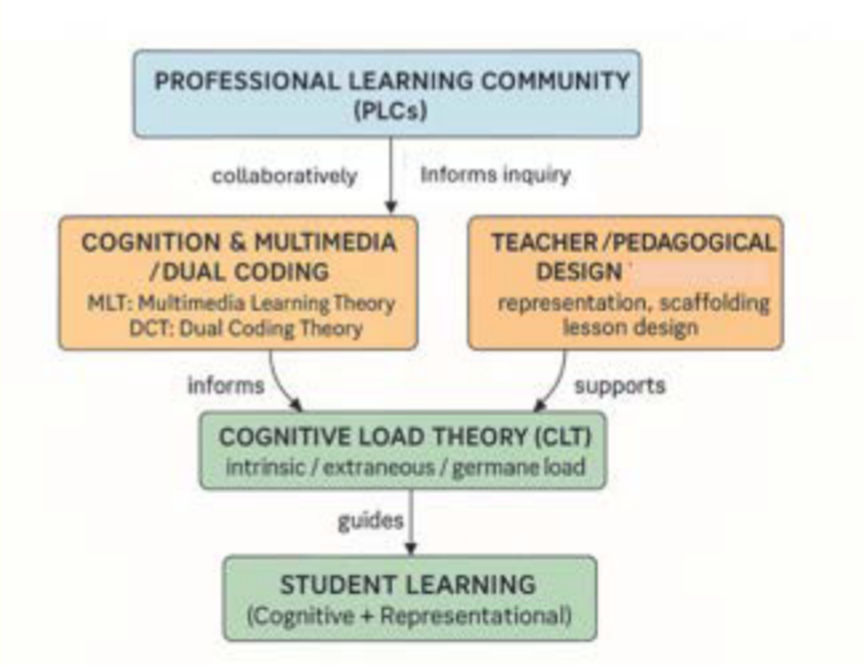
LS offers an iterative and collaborative framework for applying these theoretical principles in real-world teaching scenarios. Through cycles of planning, teaching, observing, and refining instructional strategies, educators can optimise the use of electrical wiring diagrams to align with cognitive load principles (Willems & Bossche, 2019). Peer observations and reflective discussions enable instructors to assess the effectiveness of diagrammatic representations and adjust instructional designs accordingly. By integrating CLT and instructional design theories specific to visual learning, LS can systematically enhance the teaching of electrical wiring diagrams, leading to improved student comprehension and retention. This integrated approach improves student learning outcomes and provides a structured teacher collaboration and professional development framework.

3.6 Conceptualising the Theoretical Relationships

The integration of Dual Coding Theory (DCT), Multimedia Learning Theory (MLT), Cognitive Load Theory (CLT), and Professional Learning Communities (PLCs) within this study requires explicit articulation of their interconnections and hierarchical positioning. These theoretical constructs operate at distinct analytical levels yet converge synergistically within the framework of Lesson Study. Understanding their complementarity and potential tensions is essential for establishing theoretical coherence and methodological rigour.

A conceptual model illustrating these relationships positions PLCs at the organisational and professional development level, providing the social infrastructure through which teachers engage in sustained, collaborative inquiry (DuFour et al., 2016). Within this professional learning structure, DCT, MLT, and CLT occupy the cognitive and instructional design level, informing how teachers construct and refine multimedia-enhanced lessons. DCT explains the fundamental cognitive architecture underlying dual-channel processing, proposing that verbal and non-verbal information are processed through separate yet interacting systems, thereby enhancing comprehension and retention when combined appropriately (Paivio, 2006). MLT extends these principles into design heuristics, offering evidence-based guidelines for integrating words and images whilst managing cognitive processing demands (Mayer, 2021). CLT serves as a critical mediating framework, interpreting DCT and MLT strategies through the lens of working memory constraints, ensuring that multimedia designs optimise rather than overload cognitive capacity (Sweller et al., 2011).

Figure 4 *Visual Model Showing the Theoretical Relationships*



This cognitive framework operates within the collaborative space afforded by PLCs, creating an iterative process where teachers collectively design lessons informed by DCT, MLT, and CLT principles; enact these designs in authentic classroom contexts; systematically observe student responses and learning outcomes; engage in critical reflection within the PLC; and subsequently redesign based on evidence and shared insights. Lesson Study functions as the procedural mechanism that scaffolds this cycle, providing a structured protocol for collaborative planning, observation, and refinement (Dudley, 2013). The PLC infrastructure ensures that these cycles are sustained over time, that knowledge is distributed across the community, and that innovations become institutionalised rather than remaining isolated experiments.

3.6.1 Complementarity and Theoretical Synergies

The integration of DCT, MLT, CLT, PLCs, and Lesson Study demonstrates strong complementarity. DCT and MLT guide the design of multimedia learning, explaining how dual-channel processing and principles such as spatial contiguity can reduce extraneous load and enhance germane processing (Plass et al., 2010; Mayer, 2021). These principles generate testable hypotheses, which can be explored through iterative Lesson Study cycles.

CLT acts as a safeguard preventing inappropriate application of dual-coding principles; poorly designed media can increase load through redundancy or split attention (Kalyuga & Singh, 2016). Teachers in PLCs use CLT during reflection to judge whether designs genuinely support learning, demonstrating how collaborative inquiry translates theory into situated pedagogical judgement.

PLCs provide the mechanism for teachers to co-design, test, and refine multimedia strategies, building shared repositories of practice aligned with sociocultural views of learning (Vescio et al., 2008; Wenger, 1998). The multimedia artefacts generated serve as boundary objects enabling shared interpretation (Star & Griesemer, 1989). The iterative processes inherent in PLCs and Lesson Study align with design-based research, enabling cumulative knowledge building (McKenney & Reeves, 2012).

3.6.2 Theoretical Tensions and Epistemological Challenges

Integration is challenging because DCT, MLT, and CLT operate at the micro-cognitive level, whereas PLCs function at the meso-social level (Stoll et al., 2006). Cognitive principles often originate from controlled environments (Mayer, 2021), yet classrooms are heterogeneous and socially complex, necessitating that teachers adapt design principles to local realities (Kirschner & van Merriënboer, 2013).

Epistemological tensions arise because cognitive theories rely on experimental evidence, whereas PLCs may prioritise experiential or intuitive knowledge (Horn & Little, 2010). Without an evidence-informed focus, PLCs risk privileging opinion over theoretically grounded practice. Furthermore, cognitive theories emphasise representation design but offer limited guidance on questioning, formative assessment, or relational pedagogy, which also strongly influence learning (Hattie & Zierer, 2019).

A bridging framework is therefore required. Sociocultural theory conceptualises learning as tool-mediated within social activity (Vygotsky, 1978; Wertsch, 1991), positioning DCT/MLT as informing tool design, while PLCs mediate their refinement. Design-based research complements this by supporting iterative refinement of theory-informed interventions in authentic contexts (Design-Based Research Collective, 2003).

3.6.3 Positioning Lesson Study

Lesson Study operates as a structured professional development methodology that translates cognitive design principles into collaborative practice (Lewis, 2002; Takahashi & McDougal, 2016). Teachers jointly identify challenges, design research lessons using DCT/MLT/CLT guidance, observe instruction, and refine designs based on student responses. Observation generates evidence about how learners process dual-coded materials, grounding theoretical predictions in practice (Dudley, 2013).

PLCs serve as the enabling environment for Lesson Study, providing shared purpose, time, and psychological safety needed for sustained inquiry (DuFour et al., 2016; Stoll et al., 2006). Lesson Study, in turn, offers PLCs a focused inquiry mechanism. Within this integrated structure, DCT, MLT, and CLT inform design hypotheses and evaluation criteria; PLCs support sustained collaborative engagement; and Lesson Study operationalises theory into classroom enactment through iterative reflection.

3.7 Conclusion

This conceptual framework incorporates several interconnected concepts. Paivio's DCT posits two interconnected verbal and non-verbal processing channels in the brain, emphasising the superior learning outcomes of engaging both (logogens and imagens) over single-channel processing. This aligns with multimedia learning principles, which recognise separate visual and verbal channels with limited capacity, requiring active cognitive processing in both. Effective multimedia learning involves selecting, organising, and integrating verbal and visual representations with prior knowledge, with information progressing through various stages of memory. Optimising this process requires strategic allocation of cognitive resources, minimising extraneous processing and maximising the generative process. Furthermore, a framework for collaborative teacher inquiry emphasises the importance of shared exploration, research-driven innovation, contextual understanding, and supportive communities. Such communities, often realised through PLCs, foster outward-focused, forward-thinking, collaborative, trust-building, and communication-rich communities, promoting continuous improvement through inquiry and feedback. The methodology chapter follows.

CHAPTER FOUR: RESEARCH METHODOLOGY AND DESIGN

4.1 Introduction

This study sought to understand how students learn electrical wiring diagrams using LS. Our rapidly changing, increasingly complex society places greater educational demands today as colleges prepare their students for a fast-changing future. What lecturers need to know and how they develop professionally have changed accordingly. “Lesson Study is a professional development activity characterised as classroom-situated, context-based, learner-focused, improvement-oriented and teacher-owned” (Ono & Ferreira, 2010, p. 64). LS will be used to determine if this model could help assist technical vocational education and training TVET lecturers in developing professionally to equip students better to learn to meet future challenges.

May (2011, as cited in Nundkumar, 2016, p.111) contends that “research is more than a reflection on our opinions and prejudices: it substantiates, refutes, organises or generates our thinking and produces evidence that may challenge not only our own beliefs but those of groups and societies in general”. This chapter discusses the methodological approach and research design adopted in this study. This methodology chapter furnishes the information necessary to replicate this study and explains how the research design structured the research. The chapter commences with an explanation of the methodological approach. Next, the critical paradigm and its suitability for this study are explained. This is followed by a discussion of the action research design, justifying the use of action research and explaining its strengths and weaknesses. This is followed by an outline of the research setting and the sampling strategy. Next, the data collection instruments, the data collection procedure, and data analysis are discussed. The chapter concludes by discussing trustworthiness issues, ethical considerations and limitations. The methodological approach, research design and methodological choices are justified and substantiated by relevant literature.

4.2 Methodological Approach

Cohen et al. (2007) defined methodology as the systematic procedures through which knowledge is identified, selected, processed, and analysed. This study employed a structured methodological approach to ensure reliability and validity while rigorously addressing the research questions and underlying problem (May, 2011; McLeod, 2019). Data were obtained through an action research project, providing empirical insights into introducing an innovative teaching strategy. This methodological framework was designed to offer clarity for future researchers seeking to replicate or adapt this study. Bertram (2008, p. 63) succinctly captures the essence of research methodology by questioning: "How can the inquirer go about finding out the nature of the reality?" This study adhered to that inquiry by detailing the ontological and epistemological foundations guiding the research process. The interrelationship between theoretical perspectives and methodological choices was examined (Garg, 2016; Akinyode, 2018). As Creswell and Creswell (2018) assert, theories define the characteristics of the social world under investigation, while methods serve as tools for generating, analysing, and interpreting data. These methodological choices were explicitly aligned with the study's research objectives and are further explored in Chapter Five. In addition to outlining the research design, this chapter delineates the research instruments, data collection procedures, and analytical techniques. Challenges encountered during the research process and the strategies implemented to mitigate them are also discussed (Garg, 2016; Hakim, 2012). This comprehensive approach ensures methodological rigour while reinforcing the study's contribution to educational research.

4.3 Philosophical Foundations of the Research Paradigm

A research paradigm provides a structured framework that shapes inquiry by guiding researchers' assumptions about reality, knowledge, and methodological choices. Kajee and

Balfour (2011) describe a paradigm as a "network of coherent ideas about the nature of the world and the functions of researchers that condition the patterns of their thinking and underpins their research actions"(Kajee & Balfour, 2011, p. 31). Similarly, Kuhn (1994) conceptualised a paradigm as a shared set of agreements and beliefs among scientists that inform how complex problems are understood and addressed. Moreover, Creswell (2014, p. 35) reinforced this perspective by describing a paradigm as "a basic set of beliefs that guide action." Bunniss and Kelly (2010, p. 360) further emphasise that paradigms are:

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

Weaver and Olson (2006, p. 460) argued that "all disciplinary research is conducted within paradigms," highlighting their fundamental role in shaping academic inquiry. Researchers operate within distinct paradigmatic frameworks, each characterised by differing ontological, epistemological, and methodological standpoints. Creswell (2014) identified important paradigms, including positivism, post-positivism, critical theory, constructivism, and participatory paradigms. This study adopted the critical paradigm, which challenges dominant power structures, promotes social justice, and advocates for transformative change. The critical paradigm aligns with the study's objectives by interrogating systemic issues and empowering participants through participatory engagement and reflective analysis. This approach ensured a nuanced understanding of the research problem while fostering meaningful contributions to educational discourse (Bunniss & Kelly, 2010; Creswell, 2014; Weaver & Olson, 2006)

4.3.1 Critical Paradigm

Meaningful social science research necessitates explicit articulation of the philosophical underpinnings guiding research outcomes. Researchers employ philosophical approaches to frame theoretical thinking, constructing a knowledge generation, analysis, and interpretation framework. This study, grounded in the critical paradigm, recognised the fundamental role of ontology, epistemology, and methodology in shaping research design and execution. While these concepts presented complexities, they established core attributes within the research philosophy, influencing the integration of research elements (Hammond, 2004).

Ontology, exploring the nature of social reality, examines what constitutes existence within the social world. Ontological frameworks represent shareable and valuable knowledge, forming the basis for coherent data. Epistemology addresses the researcher's relationship with the research and knowledge acquisition process. Ontological beliefs directly influence epistemological stances (Fleay, 2018). Critical theory's tension between realism and relativism centred on these epistemological and ontological questions. Realists, seeking objective truths, aimed to uncover underlying social structures, while relativists emphasised the contextual nature of knowledge and the influence of power and ideology (Al-Saadi, 2014; King & McInerney, 2019).

The ontology underpinning action research, aligned with relativism, posited that meaning and experience constituted reality. Understanding subjective experience requires dialogue and interaction (Buckley et al., 2014; King & McInerney, 2019). As a lecturer, the researcher's epistemological position acknowledged the multiplicity of truths within socio-economic power systems. The study's transformative teaching strategy aimed to emancipate students from learning challenges, aligning with the critical paradigm.

Cohen et al. (2007, p. 45) described critical educational research as "intensely practical [and]… transformative." Utilising Lesson Study, this study sought to empower students and drive change, addressing relevant social issues. Ledwith (2007, p. 597) defined critical practice as "any practice with a transformative social justice intention." As Mertens (2012, p. 804) argued, the transformative paradigm engaged with the complexities of diverse communities, focusing on social justice. The paradigm's focus is on marginalised experiences and social justice actions. Researchers should recognise prejudice and discrimination and understand communities to challenge the status quo and drive social change. This study promoted a transformative teaching strategy, engaging students from disadvantaged backgrounds (Cohen et al., 2007; Ledwith, 2007; Mertens, 2012).

Bertram and Christiansen (2014) highlighted the emancipatory purpose of the critical paradigm. Weaver and Olson (2006, p. 461) reiterated that "research becomes a means for taking action, emphasising the combination of reflection and action to effect transformation" Cohen et al. (2007, p. 47) identified "ideology critique and action research" as methodologies within the paradigm. As Koshy et al. (2011) asserted, critical theory underpinned action research, focusing on practitioner-driven change. Cohen et al. (2007, p. 26) argued that the paradigm "seeks to emancipate the disempowered," while Creswell (2014, p. 38) emphasised its action agenda for reform. This study, aiming for transformative and emancipatory outcomes, justified the selection of the critical paradigm for its action research design (Bertram & Christiansen, 2014; Creswell, 2014; Weaver & Olson, 2006).

4.4 Research Approach

This investigation employed action research as its methodological framework, designed to evaluate the efficacy of LS as a novel teaching strategy for enhancing students' abilities in reading, interpreting, and designing circuit diagrams. The research design used a qualitative approach, utilising open-ended semi-structured interviews and observational reflections. A summative task observation schedule was used for observational purposes only. Data collection and analysis adhered to rigorous procedures, aligning with the principles of qualitative design (Creswell, 2014).

This study collected and analysed qualitative data presented jointly within the data analysis chapter, which validated findings, establishing a robust foundation for the study's conclusions (Creswell, 2014; Mertens, 2012). The qualitative data elaborated and explained the findings, providing a deeper understanding of the observed phenomena. This sequential integration of data strengthens the overall validity and reliability of the research (Johnson & Christensen, 2014; Cohen et al., 2007).

Furthermore, the choice of action research, informed by its iterative and participatory nature, allowed for the continuous refinement of the LS teaching strategy based on real-time data and participant feedback. This dynamic approach enabled the researcher to actively engage with the research context, fostering a collaborative environment for pedagogical improvement (Kemmis & McTaggart, 1988). The qualitative approach, combined with action research, provided a comprehensive and nuanced understanding of the impact of LS on student learning. This allowed for a richer understanding of the research problem and the potential solutions.

4.4.1 Action Research

Mertens (2012) contends that a research study's outline, structure, or overall framework is described as the research design. Action research was the research design used in this study.

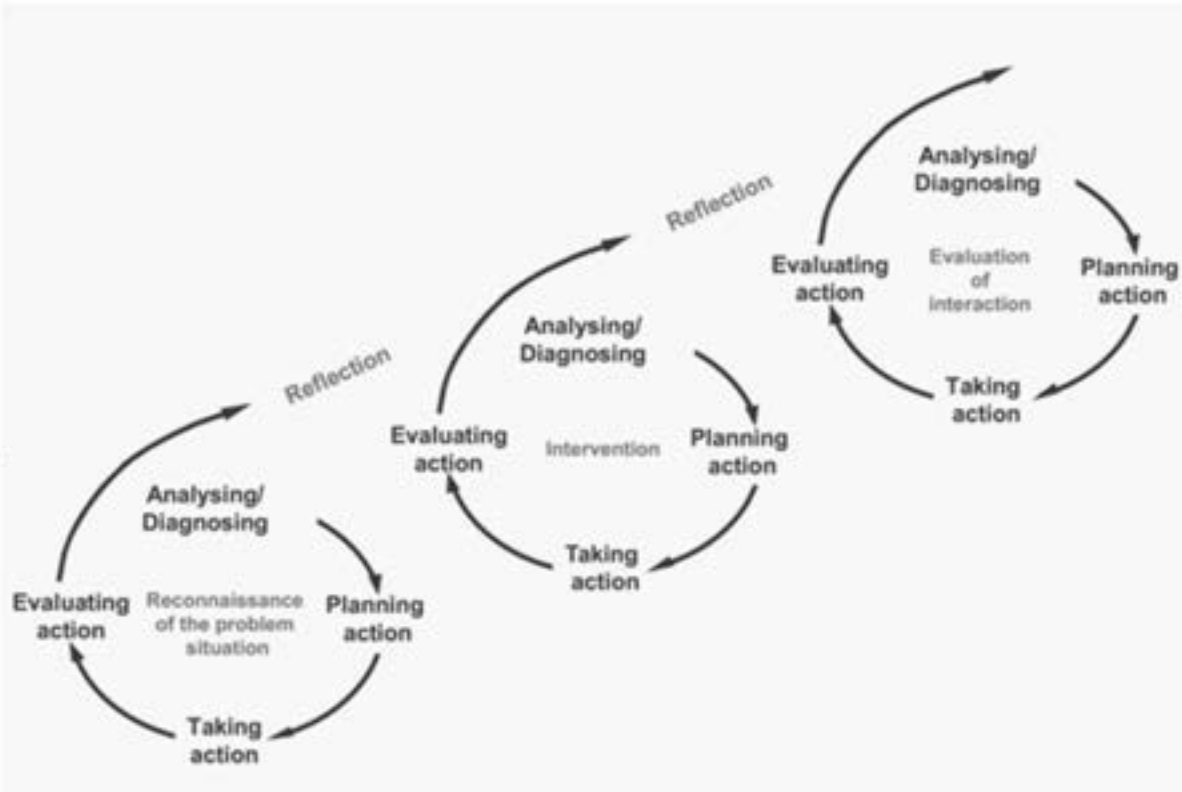
4.4.2 Defining Action Research

Action research, a dynamic and iterative inquiry process, empowered participants to systematically examine and refine their professional practices (Cohen et al., 2007). Coined by Kurt Lewin in 1944, action research described an inquiry process initiated by the need to resolve a specific problem (Schrueder, 1997). As Craig (2009) detailed, Lewin's framework involved a series of spiral steps, each constituting a cycle of planning, action, analysis, and reflection. The systematic nature of action research advocates for a more "rigorous approach to planning, acting, observing, and reflecting" than is typically employed in daily life (Cohen et al., 2007, p. 299). This spiral process was repeated until a satisfactory solution was achieved, although subsequent researchers expanded upon Lewin's model, proposing variations in the cyclic interplay between action and reflection (Coghlan & Brannick, 2014; Craig, 2009).

Coghlan and Brannick (2010) distinguished between action as intended implemental change and research as the enhanced understanding derived from the investigation. Creswell (2014) differentiated action research from routine teacher reflection, emphasising its collaborative and systematic nature, driven by a specific problem, question, or challenge. Data collection, reflection, and decision-making constituted the core components of this process. Action research can be initiated by passion, interest, or curiosity rather than solely by problem-solving. This practitioner-based approach, involving research within one's context, aims to improve strategies, practices, and knowledge. Altricher et al. (2005) highlighted self-reflection and identified resolving challenges as important elements.

Bertram and Christiansen (2014, p. 45) described action research as a "change-generating style" through "action and reflection" and emphasised its focus on professional practice improvement. Koshy et al. (2010) referenced the O'Leary model, which advocated for an empirical learning approach to drive continuous improvement. Elliott's model, like Kemmis and McTaggart's, involved a cyclical process of concern identification, fact-finding, planning, action, assessment, and revision. Collaborative inquiry, involving teams of colleagues, fostered genuine and sustained educational improvements (Koshy, 2005; Schreuder, 1997).

Figure 5 *The cycles of action research (Coghlan & Brannick, 2001, p.19).*



Unlike traditional research, which focuses on identifying literature gaps and contributing to general knowledge, action research addresses specific practical problems (Altricher et al., 2005). Craig (2009) emphasised the active involvement of participants throughout the research process, contrasting with the external and formal role of researchers in traditional studies. The intimate involvement of researchers and participants in action research democratises the research process and empowers participants to share their experiences. Koshy et al. (2010, p. 5) outlined the four core steps of action research: “Planning a change. Acting and observing the process and consequence, and then re-planning. Reflecting on these processes and consequences and then re-planning, acting, observing, reflecting, etc.” This study utilised Lewin's five-stage action research cycle, as Adelman (1993) outlined, encompassing problem identification, plan design, implementation, action-reflection, and learning capture.

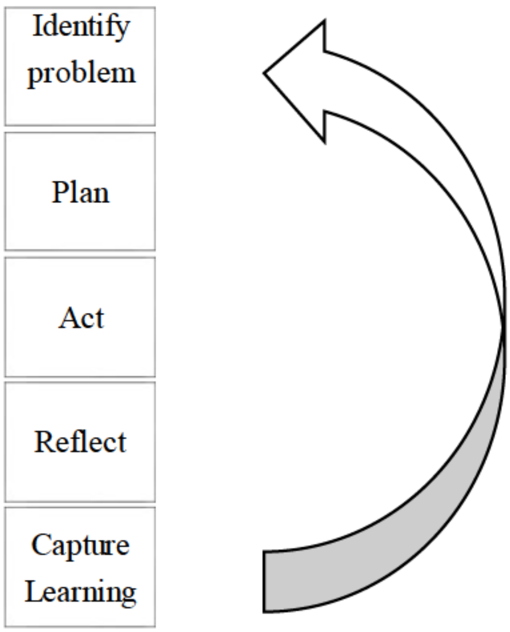
4.4.3 The Engagement Process of Integrating Action Research and Lesson Study

A productive starting point for action research involves recognising discomfort or misalignment in existing teaching practices (Altricher et al., 2005; Coghlan & Brannick, 2014; Cohen et al., 2007). Educators often develop ingrained routines that, over time, may contradict their instructional goals. Critical self-reflection identified and addressed these challenges. Cohen et al. (2007, p. 298) emphasise that "action research involves problem-posing, not just problem-solving," underscoring its role in fostering deeper inquiry rather than merely resolving surface-level issues. As the practitioner, I engaged in reflective analysis, examining my instructional methods and their impact on student learning. Koshy et al. (2010) argue that meaningful change requires an alternative course of action carefully aligned with pedagogical objectives. Unlike other research methodologies, AR is inherently transformative, prioritising iterative cycles of implementation and reflection (Koshy et al., 2010; Koshy, 2005; MacIntyre, 2000). Furthermore, Coghlan and Brannick (2010) assert that AR extends beyond mere analysis, carrying a strong moral imperative to enact positive change, particularly within educational and social justice contexts.

AR provided a structured problem-solving framework, complemented by a teacher-led, cyclical LS process that fostered sustained collaborative inquiry and professional development. This approach emphasised co-planning, observation, reflection, and iterative refinement of lessons (Fernandez & Yoshida, 2004). Unlike traditional lesson planning, it ensured that instructional strategies were continuously evaluated and improved through collective professional learning (Isoda & Olfos, 2021). The synergy between AR and this method strengthened pedagogical innovation by embedding a systematic, evidence-based approach into teaching practice, enhancing teacher effectiveness and student outcomes.

The AR process is traditionally framed as a four-stage cycle, but for this study, Lewin's (1946) five-stage model was adopted, as explained by Adelman (1993). The additional fifth stage, which focuses on capturing learning, was instrumental in creating a sustainable mechanism for ongoing improvement. Babaci-Wilhite (2017) highlights that systematically documenting learning outcomes allows for tracking progress, evaluating instructional effectiveness, and refining pedagogical strategies in alignment with student learning goals. This structured approach ensured that assessments and outcomes were accurately recorded, analysed, and reported promptly and methodically (Adelman, 1993; Babaci-Wilhite, 2017). Integrating LS with AR established a robust framework for teacher-driven educational reform, fostering a culture of continuous reflection, collaborative learning, and evidence-based decision-making. The combination of these two methodologies provided a sustainable and dynamic approach to professional development, ensuring that instructional practices remained responsive, adaptive, and impactful.

Figure 6 *An adaptation of Lewin's five-stage cycle of action research (1946, as cited in Adelman, 1993)*



4.4.3.1 Step One: Identifying the Problem and Establishing the Research Focus.

The initial reconnaissance phase of this study identified an instructional gap—most TVET Report 191 students struggled to read, interpret, and design electrical schematics effectively. This deficiency highlighted a fundamental issue in technical education, necessitating an evidence-based, iterative approach to improving student learning outcomes. Craig (2009) argues that AR originates from three perspectives: proactive problem-solving, reactive response to challenges, and innovative solution development. This study adopted a proactive and innovative stance, seeking to develop an effective pedagogical intervention to address students' difficulties in electrical schematic interpretation. MacIntyre (2000) emphasises that a structured design strategy must accompany problem identification, ensuring the approach aligns with the issue's complexity. Not all challenges suit AR; simple, easily identifiable problems do not necessitate this approach. AR most effectively addresses ‘wicked problems’, which are persistent, complex, and multifaceted (Sherman, 2016). These challenges do not have straightforward solutions, as they stem from multiple interdependent factors and require an iterative process of reflection and refinement.

LS complemented this AR phase by fostering a collaborative, teacher-driven approach to problem identification. While AR centred on diagnosing and resolving the pedagogical challenge, LS enriched this process through systematic, collective inquiry. The first LS step identified the research focus and mirrored the problem-identification stage in AR. This involved collaboratively analysing student learning needs, instructional barriers, and pedagogical inefficiencies (Isoda & Olfos, 2021). Through LS's structured collaboration, I engaged with colleagues to examine students' schematic literacy gaps, drawing on classroom observations, assessment data, and reflective discussions. Muijs (2006) suggests that assessment practices must differentiate between proper conceptual understanding and rote memorisation. In alignment with this perspective, I investigated whether students merely memorised large amounts of information or actively constructed knowledge (Muijs, 2006; Ramnarain & Ramaila, 2012; Willis, 2007). Drawing from AR and LS, this integrated approach ensured that problem identification was not just an individual reflection but a collaborative, evidence-based process leading to meaningful pedagogical transformation.

4.4.3.2 Step Two: Designing the Action Plan Through Collaborative Inquiry. Effective instructional transformation requires a well-structured and research-informed plan. Craig (2009) defines an action plan as “a framework or blueprint implemented to improve practice” (p. 4). This study aimed to enhance students’ ability to read, interpret, and design electrical schematics by introducing a new teaching strategy. This phase involved developing and refining the instructional approach in collaboration with fellow lecturers, ensuring that the proposed interventions were practical and theoretically sound. Following Coghlan and Brannick’s (2010) recommendations, the plan outlined clear objectives, strategies, and step-by-step actions to achieve the research goals. Reframing the problem broadened perspectives. Euchner (2019) emphasises that rewording and repositioning a problem often reveal deeper insights and alternative solutions. This approach enabled the research team to consider multiple viewpoints, including those of students, educators, and industry professionals. An industrial perspective was particularly valuable, ensuring the revised teaching methods aligned with real-world electrical engineering applications (Acosta, 2006; Euchner, 2019).

Acosta (2006) argues that examining a problem through diverse lenses—including career relevance, social justice, and economic implications—enriches decision-making. To foster a more inclusive and holistic approach, we explored the issue from multiple occupational standpoints, asking: How would an engineer approach this challenge? How would a schoolteacher explain these concepts differently? What barriers would a student or migrant worker face in understanding electrical schematics? LS complemented AR at this stage by emphasising collaborative lesson planning. The second step of LS, planning the research lesson, aligned closely with designing the action plan in AR. In this study, lecturers co-designed a lesson that addressed students' schematic literacy gaps. Drawing on evidence from prior assessments and industry needs, we structured a lesson plan incorporating Student-centred learning techniques to promote conceptual understanding. Problem-based learning activities to mirror real-world electrical challenges. Assessment tools to measure students' ability to apply schematic knowledge.

By integrating LS's structured, collaborative planning process, this phase ensured that theoretical insights and practical classroom needs informed instructional decisions. The synergy between AR and LS allowed for iterative lesson design, where initial plans could be refined based on feedback and evidence from classroom implementation.

4.4.3.3 Step Three: Implementing the Plan Through Collaborative Action. The third step focused on executing the action plan and integrating AR and LS methodologies. Coghlan and Brannick (2010) assert that action is the core of AR, as goals without action are ineffective. Similarly, implementation is important to test and refine instructional strategies in LS. The plan was systematically executed with a collaborative team of educators. Craig (2009) identifies three important components of this phase. First, the LS team actively monitored progress, tracking changes in student performance to determine whether improvements or setbacks occurred. This aligned with the structured observation process of LS, where educators analyse student engagement and learning outcomes. Second, data were systematically collected through classroom observations, summative assessments, and student feedback. Third, reflections on the implemented strategies were meticulously documented in a research journal, ensuring a comprehensive record of insights and areas for refinement.

The iterative nature of LS reinforced the AR cycle, allowing educators to analyse the effectiveness of instructional adjustments in real-time. This dynamic process fostered professional growth and pedagogical refinement, ensuring the intervention was evidence-based and responsive to student needs.

4.4.3.4 Step Four: Critical Reflection and Collaborative Analysis. Step Four involved a systematic and collaborative reflection on the implemented actions, integrating the reflective phase of AR and the evaluation phase of LS. Jugoo (2014) described reflection as an analytical, critical, and evaluative process. As an educator committed to continuous improvement, I critically examined all aspects of the intervention to understand the root causes of students' challenges (Craig, 2009).

The iterative interaction between action and reflection compels solutions to emerge. Similarly, Beer et al. (1990) defined reflection as "a process of entering dialogue based on the data collected and guided by a systemic framework to discover the root causes of the problem" (p. 1). This phase required deep data engagement to assess the effectiveness of the intervention. Reflection, in this sense, was not a passive process but an active inquiry into teaching and learning practices. The research team collaboratively analysed student learning outcomes, classroom observations, and assessment results as part of LS. The focus was on identifying discrepancies between expected and actual learning outcomes by addressing important reflective questions: What did we anticipate happening? What happened? Why did these differences occur? This reflective dialogue allowed a deeper understanding of instructional effectiveness and student engagement (Craig, 2009).

Outcomes often diverged from initial expectations. In some cases, challenges persisted, or new issues emerged, reinforcing the necessity of iterative refinement. Reflection helped document these findings. A reflective journal was maintained throughout the process to systematically capture emerging themes, instructional adjustments, and areas for future improvement. This step ensured that findings from both AR and LS informed subsequent refinements, reinforcing a culture of evidence-based teaching and professional growth.

4.4.3.5 Reflective Journal. Cohen et al. (2007, p.310) assert that reflection encompasses "reflection-in-action, reflection-on-action, and critical reflection," permeating every stage of action research. This iterative reflective process enabled an ongoing analysis of whether knowledge construction aligned with initial intentions (Koshy et al., 2010; Cohen et al., 2007). The data generated from these reflections were scrutinised to determine if the research problem had been adequately addressed. Creswell (2014) argued that unsuccessful or partially successful actions necessitated revisions and re-implementation, forming a cyclical process until the initial goals were achieved. A reflective journal is a structured repository for "thinking about various concepts, events, or interactions over time to gain insights into self-awareness and learning" (O'Connell & Dyment, 2011, p. 47). This study employed reflective journaling to document the progression of both AR and LS. It provided a space to capture teaching and learning experiences, observational insights, situational responses, and cognitive reasoning. Dreyer (2015) corroborated the journal's role in identifying important professional development events, a view supported by multiple scholars who recognise its contribution to effective pedagogy (Agustin, 2019; Dreyer, 2015; Dunlap, 2006; Hubbs & Brand, 2005; O'Connell & Dyment, 2011).

In the context of AR, the reflective journal served as an analytical tool for recording and assessing pedagogical interventions. As a semi-participant observer, the researcher documented observations from the study's theoretical and practical components. The iterative nature of the journal enabled real-time adaptations, ensuring that teaching strategies evolved in response to students' learning needs. Similarly, in the LS framework, the journal captured collaborative discussions, lesson observations, and post-lesson reflections from the LS team. These records provided empirical evidence of students' ability to comprehend and apply schematic designs, thereby guiding refinements in instructional strategies.

Dunlap (2006) highlighted the journal's role in facilitating formative and summative feedback, benefiting both students and educators. The researcher utilised this feedback to refine lesson delivery and instructional methods, addressing identified gaps in student comprehension and application skills (Cohen et al., 2007). Furthermore, the reflective journal was a professional development tool, fostering deeper engagement with teaching methodologies and enhanced administrative documentation and career trajectory reflection. However, effective journal utilisation necessitates adequate training and workshop participation, as many educators encountered difficulties initiating the reflective writing process (Dunlap, 2006). Additionally, O'Connell and Dyment (2011) cautioned that writing with an external audience in mind raised ethical concerns, including the potential for coercion and compromised personal disclosure. This underscores the necessity of maintaining the journal as a personal reflective tool rather than a performative exercise for external validation. By integrating reflective journaling within AR and LS, this study demonstrated its efficacy in capturing and analysing pedagogical transformations. The journal provided a structured and evidence-based approach to continuous professional development, fostering a culture of introspection and iterative improvement, ultimately enhancing student learning outcomes.

4.4.3.6 Step Five: Capturing the learning. Step Five focused on capturing and institutionalising learning to ensure the sustainability of improvements achieved through AR and LS. Schrueder (1997) argued that knowledge often fails to cascade effectively within organisations, resulting in important insights lost when individuals leave or teams disband. To prevent this, Schuiling and Vermaak (2017) emphasised the necessity of systematically capturing and embedding learning into institutional practice. Failure to do so leads to the recurrence of problems, undermining the effectiveness of intervention efforts. This study systematically generated, recorded, and analysed data to evaluate assessments, track progress, and accurately report findings. This documentation process ensured that learning was captured and accessible for future applications. The reflective phase of LS facilitated collaborative discussions among educators, allowing them to consolidate findings and refine teaching strategies. The study contributed to a structured knowledge base that could inform ongoing pedagogical development by recording observations, student responses, instructional adjustments, and outcomes.

Koshy (2005), Kemmis (2006), and Jugoo (2014) assert that the AR cycle—problem identification, design, action, reflection, and learning capture—must be continuously repeated to reinforce improvements and deepen understanding. While problem-solving remains a primary objective of AR, its actual impact is realised when learning is institutionalised. Educators risk repeating the same issues without systematically capturing insights rather than progressing toward sustained educational transformation. This study reinforced the importance of documenting the entire research process, ensuring that innovations and best practices were preserved for future refinement and broader implementation.

4.4.4 Strengths of Action Research

AR empowers researchers to comprehensively understand problems by pursuing improvement and change (Coghlan & Brannick, 2010). It facilitated the professionalisation of teaching by fostering systematic and reflective data collection on pedagogy, driving continuous growth (Cohen et al., 2007). Through its iterative design, lessons were empirically investigated, with each day's findings informing subsequent instruction (Creswell, 2014). This approach enabled reflective practitioners to enhance their practice and facilitate student achievement of learning objectives (Coghlan & Brannick, 2010; Bertram & Christiansen, 2014; Altrichter et al., 1993). AR fostered a culture of professionalism, promoting collaborative inquiry and shared vision among educators (Cohen et al., 2007). It enabled teachers to engage in independent research agendas, share findings, and transform into learning communities (Dunn et al., 2003). Dialoguing about classroom issues led to informed professional decisions (Koshy et al., 2010; Craig, 2009). Collaborative practice studies enhanced program development and institutional excellence. When educators collectively chose research topics, team building and progress on learning program improvements became shared goals (Craig, 2009; Elliot, 1991).

Action research promoted a systematic approach to professional practice, enhancing teacher motivation and efficacy (Creswell, 2014). It facilitated reflective problem identification, plan design, implementation, and learning capture (Kemmis, 2006; Jugoo, 2014). In response to the increasing demands of teaching, action research enabled educators to evaluate their practices, integrate diverse teaching styles, and assess the effectiveness of teaching and learning (Cohen et al., 2007). Integrating data into their work provided teachers with evidence of their impact, fostering a sense of empowerment (Koshy et al., 2010). Self-efficacy was balanced against student understanding and teacher knowledge of instructional strategies (Ledwith, 2007; Macintyre, 2000). Action research investigated teaching practices and promoted knowledge construction by implementing new teaching methods (McKernan, 2013). Student participation in knowledge construction through alternative teaching strategies empowered educators (Craig, 2009). Developing a holistic understanding of situations enhanced student comprehension of interrelated designs (Mor et al., 2014). Cognitive skills progressed from knowledge acquisition to application, analysis, and evaluation (Barnett & Ceci, 2002). This method moves the teacher from a consumer to a producer of knowledge.

4.4.5 Weaknesses of Action Research

As Williams and May (1996) alleged, critics questioned the scientific rigour of action research, deeming it outside mainstream research traditions. AR’s context-specific nature limited generalisability, acknowledging its validity in representing the researcher's context and the implemented changes (Williams & May, 1996). Ledwith (2007) further critiqued its narrow focus and perceived weak research design. These criticisms, however, were countered by several compelling arguments. Firstly, a substantial body of peer-reviewed literature supported action research in education (Creswell, 2014; Kemmis et al., 2014; Koshy, 2005; Schuiling & Vermaak, 2017). Wadsworth (1998) emphasised its role in facilitating teacher reflection and practice improvement. Koshy (2005, p. 3) asserted, “Research is about generating new knowledge.”

AR creates new knowledge based on enquiries within specific and often practical contexts. This highlighted the inherent value of context-specific knowledge generation. Secondly, the perceived lack of generalisability, while a valid point, did not invalidate action research's contribution to knowledge. The in-depth understanding of a specific context and the detailed documentation of implemented changes provided valuable insights for other practitioners facing similar challenges. The focus shifts from generalizability to transferability, where other researchers can see how the process was undertaken and then apply relevant components to their context. Thirdly, the critique of narrow focus and weak design often stemmed from a misunderstanding of the purpose of AR. It was not intended to replicate large-scale experimental studies but to address specific, localised problems through iterative cycles of action and reflection. The design's flexibility allowed for adaptation to the unique needs of each context, fostering a dynamic and responsive approach to research. Finally, the claim that AR is not scientific is refuted by the systematic nature of the process itself. The iterative cycles of planning, action, observation, and reflection, coupled with rigorous data collection and analysis, aligned with the core principles of scientific inquiry. The focus on evidence-based practice and continuous improvement further solidified its scientific legitimacy. AR is not about generating universal rules but valuable local knowledge for practitioners.

4.5 Research Questions

The following research questions guided this study:

1. How does the implementation of lesson study influence the teaching and learning of electrical wiring diagrams in a South African TVET college?
2. How can cognitive load theory and instructional design theories specific to diagrams and illustrations be integrated to improve the effectiveness of lesson study for teaching electrical wiring diagrams?
3. How do learners perceive and respond to electrical wiring diagrams that employ principles of dual coding theory and multimedia elements?

4.6 Research Setting

This research was conducted at a TVET College in Pietermaritzburg, Kwa-Zulu Natal, South Africa. The institution provides programs up to diploma level, encompassing engineering and general studies aligned with the National Qualifications Framework (NQF) Levels 2 to 4. Delivery modes are part-time, distance learning, and full-time classes. TVET colleges, recognised as pivotal post-school education and training providers, held strategic importance within South Africa's developmental agenda. Nundkumar (2016) highlighted their role in catering to secondary school graduates and those seeking to achieve Grade 12 through vocational pathways. Through the Department of Higher Education and Training (DHET), these colleges delivered skills and expertise to commerce, industry, and the nation.

Prior to 2002, South Africa maintained 152 Technical Colleges. These institutions were subsequently consolidated into 50 multidisciplinary entities designated as Further Education and Training (FET) Colleges. In 2014, they were redesignated as Technical and Vocational Education and Training (TVET) Colleges, a nomenclature that accurately reflected their institutional character. The TVET construct comprised 50 colleges operating across 260 campuses.

4.7 Sampling Strategies

The strategic selection of participants, a sampling process, defines the scope and representativeness of research findings (Creswell, 2014). Nundkumar (2016, p. 15) defined the "target population" as "the complete collection of cases from which a sample is extracted." This study implemented a dual sampling strategy, employing convenience and purposive sampling, to ensure comprehensive data acquisition. Convenience sampling, a non-probability approach (Cohen et al., 2007), was utilised to initially access the Report 191 N4 electrical students and the lecturer cohort. The accessibility, availability, and willingness of the 34 students, two senior lecturers, the Head of Division (HOD), and three lecturers facilitated data collection. While convenience sampling offered logistical advantages, its inherent limitations, namely the potential for bias and lack of population representativeness, were acknowledged (Creswell, 2014; Dunn et al., 2003; Cohen et al., 2007). Multiple data collection approaches were employed for triangulation and validation to mitigate these limitations.

Purposive sampling, a deliberate selection strategy, was utilised to refine participant selection. Lecturers whose syllabi included electrical or circuit diagrams were explicitly targeted. Additionally, two senior lecturers and the HOD, with extensive experience teaching electrical wiring and circuit diagrams, were included. The Report 191 N4 electrical students were purposively chosen over N5 or N6 students to assess the impact of new teaching and learning strategies at foundational levels and to evaluate the transferability of these strategies to more complex electrical schematics. As Creswell (2014) and Cohen et al. (2007) asserted, purposive sampling did not require a specific number of participants; instead, it focused on obtaining in-depth insights relevant to the research questions. Mertens (2007) further argued that purposive sampling aligned with the critical paradigm, enabling the researcher to glean nuanced perspectives for emancipatory purposes. The purposive sample comprised 34 N4 students, with a mean age of 19 years, predominantly from lower or middle-class backgrounds, residing in townships. Ngubane (2013, p. 8) defined townships as "often-underdeveloped urban living areas that, from the late 19th century until the end of apartheid, were reserved for non-whites (Africans, Coloureds and Indians)." Nongxa (2010) highlighted the prevalence of deprived educational institutions in these areas. Socioeconomic challenges impacted students' academic performance, including inadequate school facilities, long travel distances, and language barriers (Ngubane, 2013; Nongxa, 2010; Ramnarain & Ramaila, 2012; Zungu, 2016). As noted by Ngubane (2013), the educational disparity persisted, with high-levy schools providing superior academic outcomes to those serving impoverished communities. This research, therefore, was conducted within a context of significant socio-economic and educational challenges, informing the interpretation of findings and the development of pedagogical interventions.

Rationale for Sample Selection

The sample for this study comprised 34 students (with 26 completing all phases) from a single N4 Electrotechnics class and seven lecturers (four lecturers, two senior lecturers, and one Head of Department) from a South African TVET college. This sample size aligns with established principles for qualitative action research, where the emphasis lies on depth of inquiry rather than statistical generalisation (Vasileiou et al., 2018). In qualitative investigations, sample sizes typically range between 20 and 30 participants for studies employing thematic analysis, with adequacy determined by achieving data saturation—the point at which no new themes or insights emerge from additional data collection (Hennink & Kaiser, 2022; Wutich et al., 2024). The student sample of 26–34 participants provided sufficient depth to explore variations in learning experiences whilst remaining manageable for the intensive, iterative cycles characteristic of action research. Research demonstrates that thematic saturati on in educational studies frequently occurs within 9–17 interviews or focus group participants, with 20–30 participants considered robust for comprehensive thematic development (Vasileiou et al., 2018; Hennink & Kaiser, 2022). The inclusion of seven lecturers representing diverse levels of seniority ensured multiple perspectives on pedagogical practices, collaborative lesson planning, and instructional refinement. This multi-level sampling strategy enriched the study's capacity to examine both student learning outcomes and lecturer professional development within the lesson study framework.

Convenience sampling was employed due to the action research design, which necessitated sustained engagement, iterative cycles of planning and reflection, and collaborative participation over an extended period (Emerson, 2021). The researcher's position as a lecturer within the institution facilitated access to participants and enabled the deep contextual understanding essential for action research. Whilst convenience sampling limits statistical generalisation, it is methodologically appropriate for exploratory, context-specific investigations aimed at improving practice within particular settings (Emerson, 2021). As Stringer (2014) emphasises, action research prioritises local relevance and practical applicability over broad generalisability, making convenience sampling not only pragmatic but theoretically justified.

Justification for Single-Site Study Design

This study adopted a single-site design, focusing exclusively on one South African TVET college. Single-site studies are particularly well-suited to action research, which emphasises context-specific problem-solving, iterative refinement of practice, and deep engagement with localised educational challenges (Stringer, 2014; Yin, 2018). The bounded nature of the single case allowed for an intensive examination of the lesson study intervention within its authentic institutional, cultural, and pedagogical context—an approach that would have been diluted through a multi-site comparison.

Single-case designs offer distinct methodological advantages when investigating complex educational processes. They facilitate rich, holistic accounts of phenomena, enable detailed tracking of change over time, and support in-depth analysis of the contextual factors that influence outcomes (Yin, 2018). As Gustafsson (2017) argues, single-case studies are particularly valuable when the research aim is to illuminate intricate processes within bounded systems rather than to establish statistical generalisations across heterogeneous contexts. In this study, the focus on a single TVET college enabled sustained collaboration among lecturers, systematic observation of iterative lesson cycles, and nuanced exploration of how lesson study influenced both teaching practices and students' comprehension of electrical schematics.

Furthermore, the South African TVET context presents unique challenges, including resource constraints, varied student preparedness, and the imperative to align vocational training with industry demands. Concentrating on a single site enabled the research to address these contextual specificities with rigour and sensitivity. The findings contribute to the theoretical understanding of lesson study's applicability in under-researched TVET settings whilst offering actionable insights for similar institutions facing comparable challenges. Yin (2018) notes that single-case studies possess significant transferability when they provide thick description and clear articulation of contextual factors, allowing readers to assess relevance to their own settings. This study's detailed documentation of the lesson study implementation process, alongside transparent reporting of contextual conditions, supports such analytical generalisation.

Table 1 *Data Generation Framework.*

Research Phase	**Data Collection Instruments**	**Data Sources**	**Analysis Methods**
Pre-intervention	• Diagnostic assessment • Pre-intervention questionnaire • Initial focus group discussions	• 34 N4 Electrotechnics students (Report 191)	• Descriptive statistics • Thematic analysis of qualitative responses • Baseline competency mapping

Research Phase	Data Collection Instruments	Data Sources	Analysis Methods
		• 7 staff (4 lecturers, two senior lecturers, 1 HOD)	
Lesson Study Cycle 1 - Planning	• Collaborative lesson planning sessions • Researcher reflective journal • Planning documentation	• Lesson study team (lecturers) • Researcher observations • Planning meeting recordings	• Content analysis of planning discussions • Thematic analysis • Reflexive self-study analysis
Lesson Study Cycle 1 - Implementation & Observation	• Structured observation schedules • Video recordings of lessons • Student work samples • Researcher reflective journal	• 34 N4 Electrotechnics students • Teaching lecturer • Observing lecturers • Classroom interactions	• Structured observation analysis • Student work analysis • Thematic analysis of field notes • Reflexive analysis
Lesson Study Cycle 1 - Reflection & Evaluation	• Post-lesson reflection interviews • Focus group discussions • Researcher reflective journal • Student feedback questionnaires	• 7 lecturers • 26 students (final sample) • Researcher reflections	• Thematic analysis • Comparative analysis • Reflexive self-study analysis • Triangulation of data sources
Lesson Study Cycle 2 - Refinement & Re-implementation	• Revised lesson plans • Structured observation schedules • Student assessment tasks • Researcher reflective journal	• 26 N4 Electrotechnics students • Lesson study team • Student work samples	• Comparative analysis (Cycle 1 vs Cycle 2) • Student performance analysis • Thematic analysis • Pattern recognition analysis
Post-intervention Evaluation	• Post-intervention questionnaires (Likert scale) • Summative assessments • Semi-structured interviews • Final focus group discussions	• 26 students • 7 lecturers • Assessment results	• Descriptive statistics • Pre-post comparison analysis • Thematic analysis • Triangulation of findings
Synthesis & Member Checking	• Member checking interviews • Researcher reflective journal • Validation discussions	• Selected student participants • Lecturer participants • Research findings	• Credibility verification • Reflexive self-study analysis • Final thematic synthesis • Cross-case analysis

4.8 Data Collection Instruments

The research questions were addressed through robust evidence to derive the conclusive findings, informed decisions, and valid inferences, necessitating meticulous data collection (Creswell, 2014). As Koshy et al. (2010) emphasised, a comprehensive research methodology must detail the data collection methods. Diverse data-gathering techniques, including interviews, questionnaires, focus group discussions, surveys, observations, cohorts, and control trials, served to test hypotheses and elucidate phenomena (Dunn et al., 2003; Garg, 2016). Qualitative research, focusing on the 'who, what, how, when, and why,' aimed to understand the nature of phenomena (Creswell, 2014), while quantitative research quantified the magnitude of occurrences or associations.

Five distinct data generation tools were implemented in this research: lecturer-focused group discussions, questionnaires, structured observations, a self-reflective diary, and individual interviews. The interviews, comprising open-ended, reflective questions, generated qualitative data that corroborated the structured observations and diary entries. These five instruments collectively facilitated data triangulation, enhancing the credibility and validity of the findings. As Koshy et al. (2010) suggested, combining data from these diverse sources enabled the conceptualisation of robust themes, providing a comprehensive and nuanced understanding of the research phenomenon. This orchestrated approach to data collection ensured a rigorous and multifaceted exploration of the research questions.

4.8.1 Focus-Group Discussions

Focus groups, deliberately structured settings, convened a specific population segment to engage in thematic discourse, generating data through group interaction. While a potential limitation, their contrived nature proved advantageous in eliciting focused insights unattainable through individual interviews (Cohen et al., 2007). Bertram and Christiansen (2014) highlighted the efficiency of focus group discussions in generating substantial qualitative data, albeit less than that derived from individual interviews. Following Creswell's (2014) methodology, participants were strategically selected and facilitated to engage in dialogue concerning research aspects. As Cohen et al. (2007) noted, six lecturers who participated in these discussions provided an invaluable exploratory platform for capturing diverse feelings, emotions, and viewpoints through group interaction. Cohen et al. (2007, p. 376) characterised focus group discussions as a form of group interview, emphasising "interaction within the group who discuss a topic supplied by the researcher, yielding a collective rather than an individual one view."

The opinions, perceptions, and experiences revealed through these discussions were meticulously documented. The dialogues yielded detailed knowledge and insights, facilitating uninhibited participant expression. The 28 open-ended questions (Appendix E) were designed to elicit richness, sincerity, honesty, authenticity, and depth while accommodating diverse responses (Mertens, 2012; Newsome, 2016). The focus group discussions, lasting approximately two hours, produced data that, while not readily generalisable, provided valuable context-specific insights. The potential for overt participant influence and researcher bias, as cautioned by Creswell (2014), was acknowledged.

To ensure participant anonymity and confidentiality, pseudonyms were assigned. Evaluations, feedback, questions, and responses were recorded in the reflective journal. The focus group discussions directly addressed the research questions, proving to be a cost-effective and easily facilitated method for generating qualitative data (Creswell, 2014; Mertens, 2010). The interactive nature of the discussions enabled the researcher to probe for clarity, ensuring a comprehensive understanding of participant perspectives.

4.8.2 Questionnaires

The questionnaire served as a structured instrument for data collection, consisting of various questions or prompts to elicit specific responses (Bakker et al., 2014; Creswell, 2014). Cohen et al. (2007, p. 317) described it as "a widely used and valuable tool for gathering information, offering structured, numerical data, operating independently of the researcher, and being relatively simple to analyse." In this study, questionnaires were employed to collect qualitative data. Closed-ended questionnaires were clear and unambiguous, requiring minimal guidance (Mertens, 2010). These questionnaires were straightforward for participants to complete, and their results were quickly interpretable, measurable, and suitable for statistical coding. On the other hand, Pell (2005) advocated for incorporating open-ended questions due to their ability to provide greater depth, expose participants' thought processes, and deliver nuanced qualitative insights, albeit demanding more effort from respondents. Consequently, this research emphasised using closed-ended questions to ensure clarity and efficiency in statistical analysis.

4.8.2.1 Likert questionnaires. Likert questionnaires, first conceptualised by Rensis Likert, utilised a scale offering a range of responses to a specific statement or question, as outlined by Cohen et al. (2007). Jamieson (2004, p. 1217) affirmed that "Likert scales are commonly used to measure attitude, providing a range of responses to a given question or statement." This instrument demonstrated significant utility and appeal in research due to its capacity to integrate subtlety into participant responses. The Likert scale applied in this study (Refer to Appendix G) employed a linear presumption, measuring responses from rarely to mostly (McLeod, 2019; Pell, 2005). Numeric values were assigned to each response to evaluate the investigated viewpoint effectively. Jamieson (2004) highlighted the Likert scale's advantage of extending beyond binary yes-or-no options, enabling nuanced, opinion-based perspectives. Anonymity was ensured by allowing respondents to omit personal details on the questionnaire; however, Paulhus (1984) noted that participants who disclosed names and personal information tended to provide more detailed and effortful responses. To safeguard confidentiality, pseudonyms were assigned to participants who disclosed personal details. McLeod (2019) posited that Likert scales minimised social bias, ensuring that specific findings did not overshadow other important aspects.

For this study, the Likert scale questionnaire comprised 32 questions (Refer to Appendix G), generating qualitative data across four subcategories: classroom management and learning atmosphere (CM), support of exploration and experimentation (SE), support of different ideas and divergent thinking (SI), and lesson organisation and content (LO). Questionnaires maintained anonymity and proved cost-effective, enabling extensive data collection (Bakker et al., 2014). These instruments ensured objectivity and validated focus group discussions. They were expediently collected and organised into patterns and themes. However, this method demonstrated limited flexibility for participants to provide detailed explanations. Despite lecturers responding to all questions, omissions were possible, particularly in the absence of the researcher. Bertram and Christiansen (2014) criticised this data collection tool as potentially intrusive due to the time required for completion, while the sensitivity of specific questions risked being perceived as invasive.

4.8.3 Structured Observations

According to Cohen et al. (2007), what participants express may not always align with their actual behaviour, and observation schedules can elucidate such discrepancies. Kálmán (2017) argued that observations enabled researchers to explore assumed practical behavioural patterns that might otherwise go unnoticed. Cohen et al. (2007, p. 397) emphasised that observations offered the advantage of "recording non-verbal behaviour" and revealing neglected aspects that participants did not explicitly communicate. Research observations, as qualitative practices, involved examining participants' behaviour within natural settings (Creswell, 2014; Cohen et al., 2007). Cohen et al. (2007, p. 397) further asserted, “What counts as evidence depends on when, where and for how long we look.”

In this study, the observations conducted were both indirect and participatory. Students engaged in drawing circuit diagrams and compiling corresponding parts lists. They identified appropriate components and connected circuits using schematic diagrams at designated workstations. A summative assessment was administered using a structured observation schedule to evaluate competence (Refer to Appendix J). Cohen et al. (2007, p. 397) noted, “A structured observation will already have its hypotheses decided and will use the observational data to confirm or refute these hypotheses.”

4.8.4 Semi-Structured Interviews

Semi-structured interviews allowed participants to express themselves authentically through their words and actions, consistent with the principles of qualitative research. Welman and Kruger (2001) identified interviews conducted through personal visits to respondents' homes or workplaces as a prevalent and effective data collection method. These interviews relied on an interview schedule to ensure that questions remained relevant. Kumar (2005) defined semi-structured interviews as face-to-face, in-depth researcher interactions with informants designed to explore their life experiences from their perspective.

The semi-structured interviews in this study aimed to collect direct participant data addressing the research topic. This format enabled the researcher to delve deeply, uncovering patterns, emerging themes, and trends. Participants shared their curriculum implementation experiences. Bell (2010) highlighted the benefits of this approach, emphasising the interviewer's capacity to explore ideas and probe responses, which is not achievable through questionnaires (Welman & Kruger, 2001). Rich, meaningful generated data allowed for follow-up questions that provided deeper insights into participants' perspectives. Walsh (2001, p. 65) described such interviews as "guided conversations tailored to the interviewee's interests and preferences," further underscoring their value. Researchers gained comprehensive insights into participant perceptions of the research. Questionnaire items were incorporated into the interviews to enhance validity, consistency, and reliability. Lecturers were purposefully selected across diverse demographics to participate in this research. Several factors justified the use of semi-structured interviews. They allowed nuanced, face-to-face interaction beyond the constraints of written responses. Additionally, these interviews provided a deeper understanding of lecturers' varied perceptions and experiences, promoting meaningful dialogue to comprehend the subject matter thoroughly. Each interview, conducted under controlled conditions at the college premises, lasted approximately one hour and thirty minutes. Despite their advantages, semi-structured interviews presented challenges. The inability to ask extensive probing or follow-up questions and the risk of participants withholding data limited their scope (McCrady et al., 2010; Mertler, 2006, p. 116). Sensitive topics often remained undisclosed, complicating the establishment of mutual trust between the researcher and respondent. Furthermore, conducting, recording, and analysing data from these interviews was time-intensive, requiring meticulous planning to ensure a systematic and purposeful data collection and analysis approach.

4.9 Data Collection

4.9.1 First Cycle

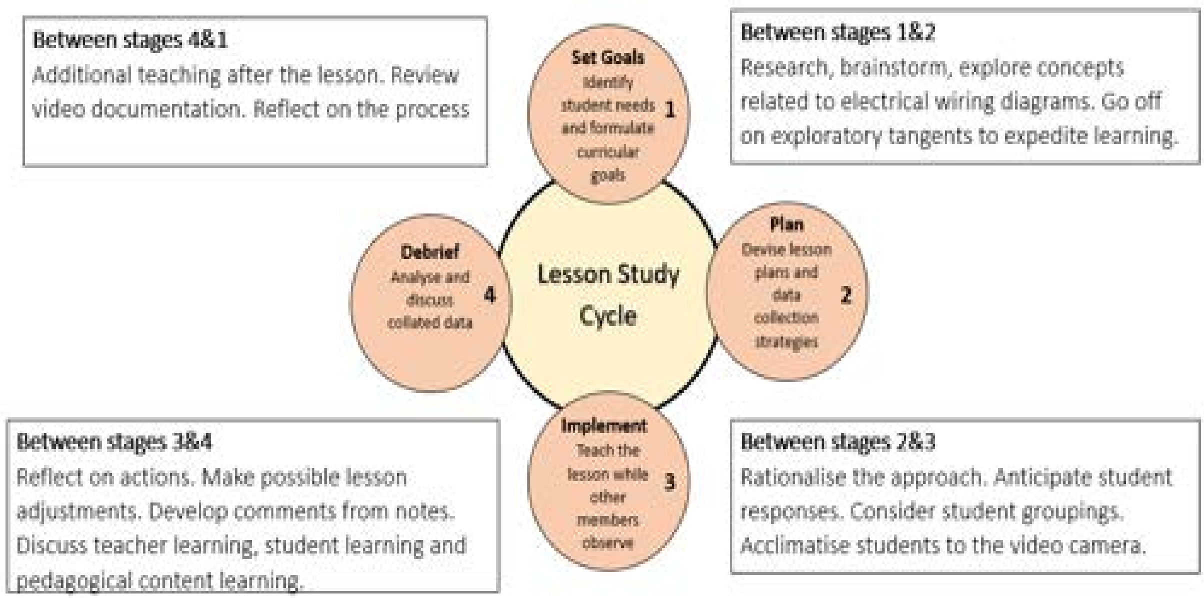
A rigorous action research (AR) project demands a flexible approach, continuous reflection, and meticulous planning (Newsome, 2016; Bates, 2015; Phillips & Carr, 2014). This study employed two cycles of AR and LS. The initial phase involved identifying the research problem, establishing the study's context, and defining explicit learning expectations. The core issue identified was that students engaged in rote memorisation of electrical schematics but struggled with interpretation. Despite the Report 191 syllabus emphasising the importance of electrical schematics, it lacked structured pedagogical strategies for reading and interpreting these diagrams, omitting a key component of electrical education (Abrahams et al., 2013; Chisholm & Leyendecker, 2008; Le Deist & Winterton, 2005) underscored the necessity of schematic interpretation for electrical competence. This study sought to address this gap through a structured intervention.

Reflective practice played a pivotal role in this research. As Nolen and Putten (2007) highlighted, documenting reflections provided valuable insights throughout the study. Electrical schematics encapsulate a wealth of information, offering clarity on structure and design. It conclusively emerged that conceptual improvements in pedagogy could be achieved through LS. Engaging a cohort of lecturers in collaboratively designing, implementing, and evaluating a lesson plan made it possible to uncover the challenges hindering students' comprehension. The objective was to enhance cognitive engagement and deepen students' understanding of complex theoretical concepts. This stage marked the reconnaissance phase, informing the subsequent design strategy.

An extensive review of LS literature guided the formulation of an action plan to enhance instructional practices (Elliot, 1991; McKernan, 2013; Nolen & Putten, 2007). The primary objective was to integrate LS into the teaching process. The initial step involved identifying and recruiting educators whose syllabi included electrical schematics or circuit diagrams. Given their extensive experience teaching electrical wiring and circuit design, two senior lecturers and the head of the division (HOD) were also considered for inclusion.

Each prospective participant was approached individually to introduce the concept and secure their engagement. The research team comprised five lecturers, two senior lecturers, and the HOD. All recognised the study's significance and expressed enthusiasm for participation. However, two lecturers later withdrew due to personal reasons. The adapted model from Bruce and Ladky (2011, p.4), “What is Going on Backstage? Revealing the Work of Lesson Study,” was implemented to structure the research process. This model provided a systematic framework for executing the LS approach within the context of electrical education.

Figure 7 *What is Going on Backstage? Revealing the Work of Lesson Study. (Bruce & Ladky, 2011, p.4)*



The action plan then commenced. The identified student needs were formulated into a goal, which prompted me to delve into extensive literature on the principles of learning electrical wiring diagrams. This became the exploratory reconnaissance phase. I also looked at different textbooks to see whether any alternate syllabi had an improved method of pedagogy related to wiring diagrams. The NCV Level 2 textbook had the best pedagogical approach to wiring diagrams.

Figure 8 *Textbook: ELECTRICAL PRINCIPLES & PRACTICE NQF2 SB (Troupant Publishers)*

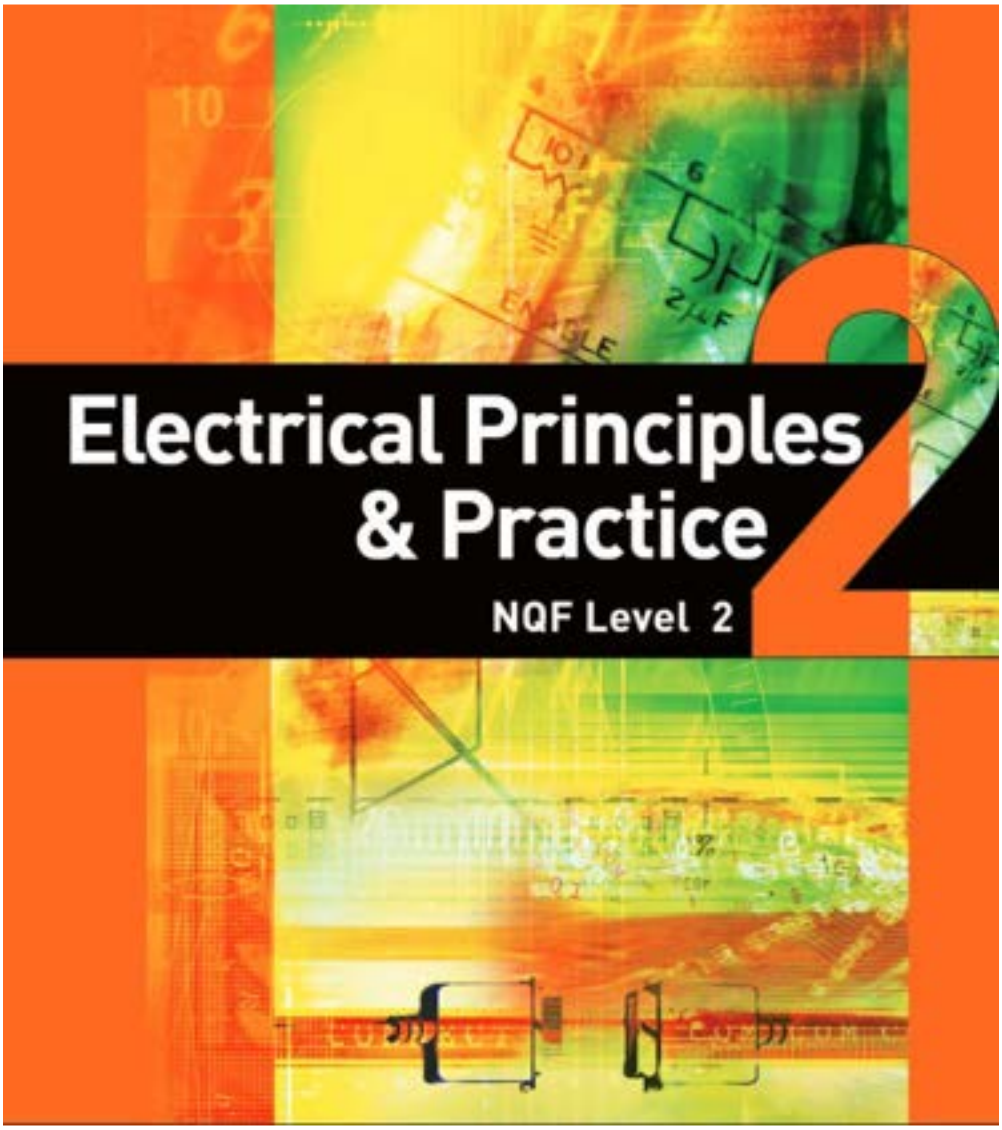


Figure 9 *Contents page from the textbook: ELECTRICAL PRINCIPLES & PRACTICE*

Contents

Topic Five Circuit Diagrams were used for this research. The subject and learning outcomes for the research were formulated from this syllabus. Stage 2 of the research then ensued. The lesson plan was then developed. The class chosen was my Report 191 N4 Electrotechnics class. This is an engineering cohort of students who only attend theory classes. This class was part of my previous semester's cohort of students. I was familiar with these students' character and behavioural strengths and weaknesses.

The process of planning the lesson was not complex. The reason is that I am a qualified electrician and have previously taught this aspect of diagrams. The students’ challenge with reading and interpreting diagrams was identified from previous experience teaching this part of the syllabus. The pedagogical content began with the lesson plan using the subject and learning outcomes.

Student participants were invited to join the research project. All were keen to join the project. However, some did not participate due to ill health and other commitments. 26 from the class of 34 completed all aspects of the research. The research timeline was clearly explained, and students were informed about the Japanese concept called LS. The reasons, aims and objectives were clearly explained, and students understood the value of the research. I met with the lecturer participants, explained the reasons for the research, and collected their personal information (Appendix D).

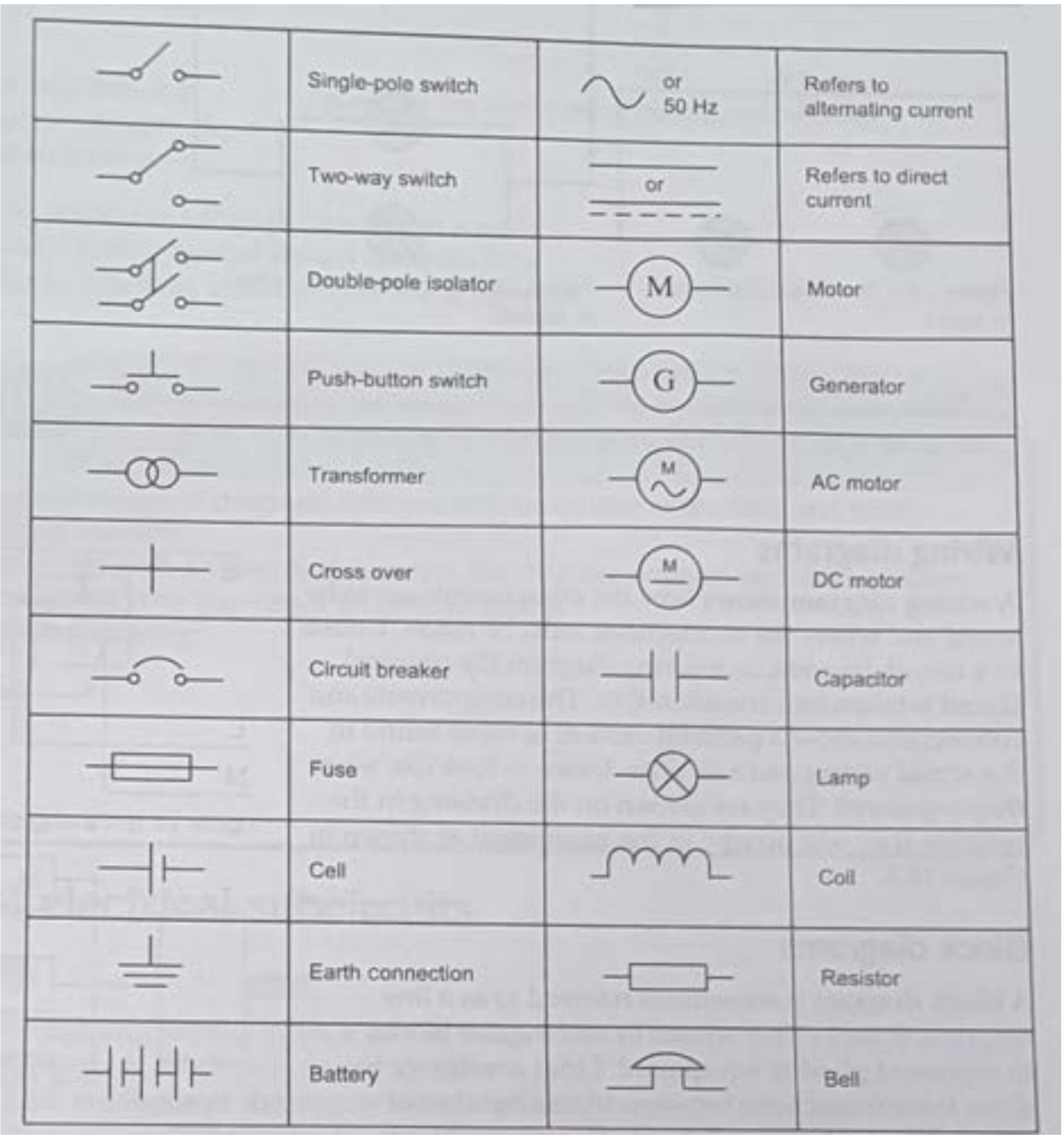
I prepared a lesson plan, invited the lecturer participants to an initial meeting, and issued the plan with an observation checklist (Appendix F) and a Likert Rating Scale evaluation tool (Appendix G) to read through and give feedback. A questionnaire was developed (Appendix E) to aid the post-lesson one interview. The participants were informed about all data generation tools. In analysing through literature various ways that LS is undertaken, the ideal would have been to discuss the content of the initial lesson plan before designing and printing it for circulation. However, poor time management can frustrate lecturers, and I realised that reducing meetings eliminated this frustration.

The lecturer participants received the lesson plan (Appendix H) and F and G.

The lecturer participants were asked to assess and evaluate the plan and suggest changes that could be made to address any gaps. They all decided to leave it as is and stated they would give feedback after the first lesson.

The first lesson was conducted on 18 October 2024 per the lesson plan. Students were given Appendix K and were informed about all data generation tools.

Figure 10 *Symbol Chart*



The lesson was conducted as per the plan, with the lecturer participants observing both the delivery of the lesson and how students responded. The initial part of the lesson was conducted in a class that used an interactive smartboard. The lesson was presented in PowerPoint. The second part was conducted in a workshop. Students had to take their generated parts list, identify and collate the parts and build the circuit with the aid of the wiring diagram. Lecturer participants noted that students enjoyed the research lesson.

This became the first cycle of the action research and the first cycle of LS. The cyclical aspect of LS and action research slowly started to formulate into a tangible working model. A semi-structured interview was then conducted with each lecturer participant. Probing questions were asked related to the lesson undertaken. Participant A highlighted fourteen different aspects that needed attention to tweak the lesson. Participant B felt that twenty-one issues needed addressing. Participant C felt the lesson was conducted well, and only one issue needed to be addressed. Participants D and E had seven and eight issues each. Participant F was absent on the day of the first lesson but joined the focused group discussion and attended the second lesson.

Participant B researched some of the complexities he had identified. He printed and submitted these findings during the semi-structured interviews. All the participants recognised the value of the research and subsequently agreed to a focus group discussion to finalise the next lesson plan. The focus group met. Participant A had to attend a funeral and was not present. The meeting started well; however, Participant B expected the researcher to collate all the feedback from the semi-structured interviews, analyse the feedback, and develop a revised lesson plan. There was a palpable sense of frustration when the participant realised that the participant team would need to do this. This was a significant finding for this research.

The discussions were robust, and there were many disagreements. The two-hour session became four hours, but the lesson plan was finally completed. The date for the second lesson was set for 17 November 2023. The amended lesson plan is reflected in Appendix I. The challenges encountered were diarised in my reflective journal. I paused and reflected on the study process.

4.9.2 The Revised Plan

This study would be impeded if the issues encountered by lecturer participants were not addressed. Lecturers needed to mark final examination scripts; they were part of the examination invigilation roster; external curriculum audits were taking place, which required files to be updated and examined internally before external evaluations; the campus was undergoing ISO accreditation, and lecturers were assigned responsibilities. The campus was also undergoing external audits for the new ministerial programmes to be implemented the following year. The college also participated in the World Skills competition, and lecturers were responsible for student training. Lecturers who were part of new programmes in the present year were in training for the next level of the syllabus for the following year. Facing all these challenges, the participant lecturers settled on 17 November 2023 to conduct the revised lesson.

Lecturers A and B had to be excused as an unannounced external examination auditor came to the campus to monitor the national examination. The revised lesson was conducted, and the video was recorded using an interactive smart board with a PowerPoint presentation, videos, and worksheets. Not all students who attended the first lesson were present for the second. Twenty-six students participated in the revised lesson. On completion of the theory component, students were taken to a workshop where they were evaluated on what they had learnt. A summative assessment tool, Appendix J, was used to evaluate understanding. Participant students and lecturers were interviewed after the revised lesson.

The Hawthorne effect had a limited impact on this study, with no drastic change in student behaviour noticed, except for the first lesson with all the participant lecturers in the venue. Students initially were quiet but gradually refocused on the lesson and not the lecturer participants. Students were grouped into eight teams of three or four. The practical task challenged several participants despite their understanding of the theory and their successful drawing of the schematic. Certain groups promptly completed the task. More males found the practical task easier; yet more females were in the class. Most students welcomed and enjoyed the opportunity to undertake the practical task and were curious and keen to attempt connecting more challenging electrical schematics. The observations improved student comprehension and understanding of electrical schematics when completing the practical tasks. This also applied to students who initially struggled with the task. To determine competence, each student was assessed using a structured summative assessment observation schedule. All aspects of the process were diarised in my reflective journal.

4.10 Data Analysis

Analysis involves the division of a whole into distinct components, which are then examined individually. Data analysis entails processing raw data and converting it into meaningful information to refute theories, test hypotheses, or address research questions (Braun & Clarke, 2006; Medelyan, 2020). Cohen et al. (2007, p. 461) asserted that "data analysis involves organising, accounting for and explaining the data; in short, making sense of data in terms of the participants' definitions of the situation, noting patterns, themes, categories and regularities."

The initial step required determining the type of data analysis to be conducted. The data were systematically and procedurally organised to ensure precision and accuracy in the analysis process (Newsome, 2016; Braun & Clarke, 2006). This study employed an inductive approach for qualitative analyses. The qualitative data were grouped and organised into relevant categories. Data cleaning was conducted to eliminate duplications and inaccuracies in tabulations (Creswell, 2014; Garg, 2016). Various analytical techniques were applied to interpret and comprehend the data. The process involved selecting, focusing, simplifying, abstracting, and transforming the data derived from the research instruments (Newsome, 2016; Creswell, 2014).

To ensure a comprehensive understanding of the data, the qualitative responses, which were primarily descriptive, were reviewed multiple times to identify patterns, themes, and regularities during the transcription process. The research questions were continuously revisited to discern relevant patterns while excluding extraneous data. A conceptual framework emerged from the broad ideas, impressions, and phrases, leading to the development of codes. The coding process facilitated the organisation and categorisation of data, enabling the identification of emerging patterns that contributed to the formulation of themes. These themes directly addressed the research questions and highlighted areas requiring further investigation. Creswell and Creswell (2018, p. 248) outlined the important steps in data analysis, which included:

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

These systematic procedures ensured a rigorous and methodical approach to data analysis, allowing meaningful insights to be derived from the collected information.

4.10.1 Thematic Analyses

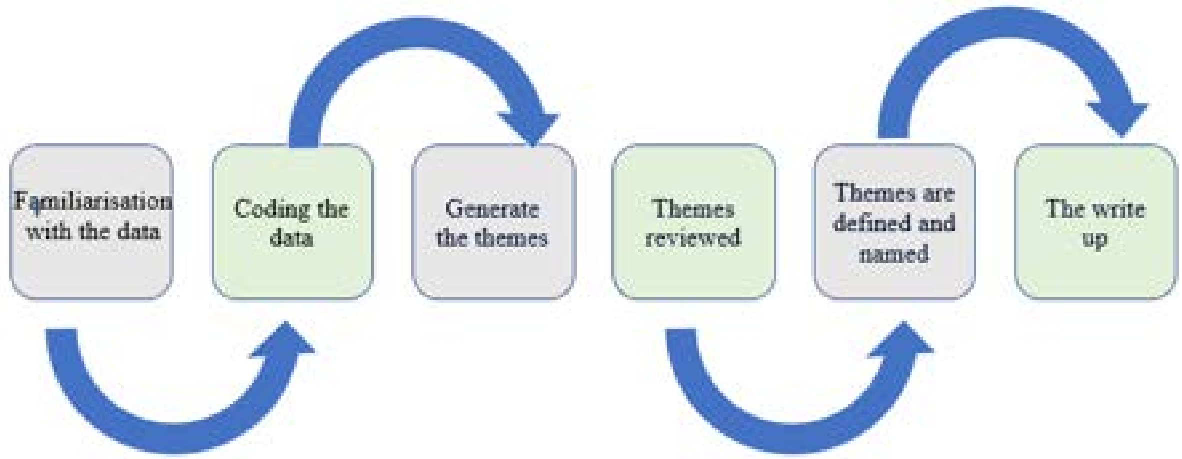
Thematic analysis was initially formulated and developed by Holton in the 1970s (Merton, 1975; Nowell et al., 2017), is a qualitative research method that explains, organises, and identifies regularities, patterns, and themes within data (Cohen et al., 2007). Braun and Clarke (2006, p. 79) defined thematic analysis as “a method for identifying, analysing, and reporting patterns (themes) within data,” which systematically transforms unstructured data into organised and detailed themes. This method is particularly effective for evaluating participants’ opinions, experiences, values, and perspectives, whether qualitatively or quantitatively. Thematic analysis offers flexibility in data interpretation, enabling researchers to categorise large datasets into broad themes (Caulfield, 2019). However, its subjective nature carries the risk of overlooking nuanced data. Researchers must reflect on their interpretations and choices, ensuring that data is not misinterpreted or prematurely discarded (Braun & Clarke, 2006; Nowell et al., 2017).

Braun and Clarke (2006) identified two distinct approaches to thematic analysis: inductive and deductive. The inductive approach allows themes to emerge organically from the data, free from preconceived frameworks (Caulfield, 2019). In contrast, the deductive approach engages data with predetermined themes derived from existing literature, theories, or research questions. While deductive analysis can streamline the research process and align findings with specific objectives, it risks introducing bias, as predefined codes may predispose researchers to confirm expected outcomes (Nowell et al., 2017).

One significant risk associated with deductive analysis is confirmation bias. Marsh and Hanlon (2007) described confirmation bias as seeking information that aligns with preexisting beliefs while disregarding contradictory evidence. Lehner et al. (2008, p. 584) defined it as "a tendency for people to seek information and cues that confirm the tentatively held hypothesis or belief and not seek (or discount) those that support an opposite conclusion or belief." This bias can compromise objectivity by influencing how data is gathered, interpreted, and recalled (Calikli & Bener, 2015; C. J. Lee et al., 2013; Lehner et al., 2008; Marsh & Hanlon, 2007). Calikli and Bener (2015) cautioned that confirmation bias may lead researchers to overlook contradictions or alternative themes, thereby skewing results. Acknowledging confirmation bias mitigates this effect, as it encourages researchers to remain open to opposing perspectives and contradictory data.

To minimise bias and ensure a comprehensive analysis, this study employed an inductive thematic approach guided by Braun and Clarke's (2006) six-step framework. This method allowed themes to emerge organically from the data, ensuring a rigorous and unbiased interpretation of participants' responses.

Figure 11 *Braun and Clarke's (2006) six-step analysis flow chart.*



A well-prepared action research project requires flexibility, continuous reflection, and meticulous planning. The researcher familiarised themselves with the data in this study by repeatedly reading and annotating the transcribed material. This process ensured a deep understanding of the data's essence and prepared the groundwork for subsequent analysis (Bates, 2015; Medelyan, 2020).

Coding the Data: Coding, defined by Medelyan (2020, p. 1) as "the process of labelling and organising your data to identify different themes and the relationships between them," was systematically applied. Sentences and phrases were highlighted and assigned condensed labels or codes that captured the key participant points, emotions, or ideas. The researcher continuously revisited the data, adding new codes as patterns emerged. These codes were then grouped and analysed to identify recurring data points, forming the basis for thematic development.

Generating Themes: Overarching themes were developed from the extensive list of codes. Subsets of codes were consolidated into main themes or sub-themes, while vague or irrelevant codes were discarded. The main themes, derived from a combination of several codes, were distinct and directly addressed the research questions. By the end of this stage, a coherent collection of themes and sub-themes had been classified, ensuring alignment with the study's objectives.

Reviewing Themes: The review process consisted of two parts. First, the coded data extracts were re-examined to ensure they formed coherent patterns within each theme. Codes were rearranged to verify their alignment with the respective themes. Second, the themes were evaluated against the entire dataset to determine their representativeness. Problematic themes were split or combined, and missing aspects were refined to ensure accuracy and applicability. This rigorous review ensured that the themes authentically reflected the data's essence.

Defining and Naming Themes: Each theme was analysed to determine its core message and whether it contained sub-themes. Working labels were purposefully refined into concise, impactful titles that captured the essence of each theme. By the end of this step, the themes were clearly defined and succinctly titled, providing a precise representation of the data's meaning.

The Write-Up: The final step involved crafting a logical, coherent, and concise write-up that presents a compelling account of the findings. Each theme was supported by vivid examples from the participants' responses, ensuring the analysis was rigorous and accessible. The write-up avoided repetition and provided sufficient evidence to substantiate the identified themes, offering a comprehensive and insightful interpretation of the data.

4.11 Trustworthiness

Trustworthiness is pivotal to qualitative research, ensuring the findings' credibility, dependability, confirmability, and transferability. Creswell (2014, p. 251) asserts, "Validity is one of the strengths of qualitative research and is based on determining whether the findings are accurate from the standpoint of the researcher, the participant, or the readers." Garg

(2016) further emphasises that validity in qualitative research is underpinned by credibility, authenticity, trustworthiness, and replicability. While quantitative research often frames trustworthiness regarding reliability and validity, qualitative research focuses on findings' dependability, confirmability, credibility, and transferability (Creswell & Creswell, 2018; Elo et al., 2014; Garg, 2016). As Elo et al. (2014, p. 2) contend, “the aim of trustworthiness in a qualitative inquiry is to support the argument that the inquiry’s findings are worth paying attention to.”

Dependability, which refers to the replicability of a study, was ensured by providing sufficient methodological detail to allow for replication with consistent results (Cohen et al., 2007; Creswell, 2014). Inquiry audits were employed to establish dependability, and member checking, as Kálmán (2017) suggested, was utilised to enhance accuracy. During follow-up consultations, participants were allowed to review and respond to the generated data, enabling corrections, clarifications, and discussions of interpretations. All participants confirmed the accuracy of their recorded responses, with no requests for changes (Kálmán, 2017; Lee et al., 2013).

Confirmability addresses the potential for researcher bias, ensuring that interpretations are not distorted to fit a preconceived narrative (Lee et al., 2013). Marsh and Hanlon (2007) emphasise the importance of maintaining neutrality and avoiding interference. In this study, confirmability was established systematically, with every step of the analysis documented and rationales provided for the findings. This ensured that the findings accurately reflected participant responses.

Credibility, which seeks to establish the truthfulness and accuracy of the findings, was achieved through triangulation. Triangulation involves using multiple data sources to construct coherent and validated themes (Creswell & Creswell, 2018; Cohen et al., 2007).

This study employed questionnaires, focus group discussions, structured observation schedules, and a reflective journal to enhance credibility.

Transferability refers to the applicability of findings to other contexts. Qualitative studies often use thick descriptions to illustrate how findings might apply to similar situations, phenomena, or populations (Creswell & Creswell, 2018). As Creswell and Creswell (2018, p. 251) outlined, specific strategies to enhance validity include "triangulation; member checking; using rich, thick descriptions; clarifying the bias the researcher brings to the study; and presenting negative or discrepant information that runs counter to the themes."

As the researcher, I took deliberate steps to ensure the trustworthiness of this action research study. My positionality as both a teacher and researcher were communicated to participants to avoid confusion. Rich, detailed descriptions were provided, as recommended by Creswell (2014), and potential biases related to my socio-economic context, culture, gender, and personal history were identified through self-reflection (Garg, 2016). Contradictory data were presented to validate the accuracy and representativeness of the findings, as evident in the analysis. The study was rigorously examined to ensure it met the criteria of dependability, credibility, confirmability, and transferability (Cohen et al., 2007; Creswell, 2014). Questions of repeatability (whether the same results would be generated if the study were repeated) and reliability (whether a different researcher would obtain similar responses) were also considered (Bertram & Christiansen, 2014).

A reflective journal was maintained to document the thought processes behind the findings, enhancing the study's trustworthiness. Pseudonyms were used to protect participant anonymity and confidentiality, further contributing to reliability. Finally, acknowledging the limitations of this action research project added to the overall trustworthiness of the study.

4.12 Ethical Considerations

Ethical considerations encompass issues such as authenticity, personal disclosure, the credibility of the research report, the researcher's role in cross-cultural contexts, and the protection of personal privacy (Creswell, 2014). These considerations were meticulously addressed in this study to ensure the integrity and ethical soundness of the research. Before the research commenced, permission to conduct the research was obtained from the institution (Appendix C). Ethical clearance was sought and obtained from the University of KwaZulu-Natal, adhering to institutional requirements (Appendix A). Informed consent was a cornerstone of the ethical framework guiding this study. A participant declaration of consent form (Appendix B) was distributed to all participants, as recommended by Bertram and Christiansen (2014), Creswell (2014), and Garg (2016). Participants were thoroughly briefed on the ethical dimensions of the research, including the principles of voluntary participation, anonymity, and confidentiality (Bertram & Christiansen, 2014). They were also informed of their right to withdraw from the study at any point without penalty. Written consent was obtained from each participant, ensuring their voluntary and informed participation. The participants' identities were safeguarded throughout the study, aligning with Creswell's (2014) emphasis on beneficence and non-maleficence. The research aimed to benefit the participants without causing harm while addressing broader ethical concerns such as authenticity, personal disclosure, credibility, cross-cultural sensitivity, and privacy (Bertram & Christiansen, 2014). Trust was established and maintained to uphold the integrity of the research, thereby preventing ethical transgressions that could reflect negatively on the institution (Garg, 2016).

Ethical considerations were integrated at four stages of the research process: prior to the commencement of the study, at the outset of data collection, during the collection and analysis of data, and finally, during the verification, sharing, storage, and reporting of findings (Creswell & Creswell, 2018). This comprehensive approach ensured that ethical principles were consistently upheld throughout the research lifecycle. Anonymity was a central ethical concern in this study. The institution and participants were anonymised to protect their identities (Bertram & Christiansen, 2014; Garg, 2016). The name of the campus and any identifiable participant details were withheld, with pseudonyms used in place of real names. Particular attention was paid to vulnerable participants during the needs assessment phase, ensuring equitable treatment for all individuals involved. Confidentiality was another ethical issue. Participant information was safeguarded through strict non-disclosure practices, ensuring no sensitive or compromising data was revealed. Data were securely stored in the supervisor's university office for five years, after which they were destroyed per ethical guidelines (Bevan, 2007; Creswell, 2014). Respect, honesty, and empathy were fundamental to the researcher's approach. Deception was avoided, and power imbalances were carefully navigated to prevent the collection of harmful or exploitative information. Leading questions were eschewed, and contradictory findings were transparently reported. These measures ensured that the research was conducted with the highest ethical standards, prioritising the dignity and rights of all participants (Cohen et al., 2007; Creswell, 2014).

4.13 Study Limitations

Creswell (2014) contends that a researcher's unique abilities and characteristics significantly influence the research quality. Garg (2016) further argues that researcher bias can shape the outcomes of a study. Johnson and Christensen (2014) concur, noting that the techniques of data collection employed by researchers, combined with their perspectives, can subtly alter the data generated. In qualitative research, demonstrating, assessing, and maintaining rigour is particularly challenging, as highlighted by Cohen et al. (2007). This action research study was not exempt from the limitations outlined below. One notable limitation was the time-intensive nature of data analysis and interpretation due to the substantial volume of data generated. Meticulous planning was required to ensure the accuracy and reliability of the findings. Additionally, the researcher's presence in the study context could have exacerbated the Hawthorne effect, where participants alter their behaviour in response to being observed. However, this did not emerge as a significant issue in this study.

Another limitation pertained to the implementation of new teaching strategies. These strategies demanded additional resources, time, and effort from educators to adopt and practice effectively. Consequently, the findings of this study may not be easily generalisable or readily adopted by other teachers, as the successful implementation of these strategies may depend on specific contextual factors and resource availability.

4.14 Conclusion

This chapter provided a comprehensive overview of the methodological framework employed in this study, detailing the necessary information to facilitate its replication. It explained how the research design was structured to address the research questions and demonstrated its suitability for the study’s purpose. The chapter began by outlining the study’s objectives and briefly explaining the chosen methodology. It then justified the adoption of the critical research paradigm, highlighting its alignment with the study’s aims.

A detailed discussion on the use of action research followed, elucidating its strengths and limitations in the context of this study. The research setting and sample selection were described, clarifying the participants and context. Five data generation tools were utilised: lecturer-focused group discussions, questionnaires, structured observations, a self-reflective diary, and interviews. Data collection and analysis processes were also outlined, ensuring transparency in the methodological approach. The chapter further addressed issues of trustworthiness, ethical considerations, and study limitations, underscoring the rigour and ethical integrity of the research. The relevant literature justified and substantiated all methodological and design choices, ensuring a robust and theoretically grounded approach.

The following chapter will present and analyse the data generated through this methodological framework.

CHAPTER FIVE: PRESENTATION AND ANALYSIS OF DATA

5.1 Introduction

The methodological approach and research design employed to address the research questions were detailed in the preceding chapter. This chapter presents the clustered codes, patterns and themes derived from the analysed data (Creswell, 2014). Three conceptual frameworks were the analytical lens for interpreting the data, ensuring a robust and theoretically grounded analysis. Excerpts from participant responses are included to enhance the credibility of the findings and accurately reflect the participants' perspectives. The data generated from student and lecturer participants are presented and analysed through conceptual frameworks and relevant literature. The analysis is structured according to the research questions, using data from the following research instruments: lecturer-focused group discussions, questionnaires, structured observations, and interviews. Entries from a personal reflective journal supplement and corroborate the identified codes and themes, providing triangulation to ensure the accuracy and reliability of the analysis.

The three research questions are addressed using DCT, MLT, and the framework of PLC. These frameworks guide the interpretation of the data, enabling a nuanced understanding of the findings. Following an inductive analysis, the emergent concepts and themes are systematically organised and presented in tabular form. All participants were assigned pseudonyms to uphold ethical standards and ensure participant confidentiality. This measure allowed participants to communicate freely and honestly, fostering an environment conducive to authentic and uninhibited responses. The integration of multiple data sources, coupled with the application of established theoretical frameworks, strengthens the validity and trustworthiness of the findings, providing a comprehensive and insightful analysis of the research questions.

5.2 Overview of Methodological Approach and Research Design

Cohen et al. (2007) define methodology as the systematic process through which knowledge is discovered and analysed, describing the nature of research itself. Bertram (2008, p. 63) captures this by asking, "How can the inquirer go about finding out the nature of reality?" Garg (2016) clarifies that methodology differs from methods, as the latter refers to specific data-gathering techniques such as interviews or surveys. Methodology encompasses both ontological and epistemological perspectives, and may include quantitative or qualitative dimensions.

5.2.1 Ontological and epistemological underpinnings of action research

This Action Research (AR) Lesson Study (LS) project is situated within the critical theory paradigm, which emphasises power relations, social transformation, and emancipatory education. Ontologically, critical theory aligns with critical realism, which acknowledges an objective reality shaped by social, cultural, and historical forces (Mertens, 2012). Power structures, institutional norms, and ideology influence both what is known and how it is understood. As Ledwith (2007, p. 597) explains, critical practice involves "any practice with a transformative social justice intention."

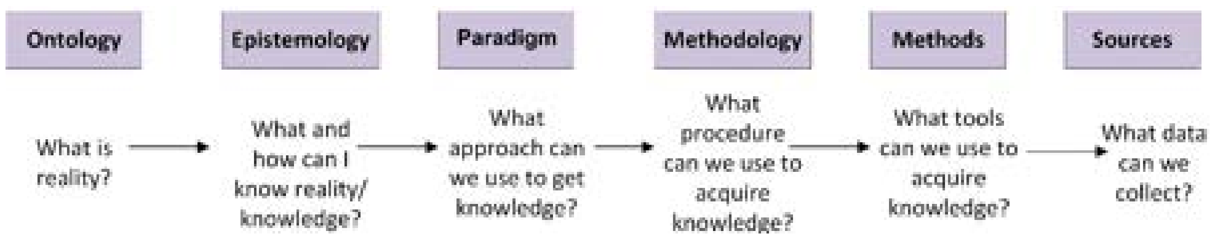
In this study, education is viewed as a socially embedded process that both reflects and reproduces broader inequalities (Koshy et al., 2010). The LS process challenges hierarchical models of professional development by positioning lecturers as agents of change rather than passive recipients of knowledge.

Epistemologically, knowledge within this paradigm is seen as constructed, mediated by context, and inherently political. It questions dominant narratives and seeks to promote equity

(Weaver & Olsen, 2006). This AR LS project adopted an emancipatory stance, enabling lecturers to reflect on their practice, interrogate bias, and foster more inclusive, student-centred approaches. As Cohen et al. (2007, p. 45) describe, such inquiry is "intensely practical [and] transformative." Grounded in praxis, it integrates theory, action, and reflection (Mertens, 2012).

The methodological orientation positioned lecturers as practitioner-researchers critically engaging with their own power to shape curriculum and pedagogy. Lesson Study provided a platform for identifying and addressing inequities in teaching, learning, and assessment. Knowledge was co-constructed through reflection, critique, and collaborative dialogue rather than imposed hierarchically (Creswell, 2014). Data collection methods—such as classroom observations, reflective journals, and focus group discussions—sought to uncover bias, systemic barriers, and diverse perspectives.

Figure 12 *The links in research philosophy. (Patel, 2015, p.1).*



5.2.2. Conceptual Framework

The conceptual framework for this LS project integrates Dual Coding Theory (DCT), Multimedia Learning Theory (MLT), and Professional Learning Communities (PLCs). DCT and MLT provide the cognitive foundation for instruction, while PLCs offer a collaborative model for improving teaching and learning. Collectively, these frameworks promote a holistic and reflective approach to enhancing vocational and technical education.

5.2.2.1 Role of Participant Excerpts in Analysis. Participant excerpts were crucial in validating the findings and grounding the analysis in authentic, lived experiences. Direct quotations provided tangible evidence of participants' perspectives, emotions, and reasoning, thereby strengthening the study's credibility and rigour.

These excerpts humanised abstract themes and revealed the nuances within the data. They also enhanced transparency by illustrating how themes emerged, allowing readers to evaluate and interpret findings independently. Furthermore, participant voices conveyed the cultural and emotional depth of the study, underscoring its authenticity and interpretive integrity.

5.3 Overview of Data Instruments.

Table 2 Progression of the generated data from the three research questions.

Questions	Participant	Data Generation	Analysis	Research Type
Question 1 Question 2 Question 3	Lecturer	Questionnaire	Qualitative	Inductive/ Deductive
	Lecturer	Focus group discussion	Qualitative	
	Lecturer	Interviews	Qualitative	
	Student	Interviews	Qualitative	
	Student/ Lecturer/ Researcher	Structured observation schedule	Qualitative	
	Researcher	Personal diary (PD)	Qualitative	

5.4 Participant Profile

5.4.1 Demographic and Professional Backgrounds

The South African TVET system comprises complex interconnections among the Department of Higher Education and Training, Sector Education and Training Authorities (SETAs), and multiple colleges that deliver vocational programmes (Zungu, 2015). The sector's effectiveness depends on how these entities collaborate to facilitate the transfer of skills and the dissemination of knowledge.

Despite its pivotal role in addressing skills shortages and supporting economic growth, TVET remains stigmatised as inferior to academic education. This perception, fuelled by the misconception that TVET students are academically weaker, undermines the sector's societal value.

5.4.1.1 Lecturer Profiles and Experience. Four lecturers participated in this study: two senior lecturers and the Head of Department (HOD), all of whom are from the Electrical Faculty. Five participants are qualified electricians, and one is an artisan in air conditioning and refrigeration. The HOD specialises in electronics. All possess over ten years of teaching experience and significant industry backgrounds.

5.4.1.2 Student Profile. My target population was the thirty students from my Report 191 N4 Electrotechnics full-time class.

5.4.2. Challenges and Contextual Considerations

5.4.2.1 Language and Cultural Barriers. Most students reside in townships, defined by Ngubane (2013, p. 8) as "underdeveloped urban living areas that, from the late 19th century until the end of apartheid, were reserved for non-whites (Africans, Coloureds, and Indians)." English is not the first language for many, creating challenges in communication and comprehension (Mutemeri & Chetty, 2011). Despite strong motivation, many individuals lack the foundational preparation necessary for a career in engineering (Huchzermeyer, 2010). This is compounded by limited conceptual and problem-solving skills (Chisholm & Leyendecker, 2008; Mutemeri & Chetty, 2011; Ngubane, 2013; Nongxa, 2010; Nundkumar, 2016).

5.4.2.2. Socio-Economic Influences on Learning Readiness. The Report 191 curriculum, originally designed under apartheid to support apprenticeships, has since evolved. Under the current system, school leavers enter TVET colleges directly, where theoretical training occurs at the outset (Nundkumar, 2016; Chisholm & Leyendecker, 2008). A key finding was that students' limited prior technical knowledge was attributed to under-resourced township schools lacking adequate infrastructure and materials (Nongxa, 2010).

5.5 Overview of Thematic Analysis Methodology

Data were systematically labelled, dated, and organised (Akinyode & Khan, 2018). Thematic analysis was conducted using Braun and Clarke's (2006) framework, which employed both inductive (data-driven) and deductive (theory-driven) coding approaches (Caulfield, 2019; Medelyan, 2020).

Patterns were identified through familiarisation, coding, theme generation, and synthesis (Cohen et al., 2007). In line with Koshy et al. (2010), attention was given to accurately interpreting participant responses and acknowledging divergent findings (Creswell, 2014; Newsome, 2016; Putnam & Borko, 2000).

Themes were refined and connected to the conceptual framework and relevant literature to explain emergent phenomena (Creswell, 2014; Koshy et al., 2011). While many findings aligned with prior studies, care was taken to recognise areas of divergence and innovation (Garg, 2016).

Table 3 below presents a structured overview of how data from focus groups, interviews, and reflective journal entries converged to reveal key patterns and themes related to the implementation of Professional Learning Communities (PLCs) and Lesson Study (LS) within a South African TVET context. Each data source contributed distinct yet interconnected insights into how teachers engage in collaborative professional learning, reflect on their practice, and align their teaching with institutional goals. Focus group discussions highlighted a culture of continuous improvement, teacher well-being, and the development of supportive classroom environments. Interview data revealed how tacit knowledge becomes explicit through peer collaboration, leading to more effective teaching strategies, curriculum alignment, and inclusive practices, central to the functioning of PLCs and LS cycles. Journal reflections reinforced themes of collective responsibility, teamwork, and the challenges of sustaining collaboration over time, pointing to the need for resilience and shared professional values. When aligned with the conceptual frameworks guiding the study, the analysis demonstrates that effective PLCs are sustained through institutional support, including clear goals, leadership commitment, structured frameworks, and integration with broader college improvement plans. Overall, the table illustrates how teacher collaboration within PLCs fosters professional growth, enhances pedagogical practice, and contributes to a deeper, more reflective culture of learning within the institution.

Table 3: *Combined codes and amalgamated themes for research question 1*

Codes/Phrases/Patterns Focus group	Codes/Phrases/Patterns Interviews	Codes/Phrases/Patterns Journal Entries	Themes RQ1	Conceptual Frameworks
1. Continuous Improvement Culture. 2. Teacher Well-being. 3. Classroom Culture and Management.	1. Tacit knowledge becomes explicit among peers. 2. Effective Teaching Strategies. 3. Curriculum Alignment.	1. Developing solutions to anticipated student responses. 2. Inclusive Practices.	***Teacher Collaboration Encourages active participation in knowledge construction.***	***PLCs in teacher wellbeing***
1. PLCs as collaborative learning opportunities 2. Classroom culture and management.	1. Recognising Challenges in Sustaining PLCs 2. Collective responsibility.	1. Teamwork and shared experiences. 2. Teacher Collaboration.	***Professional Learning Communities (PLCs)***	***PLCs***
1. Planning to connect to student understanding. 2. Select and sequence simple to complex. 3. Advance student thinking.	1. Declarative memory. 2. Comprehension through variation. 3. Comprehension facilitated action.	1. Deep and surface learning. 2. Formulating mind pictures. 3. Conceptual meaning	***LS developed improved instructional strategies.***	***PLCs in AR& LS***
1. Time management. 2. Integration with the college improvement plan.	1. Clear goals and vision, access to professional development resources, and receiving administrative support. .	1. Collaborative culture. 2. Structured frameworks, protocols, together with monitoring and evaluation	***Fostering strong institutional Support***	***PLCs in institutional engagement***

5.6 Research Question Analysis: Lesson Study's Influence on Teaching and Learning

5.6.1 Analysis of research question 1

How does the implementation of lesson study influence the teaching and learning of electrical wiring diagrams in a South African TVET college?

5.6.1.1 Teacher collaboration in LS encouraged active participation in knowledge construction. In this LS research project, teacher collaboration encouraged active participation in knowledge construction by fostering a culture of continuous improvement. A professional learning community composed of educators worked together to enhance student learning through focused, continuous improvement. An environment was created where teachers consistently engaged in learning, reflection, and the enhancement of their teaching practices. Setting clear, achievable goals for the LS helped maintain focus and provided a benchmark for evaluating progress. Clearly defined expectations about collaboration, reflection, and idea sharing encouraged research participants to strive for continuous improvement. However, in institutions with limited resources or support, disparities may arise in implementing LS, resulting in unequal access to high-quality instructional practices.

A culture of constant improvement thrived in a collaborative environment where teachers felt safe sharing their successes and challenges. Establishing trust among team members led them to discuss their practices openly without fear of judgment. "I am using my way of manipulating those formulas. Someone else is bringing their way, and the third person is using their way. [Moreover], I could be sitting quietly in my corner and saying it [should be] like this, but when we sit together and review it, it is an open forum [and] no one should get offended, and we can ask why your way is different [from mine]. We can thrash it out; finally, it is improved when put forward" (Lecturer A). When teachers felt supported and understood, they were more likely to engage in honest reflection and collaborative problem-solving, leading to meaningful improvements in teaching and learning. Creating an environment that promotes teacher well-being required encouraging open communication, fostering mutual respect, providing emotional support, celebrating efforts and achievements, promoting risk-taking and innovation, offering constructive feedback, building team cohesion, and providing resources and support.

Educators planned joint lessons to promote a positive classroom culture and effective student interaction. "When different brains come together speaking one language and addressing one task. It becomes easy because we complement one another. Everyone brings their best practice and their knowledge. Moreover, we sit together. Moreover, we develop a Lesson plan that everyone can use" (Lecturer D). This collaboration enabled them to develop activities that promoted student participation and created a conducive learning environment. Additionally, teachers modelled the behaviour they expected from students and observed each other to implement effective modelling techniques during LS, promoting respect and responsibility in the classroom. "It brings all different people with knowledge together, and if you bring more people with knowledge together who complement one another, they can produce a lesson which is not perfect close to perfect because when they do meet together, you find everyone brings their expertise and we can take the positives from that and we cancel what is negative from one another" (Lecturer C). Through collaborative discussions in LS, educators worked towards establishing clear and uniform expectations for behaviour and academic performance across different classrooms.

Building strong, positive connections with students was crucial. Creating engaging and participatory lessons was essential to keep students motivated and invested in their learning. When asked about impressions of the first lesson, Lecturer D noted it *"created real-life situations using smartboards, pictures, etc., incorporating the visual and the media* *approach."* In LS, teachers shared and improved strategies to capture students' interest and maintain their focus. Positive reinforcement and consistent classroom routines were important elements of effective classroom management. Educators exchanged ideas through LS and identified best practices in reinforcement techniques and routine creation.

LS sessions provided ongoing professional development focused on classroom management and culture. *"One of the things I identified was the cultural things, speaking about where people are staying. So, you [have] to introduce more speaking about where people are staying, including rural areas. How is this thing going to help them there? We must consider that not everyone comes from urban areas and the factors of their situation"* (Lecturer A). Observing and reflecting on classroom interactions and management strategies was important for improvement. LS provided opportunities for teachers to observe one another's classrooms and reflect on successful strategies and areas for improvement. *"If someone with knowledge like yours is sitting in that class to evaluate you, it is also good for you and him. [Furthermore], although he is evaluating you, he could say I like how [this lecturer] is doing this or that. I am not applying this; I am not doing this, or I am not doing that. It is two-way learning for lecturers, the one teaching and the one observing"* (Lecturer C). Using LS's cyclical nature, teachers continuously refined and improved classroom culture and management practices by planning, implementing, observing, and reflecting on lessons.

Tacit knowledge, gained through experience and difficult to articulate, became explicit when educators collaborated during this LS research project. This transformation was facilitated through various mechanisms. During collaborative planning sessions, educators conversed and exchanged their methods, tactics, and perceptions, articulating the intuitive aspects of teaching. *"I feel this was a good thing to do because if you have lacked on something [you have] people who are experienced in this field as well as the teaching part they can try and help where you lag or where you have missed out [key information]"* (Lecturer E).

Classroom observations enabled educators to witness the application of implicit strategies and techniques in action research, prompting them to articulate their tacit knowledge. Reflective discussions following class observations allowed educators to elucidate their reasoning, decision-making, and instructional choices, thereby verbalising and sharing tacit knowledge. Educators recorded their lesson plans, observations, and reflections, which compelled them to articulate their implicit knowledge. Feedback and peer review compelled educators to communicate the implicit knowledge guiding their teaching, making it explicit. Seasoned educators demonstrated effective practices to less experienced colleagues, converting tacit knowledge into explicit knowledge. *"If someone with knowledge like yours is sitting in that class to evaluate you, it is also good for you and him. Moreover, although he is evaluating you, he could say I like how [this lecturer] is doing this or that. I am not applying this; I am not doing this, or I am not doing that. It is two-way learning for lecturers, the one teaching and the one observing"* (Lecturer C). Fostering a culture of questioning and probing helped uncover the underlying knowledge that educators utilised in their practice. Drafting reports or presenting findings compelled educators to articulate their insights and methodologies. Utilising visual aids helped in making tacit knowledge more explicit. *"Yes, even for students, a theory learned and a practical done are two different components"* (Lecturer E). Participation in professional learning communities fostered continuous sharing and dialogue, allowing educators to share their tacit insights and make them explicit over time.

Improving effective teaching strategies and curriculum alignment within the LS research project involved a systematic and collaborative approach. Collaborative lesson planning among educators involved integrating effective teaching strategies aligned with curriculum standards. *"That was addressed in the Lesson plan where we covered the aspect of prior knowledge. Students had to have embedded knowledge before coming to this lesson"* (Lecturer B). By pooling their expertise, educators created comprehensive and well-rounded lesson plans. Educators ensured lesson objectives were consistent with the overall curriculum, with LS sessions helping to review standards and maintain alignment. Successful teaching strategies were shared during the LS focus group meetings, disseminating effective practices across the team. Students' performance data guided adjustments to teaching methods. *"The circuit diagram was one of the changes for me. The first time, I felt clueless. The second time, it felt OK. I know you explained it to us the first time, but the second time felt very different from the first. The change was how to read the diagram the second time"* (Student 3). Educators addressed gaps in understanding and tailored their approaches accordingly. After implementing the lessons, educators reflected on their effectiveness and made necessary revisions, thereby improving teaching strategies and aligning the curriculum.

LS allowed experimentation with various instructional approaches, including cooperative learning, inquiry-based learning, and the integration of technology. *"We saw a video on how to connect the direct-on-line. That made it much easier to do the connection"* (Student 4). Cross-curricular connections were explored to enhance student engagement. Observing peers' classrooms provided insights into effective teaching strategies and curriculum alignment. Clear, replicable lesson plans with specific objectives and assessment methods were formulated. Consistency in curriculum delivery was a priority, and a mindset of continuous refinement, based on feedback and reflection, was fundamental to enhancing teaching strategies and ensuring alignment.

Developing responses to expected student reactions in LS was a methodical and collaborative process. This process began by identifying the lesson's learning goals and objectives, explicitly delineating the specific learning targets and the fundamental concepts and skills essential to the lesson. The planning necessitated creating a detailed lesson plan that elaborated on the teaching methods, activities, and materials to be employed. Additionally, it required anticipating possible student reactions to various lesson elements, encompassing both accurate and inaccurate responses, as well as potential misunderstandings. Anticipating challenges and misunderstandings was imperative, involving consideration of potential areas where students might encounter difficulties or misconceptions based on prior knowledge of student capabilities and prevalent misconceptions associated with the topic. *"Yes, when you explained about the wires crossing and the dots, I came across that in the exam and the textbook, and I did not understand what they were all about. It helped"* (Student 1). This step also entailed constructing questions and tasks designed to elucidate student thought processes and misconceptions.

Insights gleaned from colleagues' past experiences were utilised to enhance the ability to forecast how students might react. *"Sometimes in the delivery of the subject that we are teaching, someone else [another lecturer] might see something from their point of view"* (Lecturer A). Developing strategies for reactions involved formulating specific approaches to address anticipated student reactions, planning for differentiation, scaffolding, and additional assistance for students who may have faced challenges. This step also encompassed preparing guiding questions aimed at helping students contemplate their understanding and rectify any misconceptions.

Integrating inclusive practices into LS encouraged knowledge construction by creating and executing lessons that met the diverse needs of all students. *"We all know something, and that is something that someone else might not know. Everyone's contribution is counted. It is about how we develop one idea, one method for the lesson that must be delivered"* (Lecturer C). This process ensured student engagement and comprehension of the material, resulting in a more inclusive and effective learning environment. The initial step involved understanding student diversity. Educators acknowledged their students' varied backgrounds, abilities, and learning styles. *"One of the things I identified was the cultural things, speaking about where people are staying. So, you [have] to introduce more speaking* *about where people are staying, including rural areas. How is this thing going to help them there?"* (Lecturer A). Lesson content became culturally relevant and accessible to all.

The next step was to establish inclusive learning objectives. Goals were challenging yet attainable for all students, considering their starting points and potential learning barriers. Collaborative planning was vital in this process. *"Start at the basics, like building a house where you start at the foundation. We looked at common things and how it can be narrowed down so that everything on that list is the essentials"* (Lecturer D). Lecturers brought different planning perspectives and ideas to make the lesson inclusive. Moreover, incorporating student feedback about their learning preferences and needs was invaluable. *"In the first lesson, you gave us a large wiring diagram. That made it easier for us to see those connections"* (Student 1). Lecturers predicted and anticipated student reactions based on their varied needs and prepared inclusive strategies to support all learners.

Presenting information in multiple ways ensured all students could access and understand the content through visual, auditory, or kinaesthetic materials. *"We saw a video on how to connect the direct-on-line [wiring diagram]. That made it much easier to make the connection"* (Student 4). Students demonstrated their understanding by writing, speaking, drawing, or using digital tools to express their knowledge. Engaging students by offering choices in how and what they learnt helped to sustain their interest and motivation. *"It was the first time that we had done practicals. I did not understand how the components function. Moreover, how to connect them. But when we started to work with them practically, I started to understand better"* (Student 2). Educators prepared to adjust their teaching strategies based on assessment data to better meet all students' needs. *"There was a big jump between the two-way switching and the direct online. We should have gone from two-way switching and added one or two components to the circuit"* (Lecturer A).

Reflection and sharing came after the lesson implementation. Feedback from students about their learning experiences informed future lesson planning and design. *"I must highlight that it was not just my contribution, but the contribution of the group, because you do not want to use just one person's idea, experience or knowledge"* (Lecturer C). The LS cycle was iterative and inclusive, continuously refining and improving lessons based on reflections and feedback. Building an inclusive repository of successful practices and sharing them with colleagues helped create value. A community of practice focused on inclusive education allowed educators to share resources, strategies, and support. *"I think it is a shared best practice approach"* (Lecturer A). Inclusive practices promoted knowledge construction for all students by supporting teachers in responding to individual differences among learners (Norwich et al., 2021).

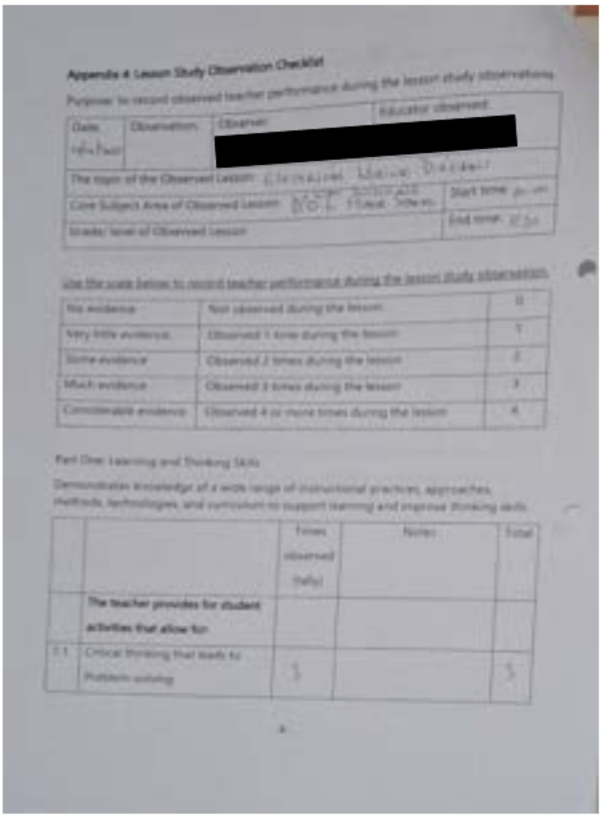
5.6.1.2 Professional Learning Communities (PLC)

5.6.1.2.1 PLCs as Collaborative Learning Opportunities. Professional learning communities fostered a rich culture of shared learning amongst educators. PLCs transcended the concept of mere meetings; they acted as dynamic ecosystems where educators engaged in ongoing professional development, learnt from one another, and embraced innovation. This collaborative environment fostered individual growth for educators and enhanced the quality of education, leading to transformative experiences for their students. Through these efforts, educators collectively contributed to a vibrant learning culture that consistently prioritised student success.

5.6.1.2.2 Recognising Challenges in Sustaining PLCs. Academic staff join the profession with different worldviews, sometimes conflicting with the institution's and ultimately the collaborative team's stated goals and objectives (Eaker & Marzano, 2020a). This was the root of many PLC challenges.

5.6.1.2.3 Teacher Collaboration Brought Various Skills and Viewpoints to the Discussion. Each educator offered their unique perspectives and experiences, contributing to the development of a more thorough and effective lesson plan. *"For me, I think this could be very good, as you know, students cannot evaluate us as we are the more knowledgeable. Students do not know much about what you are teaching them; however, if there is someone with the knowledge like yours who is sitting in that class to evaluate you, it is good for you and him as well"* (Lecturer C). The evaluation process referenced by Lecturer C commenced with Appendix F below.

Figure 13 *Lesson Study Observation Checklist (Appendix F)*



Appendix 4 Lesson Study Observation Checklist

Purpose: to record observed teacher performance during the lesson study observations

Date:	Observation:	Observer:	Educator observed:
		[redacted]	
The topic of the Observed Lesson:			
Core Subject Area of Observed Lesson:			Start time:
Grade/ level of Observed Lesson			End time:

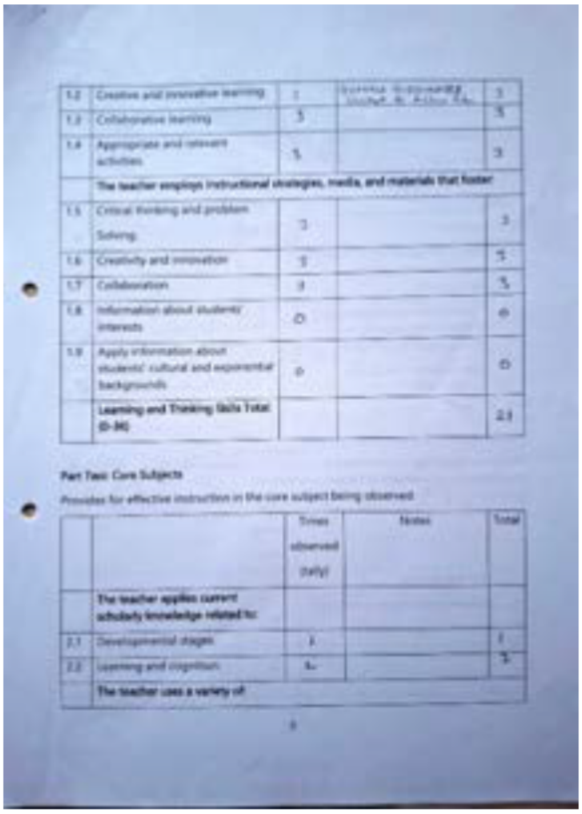
Use the scale below to record teacher performance during the lesson study observation.

No evidence	Not observed during the lesson	0
Very little evidence	Observed 1 time during the lesson	1
Some evidence	Observed 2 times during the lesson	2
Much evidence	Observed 3 times during the lesson	3
Considerable evidence	Observed 4 or more times during the lesson	4

Part One: Learning and Thinking Skills

Demonstrates knowledge of a wide range of instructional practices, approaches, methods, technologies, and curriculum to support learning and improve thinking skills

		Times observed (tally)	Notes	Total
	The teacher provides for student activities that allow for:			
1.1	Critical thinking that leads to Problem solving	3		3

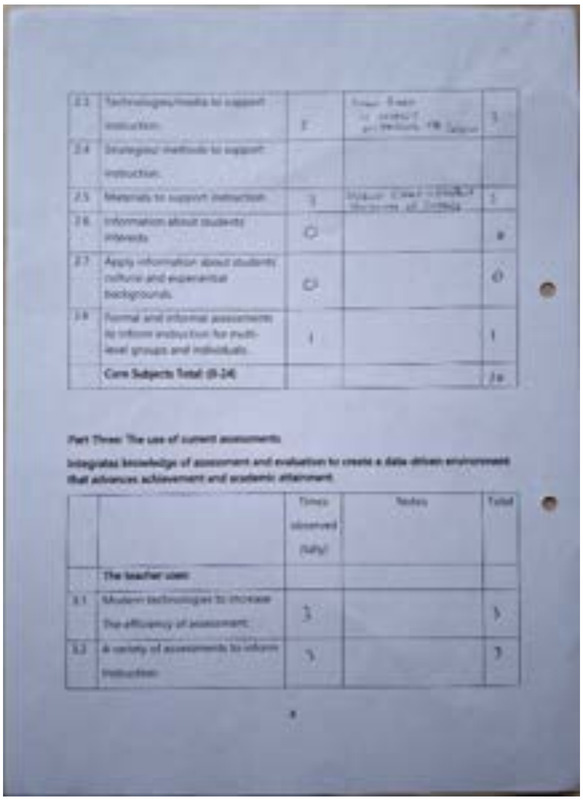


1.2	Creative and innovative learning	1		1
1.3	Collaborative learning	3		3
1.4	Appropriate and relevant activities	3		3
	The teacher employs instructional strategies, media, and materials that foster			
1.5	Critical thinking and problem Solving	3		3
1.6	Creativity and innovation	3		3
1.7	Collaboration	3		3
1.8	Information about students' interests	0		0
1.9	Apply information about students' cultural and experiential backgrounds	0		0
	Learning and Thinking Skills Total (0-36)			21

Part Two: Core Subjects

Provides for effective instruction in the core subject being observed

		Times observed (tally)	Notes	Total
	The teacher applies current scholarly knowledge related to:			
2.1	Developmental stages	1		1
2.2	Learning and cognition	2		3
	The teacher uses a variety of			

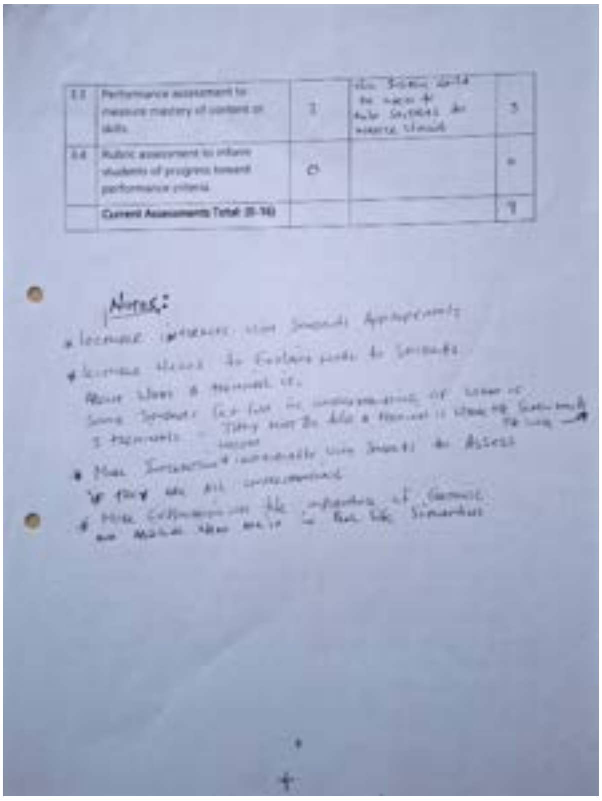


		Times observed (tally)	Notes	Total
2.3	Technologies/media to support instruction.	2	[illegible]	3
2.4	Strategies/methods to support instruction.			
2.5	Materials to support instruction.	3	[illegible]	1
2.6	Information about students interests.	0		0
2.7	Apply information about students cultural and experiential backgrounds.	0		0
2.8	Formal and informal assessments to inform instruction for multi-level groups and individuals.	1		1
	Core Subjects Total: (8-24)			[illegible]

Part Three: The use of current assessments

Integrates knowledge of assessment and evaluation to create a data driven environment that advances achievement and academic attainment.

		Times observed (tally)	Notes	Total
	The teacher uses:			
3.1	Modern technologies to increase the efficiency of assessment.	3		3
3.2	A variety of assessments to inform instruction.	3		3



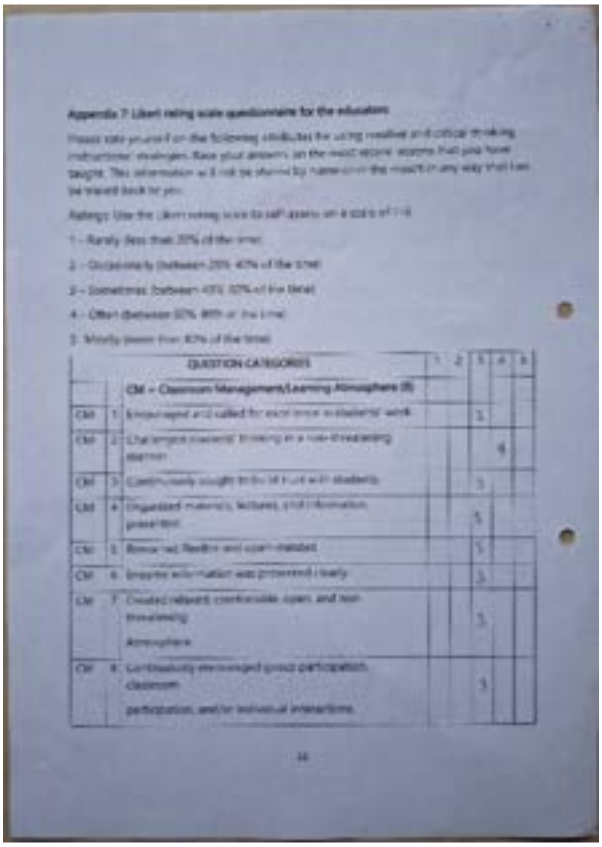
3.3	Performance assessment to measure mastery of content or skills.	3	[illegible]	3
3.4	Rubric assessment to inform students of progress toward performance criteria.	0		0
	Current Assessments Total: (8-16)			[illegible]

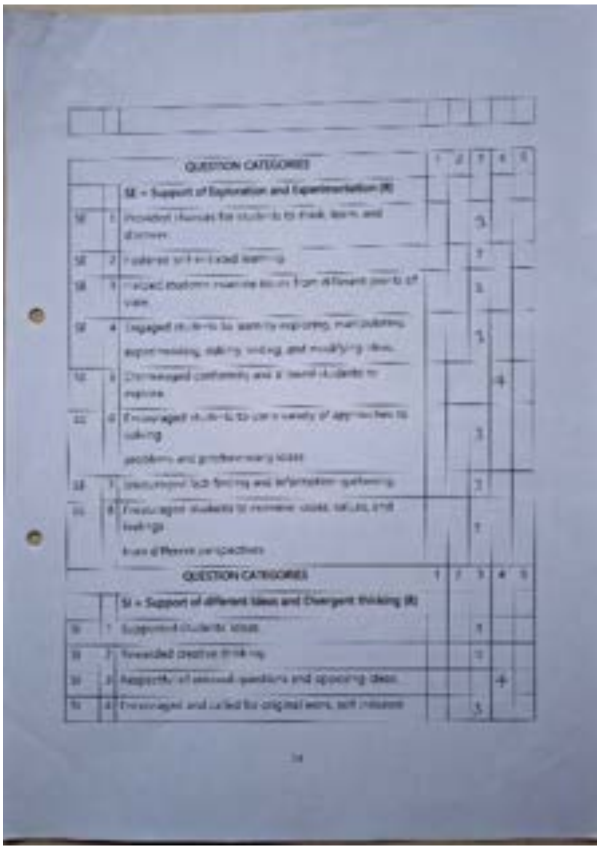
Notes:

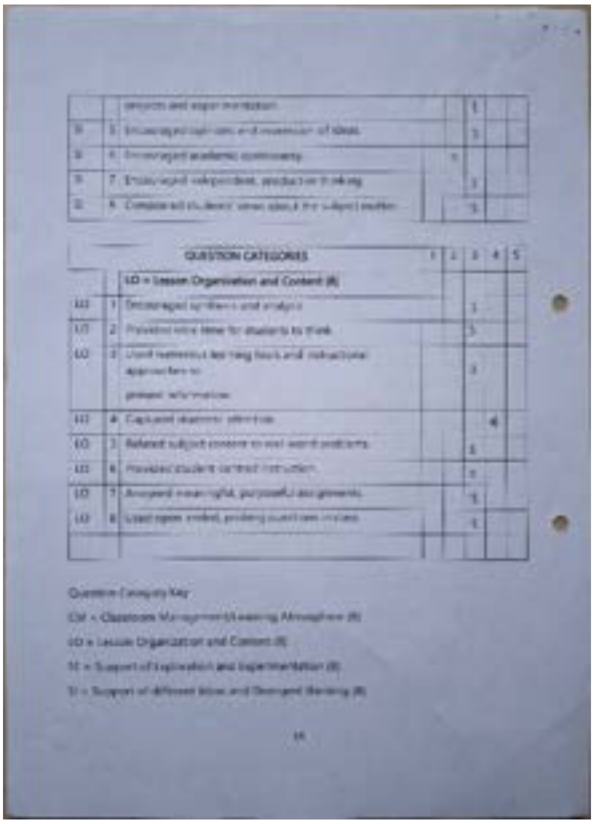
[illegible]

The exchange of successful practices and strategies elevated the overall quality of teaching. Collaboration within LS entailed joint problem-solving. Teachers collaborated to pinpoint potential difficulties and misunderstandings that students might encounter. *"When teaching [diagrams], you only touch on this, this, and that. Furthermore, I am touching this, this, and that, and I am touching [on] this. [However], let us emphasise this. Let us get them to do this method"* (Lecturer E). By addressing these issues, as seen in Appendix G below, they brainstormed and devised innovative solutions.

Figure 14 *Likert Rating Scale Observation Questionnaire for the lecturer participants*







This collaborative problem-solving process ensured that multiple perspectives were considered, resulting in more effective and creative teaching and learning strategies. *"When we sit together and review it, it is an open forum. No one should get offended, and we can ask why your way is different [from mine]. We can thrash it out; finally, it is improved when put forward"* (Lecturer A).

Teacher collaboration promoted a culture of reflective practice. Following a lesson, educators came together to reflect on what went well and what could be improved. *"My contribution was based on what the regulations states on whether you can connect the input and output on the top or the bottom of the circuit breaker"* (Lecturer C). *"You are saying you are taking out the power, yet you are energising the stop button. You must clarify these aspects"* (Lecturer F). This reflection was informed by analysing student responses and data collected during the lesson. Reflective practice catalysed educators to assess their instructional strategies and interactions with students, fostering ongoing professional development. By engaging in collaborative dialogue, teachers participated in professional discourse, which facilitated their growth and enriched their teaching practices. Through this exchange of experiences, educators gained new perspectives that deepened their comprehension of teaching and learning, ultimately contributing to their continuous improvement as practitioners, as indicated by Lecturer A below:

We sat together in a group with all the other subject matter experts. Each one had a chance to air their opinions. We met in one venue. We had individuals who brought forward a point, explaining how and why it should be used. Other members of the group would listen, and if there were anything that they weren't sure about, they would tear it to pieces [interrogate] until we arrived at a common understanding or agreement.

This ongoing professional development helped teachers stay current with the latest educational research and pedagogical approaches, enabling them to implement enhancements to student learning in their classrooms.

Collaborative work enhanced teacher motivation and morale. Teachers frequently experienced a sense of support and encouragement from their colleagues, which alleviated feelings of isolation and reduced stress. This collegial environment bolstered individual well-being and cultivated a positive and proactive attitude towards teaching and learning. Such a supportive atmosphere fostered a more dynamic and engaging educational experience, benefiting student outcomes. The mutual exchange of ideas and resources amongst educators helped create a sense of community that reinforced their commitment to professional growth and student success. *"If we add a few more people, we would have more feedback. However, [this was] a good starting place. I see this as an evolving, constantly changing process for improvement. No person by himself can say he knows everything. It has got to be a collective approach"* (Lecturer A). Motivated and valued, lecturers were enthusiastic and effective in their vocation.

Collaboration in LS resulted in the creation of more engaging and student-centred lessons. Teachers developed activities and materials tailored to students' diverse needs. Anticipating various student responses and planning accordingly created lessons that actively engaged students in the learning process. Engaged students constructed knowledge through meaningful interactions and activities. *"The two-way switch also helped us to develop a parts list"* (Student 1). This collaboration fostered a community of practice where student learning was enhanced, professional growth was supported, and teachers continuously shared resources, ideas, and feedback, creating a sustainable environment for ongoing collaboration and knowledge construction. *"There are different methods of teaching. I might be a direct teacher who only* *focuses on the textbook. [However,] when you get different views about what could have been omitted, then you understand what you need to address or fix"* (Lecturer E).

Collaboration played a pivotal role in promoting the use of data to inform teaching practices. By collaboratively analysing student work and assessment data, educators were empowered to make well-informed decisions about adjusting their instructional strategies. Data-informed decision-making ensured that teaching practices were grounded in evidence, contributing to more effective instruction and improved student outcomes. *"Students need to be told that although we [are] using this symbol for a switch, it can also be used as a circuit breaker. This must be clarified"* (Lecturer F).

Teacher collaboration leveraged the collective expertise of educators while fostering a culture of reflective practice and professional growth. This collaborative approach enhanced student engagement by enabling teachers to design more inclusive and responsive lessons that addressed the diverse needs of their students. As a result, the learning experience became richer and more dynamic for all participants, with teacher collaboration encouraging active participation in the construction of knowledge.

5.6.1.3 Lesson Study Developed Improved Instructional Strategies. LS plans to connect to student understanding whilst developing improved instructional strategies that involve systematic learning outcomes and engagement, starting with clear learning goals. Areas where students typically struggled and needed more support were identified. *"In the first lesson, you gave us a large wiring diagram, which made it easier for us to see those connections. In the second lesson, you asked us to draw it. This confused us slightly"* (Student 1). This insight led to strategy sharing and the production of richer, more effective lessons through observation and engagement about what worked and what did not.

Designing engaging and differentiated instruction was another crucial step, which incorporated a mix of direct instruction, group work, hands-on activities, technology, and planning for varied instructional approaches that met the diverse needs of students. *"Before you start, you need to compile the portfolio assessment, discuss what you assess. And that happens over 10 to 14 weeks"* (Lecturer B). Planning for active learning was necessary. Designed student-centred activities required students to actively engage with the content through discussions, problem-solving, and hands-on tasks. *"It was the first time that we had done a practical. I did not understand how the components functioned, and how to connect them, but when we started to work with them, I started to understand better"* (Student 2).

Support structures were provided to help students build on their prior knowledge and gain a deeper understanding. Reflective practices enhanced student learning. *"Figuring out everything during the practical together was helpful. Each member of the team contributed to the completion of the task"* (Student 4). This encouraged students to reflect on their learning process, understand their own thinking, and receive timely and specific feedback to guide their improvement. Teacher reflection focused on the effectiveness of lessons in meeting learning goals. The lesson was evaluated and revised after it was taught. The process was documented and shared. Detailed records of the lesson plans, student responses, and reflections were shared with the campus educational community to contribute to ongoing professional development. *"I would implement it in the robotics program immediately. We have new lecturers there. We also have lecturers from other colleges"* (Lecturer B).

LS aided in choosing and arranging instructional strategies from easy to challenging. The lessons were logical and scaffolded, effectively helping students learn. Lecturers planned, observed, and improved lessons, shared diverse viewpoints and determined the most effective ways to introduce new concepts and theories and adapt to technological change. Lessons started simply and gradually progressed to more complex ones, making learning more engaging for students focused on applied competence. LS aligned lesson plans with educational standards and benchmarks, ensuring all students were well-prepared for future learning challenges. This structured approach ensured that lessons were well-organised, coherent, and effectively supported student learning progression. *"The circuit diagram was one of the changes for me. The first time, I felt clueless. The second time, it felt okay. I know you explained it to us the first time, but the second time felt very different from the first. The change was on how to read the diagram the second time"* (Student 3).

LS advanced student thinking by providing a structured, collaborative framework for teachers to build a knowledge base about student thinking, implementing and refining instructional strategies. This process emphasised deep understanding, active engagement, and continuous improvement in teaching practices. Lecturers collaboratively designed lessons based on best practices that ensured multiple perspectives were considered, leading to more comprehensive and effective instructional strategies. *"When they meet, you find everyone brings their expertise, and we can take the positives from that and cancel what is negative"* (Lecturer C). Important concepts and skills were identified that students needed to prepare for future learning with a deep understanding of the teaching materials and sequences. This approach emphasised student-centred learning, encouraging conceptualisation and better understanding through discussions, problem-solving, and hands-on activities.

Lecturers observed students in real-time during LS, gaining valuable insights into student thinking. Immediate feedback adjusted instructional strategies, tailoring lessons to advance student thinking effectively. By reflecting on a lesson's effectiveness and discussing what worked and what did not, teachers used concrete evidence, such as student work and classroom interactions, to improve their strategies to support and challenge students' thinking. *"The other thing was you said that although we used the fuse, we are leaving it out and not discussing it* *because we are not using it in this circuit, but it would have been better for me if you explained what it is and why it's there"* (Lecturer F).

Formative assessments provided ongoing feedback on student understanding throughout the lesson. These assessments helped teachers identify areas that needed support to adjust their instructional strategies and promote critical thinking skills. Developmental techniques scaffolded student learning effectively. *"We can use a sort of tea strainer to find out what the little bits are that hinder the whole process of this teaching"* (Lecturer A). Initial support through guided practice gradually transferred responsibility to students as they became more proficient. This approach helped students build confidence and competence, enabling them to tackle complex problems and think independently. *"The circuit diagram was one of the changes for me. The first time, I felt clueless. The second time, it felt okay. I know you explained it to us the first time, but the second time felt very different from the first. The change was in how to read the diagram the second time"* (Student 3). This comprehensive approach ensured that instructional strategies were continually improved to support and enhance student thinking effectively.

LS enhanced the development and implementation of instructional strategies, leading to a notable improvement in declarative memory. *"So, after I completed this lesson, I asked myself why we did two-way switching. I was curious to know what the main purpose is for doing these things. I asked myself why I am doing this"* (Student 3). LS demonstrated cooperative and methodical preparation. Meticulously planned lessons highlighted facts, concepts, and events for students to retain, improving declarative memory. Enhancing instructional strategies improved declarative memory, crucial for students' academic achievement.

Lecturers established clear learning goals, provided explicit instruction and implemented evidence-based teaching methods such as spaced repetition and retrieval practices to improve memory retention (Agarwal et al., 2012). Lessons included tasks that promoted active content engagement, such as conversations, assessments, and practical exercises. *"It was the first time that we had done practicals. I did not understand how the components functioned, and how to connect them, but when we started to work with them, I started to understand better"* (Student 2). Active participation helped to improve retention by creating a more dynamic and interactive learning experience. Real-time student observations enabled quick adjustments for memory retention. *"The other thing was you said that although we used the fuse, we are leaving it out and not discussing it because we are not using it in this circuit, but it would have been better for me if you explained what it is and why it's there"* (Lecturer F).

Complex information when broken into smaller segments provided structured support and ensured that students understood basic concepts before moving on to more advanced material. Inclusivity diminished anxiety and boosted motivation, improved memory retention and enhanced declarative memory. Instructional strategies included visual aids, hands-on activities, discussions, and technology integration, catering to different learning styles and preferences to improve comprehension. However, LS may lead to fragmentation, causing confusion and a lack of coherence in the curriculum. *"It was easier working with the diagram on a piece of paper, but when we watched the video and tried to follow the connections as the wires moved from one component to the next, it became too much, and there were so many wires that were being connected that it became confusing"* (Student 2). Diverse instructional strategies may hinder mastering a specific teaching method, reducing in-depth comprehension.

LS entrenched metacognition, helping students to think about their thinking and employ better-developed metacognitive skills, such as flexibility, innovation capacity, continuous learning, challenge-seeking, and creativity. *"So, after I completed this lesson, I was asking myself why we did two-way switching. I was curious to know what the main purpose is for doing these things. I asked myself why I am doing this"* (Student 3). Students reflected on their learning process and used strategies like summarising, questioning, and predicting, helping students improve comprehension. *"The diagram on the board made it simple. So, you can picture it in your head if you know what those components are"* (Student 1). LS cultivated an engaging learning atmosphere with lively classrooms and various instructional methods, promoting inquisitiveness, inter-thinking and active student participation. Although immediate modifications were beneficial, standardised assessments became challenging.

LS improved comprehension-facilitated action by providing a collaborative framework for wiring diagrams. Visualisation can be considered not only as a cognitive tool in science education but also as an epistemic object that can potentially support students to understand aspects of the nature of science. Active learning facilitated better comprehension and application of knowledge. *"Figuring out everything during the practical together was helpful. Each member of the team contributed to the completion of the task. If we had individually connected the circuit, it would have been time-consuming as most of us had never done this before. Figuring out with fellow students was fun and educational"* (Student 4). The iterative process integrated into LS required a more reflexive, transformative framework if its full effect was to be achieved.

Scaffolding techniques offered initial assistance and gradually transferred responsibility as students acquired proficiency. *"It was the first time that we had done practicals. I did not understand how the components functioned and how to connect them, but when we started to work with them, I started to understand better"* (Student 2). This approach fostered confidence and expertise, promoting independent thinking. Lecturers were cognisant that scaffolding techniques may inadvertently limit students from taking full ownership of their learning. By guiding students to consider their understanding and actions, educators assisted them in developing heightened self-awareness and control over their learning. This self-reflection translated comprehension into practical skills. *"I did ask myself, is this three-phase? That was the question I had. The picture in my mind was completely different from what I found in the* *workshop"* (Student 3). The emphasis on metacognitive approaches may be time-consuming and detract from instructional time, potentially hindering content coverage and student engagement in LS.

Lecturers structured conceptual comprehension and active participation to promote deep learning using deep and surface processing concepts, and the influence of internal and external variables. Deeper processing yielded better learning outcomes whilst more shallow processing did not (Dunlosky et al., 2013). Learning tasks challenged thinking and problem-solving. *"It was confusing; however, it was better when we got to the practical task. But in the class, watching that video was confusing. I do not think I would have understood it on my own"* (Student 3). Graphicacy helped understand complex concepts. Whilst collaboration is a core component of LS, too much emphasis on teamwork may lead to groupthink or the suppression of innovative teaching approaches. Teachers should have more autonomy in designing and implementing instructional strategies.

Although students were encouraged to reflect on their learning process and understanding through self-evaluations and group discussions, it was apparent that metacognition, self-regulation, and self-regulated learning were not always explicitly understood. Lecturers promoted a classroom environment that valued effort and resilience and encouraged collaborative learning. Measuring LS's direct impact on student learning outcomes proved challenging, making it difficult to justify the time and resources invested in this approach without evidence of improved academic performance.

Insights and successful strategies were exchanged on how deep and surface processing aids or hinder learning in various situations. Continual professional development improved instructional techniques that clarified definitions, identified types of measurement used, searched for evidence supporting validity and imposed academic discipline. The successful implementation of LS needs support from educators who are comfortable with traditional teaching methods or sceptical of novel approaches. *"Some lecturers are stubborn. Even though you are dealing with the same thing, there are some lecturers who, when you try to explain something, do not want to take it in because they always think they are right"* (Lecturer E). Critics argue that LS emphasises the teaching process rather than the content. They suggest that teachers should prioritise delivering comprehensive content knowledge to students over refining instructional techniques. What has been missing is a theory that could explain the effects of teachers' actions on student learning in a useful way.

Students improved learning through vivid mental images and formulated mind pictures through creative strategies. Using descriptive and colourful language, lecturers sparked students' imaginations, allowing them to visualise the material more clearly. *"We saw a video on how to connect the direct-on-line [wiring diagram]. That made it much easier to make the connection"* (Student 4). Image literacy brought complex ideas to life when students conceptualised different scenarios, making learning interactive and memorable. *"The diagram on the board made it simple. So, you can picture it in your head if you know what those components are"* (Student 1).

Electrical drawings and diagrams expressed the student's knowledge and conceptualisation. However, students may not always see what the instructor demonstrates, particularly when the involved scientific principles are profound. Although mental images were created, resulting in a deeper understanding and better material retention, it was pivotal that sophisticated and sufficient instructional guidance was always provided, regardless of students' prior learning experiences.

Not all students responded well to image literacy; some found it distracting or confusing, and an over-reliance on image literacy overshadowed the importance of auditory or kinaesthetic learning. Critics questioned how skills developed through graphicacy transferred to real-world contexts or other learning domains. These studies suggest that synesthetic communication can lead to the oversimplification of complex concepts and hinder students' development of conceptual skills. *"It was easier working with the diagram on a piece of paper, but when we watched the video and tried to follow the connections as the wires moved from one component to the next, it became too much, and there were so many wires that were being connected that it became confusing"* (Student 2).

Whilst these counterarguments raise valid concerns, proponents of visualisation techniques argue that when used thoughtfully and in conjunction with other instructional methods, they can be valuable tools for promoting learning and enhancing students' understanding of complex concepts. The conceptual meaning of this instructional approach was impacted when comprehension was prioritised over memorisation. Lessons were structured and intertwined around pivotal concepts and frameworks, such as PLC, multimedia learning theory and DCT. *"Key questions to ask. Where does this fit in? What do I need to teach you before I have brought you to this teaching on circuit diagrams?"* (Lecturer F). In this electrical engineering class, educators utilised theoretical frameworks demonstrating how each aspect of the curriculum related to the central concept of wiring diagrams. Students were urged to question, analyse, and assess information rather than receive it passively. *"I think the students could have been given a little bit of time to apply the knowledge. We need to determine how they would assimilate the knowledge and draw that circuit"* (Lecturer C). Lecturers identified subject correlations. *"I think this research can be transferred to other programmes as well"* (Lecturer D), and identified terminologies used to distinguish conceptual differences in teaching content. This research project required students to apply concepts to real-world industrial activities and practical applications.

The lesson plan leveraged students' knowledge and gradually introduced more advanced concepts. Lecturers integrated and crafted captivating, efficient, and meaningful learning experiences improving conceptual comprehension and long-term knowledge retention.

Focusing solely on conceptual meaning in instructional strategies has advantages. However, lecturers addressed opposing viewpoints and perspectives.

5.6.1.4 Lesson Study Fosters Strong Institutional Support. Lecturers realised that to implement LS effectively, they would need to manage their time strategically. *"I think our time frames looked at ideal situations. However, in the real world, things change"* (Lecturer B). The reality of implementing professional learning initiatives requires sustained commitment over extended periods, not merely brief interventions. Administrators managing non-teaching responsibilities can free up lecturers' time, allowing them to focus on instructional activities and planning. *"We are talking about time here, and those two or three weeks of invigilation could be time that we could utilise. In that instance, we are not wasting time. However, we are preparing ourselves to become better lecturers for the advantage of our students"* (Lecturer C).

Access to educational technology enabled lecturers to save time on preparation. *"I like how you use these smart boards because they bring us into a real-life situation"* (Lecturer A). Collaborative planning improved the quality of instruction and time management through the sharing of ideas, the division of workload, and the development of cohesive instructional strategies.

Lecturer A shared an administrative challenge*: "We cannot have combined meetings within the college [as English or Mathematics lecturers do]."* Efficient administrative processes, clear policies and procedures, and streamlined communication reduced bureaucratic delays and confusion, positively impacting time management. This was evident in the disconnect between the syllabus and examination requirements. *"Many times, I must remind myself that I just need to stick to what is relevant to the module. Sometimes I must caution myself that the* *wealth of information I have gained through industry might not be relevant to certain exam questions"* (Lecturer A). Healthy work-life balance, constructive feedback, and efficient evaluation systems improved and optimised time management, enhancing instructional quality.

Management support proved critical for successful implementation. *"Some have large workload[s], some of the lectures have urgent [matters to address], but if it gets rubber-stamped by the campus manager. He must sit down [his staff] and say, guys, look, this is what will be. So, do not consider it tedious when you get called for this. [But an instruction] from the campus manager [which must succeed and not become a] failure at training"* (Lecturer A). Three members of our CMT (Campus Management Team) were part of our lecturer participant cohort, demonstrating institutional commitment. However, resource constraints can hinder effective implementation even when support is available. Moreover, excessive institutional support can undermine teacher autonomy and lead to dependency, whilst one-size-fits-all approaches often fail to address the specific needs of individual teachers or schools. Bureaucratic inefficiencies add to teachers' administrative burdens, leading to increased stress and reduced time for instructional activities. *"Otherwise, it becomes a thing where people wonder how am I going to do this when I am so long away from my class?"* (Lecturer A).

Professional development structures also played an important role. *"But nowadays, we have different committees. I have been tasked with aiding the new lecturers in terms of the portfolio of evidence, portfolio of assessment, and resource files. So, there is a support structure"* (Lecturer B). Providing focused development expanded teachers' conceptions about their professional growth and ensured educators had the skills and knowledge to fulfil the institution's objectives. This encompassed training on the most recent industry practices, innovative technologies, and effective teaching methodologies. *"The way I prepared to introduce it was not how he showed me how to do it. He showed me an easy way to do it. When we met, he corrected what was right and wrong. It was for the benefit of the student"* (Lecturer C). Well-trained educators can deliver high-quality instruction that adheres to industry standards, thereby enhancing student readiness for the professional environment. However, differences in the nature of work, time scheduling, and challenges created barriers to collaboration. *"We cannot have combined meetings within the college as English or mathematics lecturers do"* (Lecturer A).

Strong commitment from the administration emerged as another important factor. Administrators provided the necessary support and resources for the institution to achieve its goals. *"We also can apply it to the LMS system. We can also use this for our online platform, which needs to be revised. We need to get Academic Board approval so that it can be applied across campuses"* (Lecturer B). Effective collaboration occurs when tasks are complex enough to warrant the extra time and effort required for collaborative activities. When everyone understood the institution's direction and priorities, it fostered teamwork and collective problem-solving. *"Remember, we are tied to all the other colleges, and the other colleges teach the same curriculum. It is nice to take it to the higher authorities in DHET. Wherever stuff is identified, that will enhance students' and lecturers' norms and outcomes"* (Lecturer A).

Regular communication ensured that all stakeholders were well-informed and engaged. Structured frameworks and protocols, alongside effective monitoring and evaluation, greatly enhanced educational institutional support by bringing clarity, uniformity, and continual improvement. Initially, they established clarity and consistency. *"The lesson plan we constructed was good and within the design parameters. Notational hours were also made* *available for contact time. That will guide the construction of the modules. There is an NQF system we follow"* (Lecturer B). These guidelines ensured everyone understood their roles and responsibilities, leading to a more organised and efficient educational environment.

"Prior to this, we studied the concept of making a Lesson plan, and that was done according to the institution and their rules and regulations and their guidance and support, which we implemented" (Lecturer B). This standardisation facilitated easier training and onboarding of inexperienced staff, as they had a clear reference for institutional practices. Moreover, they created a system of accountability. *"Also, best practices [standardisation] are created where you would find that a lesson done in the Nated programme will also be similar if not identical to that conducted in the NCV programme. There is now uniformity there. This also adds value to the institution"* (Lecturer B). Frameworks and protocols set clear guidelines and expectations, making it easier to hold individuals and teams accountable for their performance.

Structured frameworks identified specific areas where educators needed additional support or training. *"From a manager's point of view, we could see what they call the didactical supervision that one would give to a group of people"* (Lecturer B). Monitoring and evaluation highlighted gaps in knowledge or skills, allowing institutions to design targeted professional development programmes and enhance overall education quality. *"It is easier to work with other students. When some of us were getting confused, other students knew something else they could add and contribute"* (Student 1). This engagement fostered a sense of community and shared responsibility for educational outcomes.

One counterargument is that structured frameworks and protocols create additional bureaucratic burdens for educators and administrators. Structured frameworks can sometimes be too rigid, leaving little room for flexibility and innovation. A notable drawback is that structured frameworks often adopt a one-size-fits-all approach. This can be problematic in diverse educational settings where the needs of students, teachers, and communities vary widely. Understanding and sustaining national adaptations of LS requires specifying conditions concerning the adapting country's teaching culture (Skott & Møller, 2020).

Table 4 below presents the integration of data codes and emerging themes related to Research Question 2, which explores how Lesson Study (LS) and Professional Learning Communities (PLCs) influence teaching cognition, instructional design, and long-term student learning outcomes. The table synthesises data from focus groups, interviews, and journal entries to reveal how participants conceptualised their teaching practices within these collaborative frameworks. The findings indicate that lecturers grappled with issues of extraneous cognitive load, emphasising the need to plan lessons that connect with students' existing understanding and sequence content from simple to complex, reflecting principles from Dual Coding Theory (DCT) and Multimedia Learning Theory (MLT). Participants also described a growing awareness of the long-term impact of adaptive teaching, where anticipating student responses and advancing higher-order thinking skills fostered flexibility and responsiveness. Discussions on inclusive practices highlighted efforts to engage all learners through differentiated instruction and increased understanding of LS as a reflective, student-centred process. The incorporation of technology and multimedia was linked to more effective teaching strategies and real-world application, underscoring the role of instructional design and PLC support in improving practice. Conversely, some participants noted instances of rigid or closed learning, where duplication of materials limited creativity and deeper learning, suggesting tension between surface and deep approaches to teaching. Finally, references to collaborative work and lecturer expectations revealed both genuine cooperation and elements of contrived collegiality, indicating that while collaboration was encouraged, authentic professional dialogue required stronger cognitive and institutional scaffolding. Overall, the table illustrates how LS and PLC participation impacted teachers' cognitive development, pedagogical flexibility, and ability to design inclusive, conceptually rich learning experiences.

Table 4 *Combined codes and amalgamated themes for research question 2*

Codes/Phrases/Patterns Focus group	**Codes/Phrases/Patterns Interviews**	**Codes/Phrases/Patterns Journal Entries**	**Themes RQ2**	**Conceptual Frameworks**
Extraneous processing overload	Planning to Connect to Student Understanding	Select and sequence simple to complex.	***Cognition***	***DCT MLT***
Long-Term Impact on Student Learning	Developing solutions to anticipated student responses	Advance student thinking.	***Adaptability and Flexibility.***	***DCT MLT***
Inclusive Practices	Student Understanding and Engagement	Understanding of LS	***Differentiated Instruction.***	***DCT MLT***
Technology and multimedia	Real-world Application	Effective Teaching Strategies.	***Instructional design***	***PLC***
Rigid or closed learning	Formulating mind pictures	Duplication of teaching material	***Deep and surface learning***	***DCT MLT***
Collaborative work	Lecturer expectations		***Contrived collegiality***	***DCT MLT***

5.6.2 Analysis of Research Question 2

How can cognitive load theory and instructional design theories specific to diagrams and illustrations be integrated to improve the effectiveness of LS for teaching electrical wiring diagrams?

5.6.2.1 Cognition

5.6.2.*1.1 The Working Memory and the Link to Long-Term Memory.* Working memory processes sensory information before it is lost forever or successfully transitioned into our long-term memory. Working memory has a limited capacity and a limited lifespan, whilst long-term memory retains information. Efficiently organising information from working memory into long-term memory sequentially is a process that involves cognitive load. Cognitive load theory aims to explain how the information-processing load induced by learning tasks affects students' ability to process new information and construct knowledge in long-term memory (Sweller et al., 2019). *"With you explaining it step by step with the logic behind it, it created a better understanding for me as a student"* (Student 1).

Cognitive load has subcategories. The first is intrinsic load, which relates to the information content itself and is determined by the number and complexity of the elements that must be processed simultaneously in the working memory. This cognitive load is inherently and intrinsically built-in, inseparable from the information you are trying to learn. Sweller et al. (2019) argue that intrinsic cognitive load is determined by both the complexity of the information and the individual's knowledge in processing that information. *"The diagram on the board made it simple. So, you can picture it in your head if you know what those components are"* (Student 1). If you are trying to memorise the first twenty elements of the periodic table, the intrinsic load is the minimum mental effort required to memorise those facts.

5.6.2.1.2 Extraneous and Germane Load. Extraneous or extrinsic load refers to any mental effort not inherent to the intrinsic learning tasks and can be changed by changing instructional procedures (Sweller et al., 2019). Regarding the periodic table, unrelated information about the elements is an extraneous load. However, if the learner is hungry, tired, stressed, or has disabilities, these can also be forms of extraneous load. *"In the first lesson, you gave us a large wiring diagram. That made it easier for us to see those connections. In the second lesson, you asked us to draw it, and I think this confused us slightly"* (Student 1). This required extra mental effort. In audiovisual aspects, interference can impact extraneous load. This refers to unnecessary pictures, flashing lights, colours, or anything else distracting. *"It was easier working with the diagram on a piece of paper, but when we watched the video and tried to follow the connections as the wires moved from one component to the next, it became too much, and there were so many wires that were being connected that it became confusing"* (Student 2).

The more nuanced of the three subcategories of cognitive load is germane load. It is the additional mental effort used to facilitate learning rather than that which is intrinsic to the information itself. Germane cognitive load redistributes working memory resources from extraneous activities to activities directly relevant to learning (Sweller et al., 2019). For extraneous load, more is usually worse. However, an optimal quantity is desired for germane load as too little will result in the learner not getting enough information to comprehend the concept. *"The circuit diagram was one of the changes for me. The first time, I felt clueless. The second time, it felt OK. I know you explained it to us the first time, but the second time felt very different from the first. I felt the change was in reading the diagram the second time"* (Student 3). Educators use fun animations, videos, and interactive games to exploit germane load.

5.6.2.1.3 Schemas in Cognitive Load. Working memory has an unlimited capacity but a limited time frame. The learner uses any educational sensory input, such as a PowerPoint presentation, video, or textbook, to identify relevant information (intrinsic) while removing extraneous material. *"We saw a video on how to connect the direct-on-line. That made it much easier to make the connection. I also understand now that circuit diagrams are an international language that electrical engineers or electricians use to understand certain connections they will focus on"* (Student 4). Long-term memory waits for nicely packed information to be stored. To overcome information loss, educators use schemas. Schemas enable a streamlined understanding and processing of familiar information, while quickly adapting to new experiences. Schemas allow individuals to organise vast amounts of information into coherent categories or structures. *"I think in the first lesson there was a little bit of confusion because we had not considered prior knowledge. Also, there was much information in a short period"* (Lecturer C). When encountering new information, individuals either integrate it into an existing schema (a process called assimilation) or adjust their schema to accommodate the new information (accommodation).

5.6.2.1.4 Solution Development of CLT, MLT, and DCT. All learning theories contributed to the development of solutions for anticipated student responses and challenges by focusing on how students process, understand, and retain information. Each theory offered strategies to address common learning obstacles, support comprehension, and facilitate long-term retention.

5.6.2.1.5 The Role of Cognition Utilising Cognitive Load Theory (CLT). CLT managed cognitive load, reducing overload, a common learning challenge, by limiting the amount of information processing at once. CLT eliminated potential points of overwhelm or confusion. *"We reassigned other parts of the information initially shared to a following* *lesson, which helped to remove confusing aspects. I think the students started to enjoy the lesson better because the knowledge shared on that day was specific and targeted for that lesson"* (Lecturer C). CLT advocated scaffolding tasks and progressing from simple to complex ideas. *"Start at the basics, like building a house where you start at the foundation"* (Lecturer D). This ensured students built a solid foundation, reducing frustration and enhancing understanding. CLT excluded unnecessary information (extraneous load) that could conceptually distract.

> The first part of the video showed us that the connection from the circuit breaker comes out from the top and then goes into the contactor. I found this very confusing because we had previously seen how it should have been coming from the bottom of the circuit breaker and entering the contactor. I did not understand that part because I was unsure how we would do it. How do you connect wires from the bottom when they should be coming from the top? (Student 3)

By eliminating irrelevant details, lecturers prevented misunderstandings and cognitive fatigue. Information was sequenced from simple to complex, gradually increasing in complexity to support efficient learning and reduce cognitive overload. *"With your explanation, it was easier. If I were going to read it alone, it would be difficult"* (Student 3). This instructional design approach is aligned with the learner's mental capacity to build foundational knowledge before tackling more challenging concepts. *"No, I did not find anything difficult. With you explaining it step by step together with the logic behind it, it created a better understanding for me as a student"* (Student 4). Learning to read, for instance, may involve starting with letters and sounds before progressing to words and sentences, and ultimately comprehending entire paragraphs.

The content is then sequenced to introduce more complex concepts. This gradual progression prevented cognitive overload and enabled students to relate the latest information to what they already understand. *"This lesson was a continuation from the previous module. If the student did not have the embedded knowledge before commencing with this lesson, they would have found it very challenging"* (Lecturer B). However, drawing pictures on paper while reading a text might represent a secondary task that imposes an additional cognitive load on the learner, competing with the cognitive resources required for the primary task of understanding the text.

5.6.2.1.6 Theoretical Basis of Dual Coding Theory in Lesson Study. DCT recognised that students had difficulty recalling or understanding information when presented in a single format, such as text alone. This theory suggests visual cognition presents information, offering multiple retrieval cues. Providing varied representations enhanced memory by allowing students to access information through different pathways. *"You can do things much quicker and then explain and then show pictures of things we are doing. It is much clearer to see than compared with classes where the teachers are using [only] whiteboards"* (Student 4). DCT encouraged the use of images, diagrams, and written explanations to cater to diverse learning preferences and address potential difficulties with abstract or purely verbal content. Concepts became tangible and easier to remember.

5.6.2.1.7 Practical Applications of Multimedia Learning Theory in a Classroom. MLT acknowledged that students' responses vary based on presentation. Multimedia instructional messages designed in light of how the human mind works are more likely to lead to meaningful learning than those not so designed (Mayer, 2014). The theory infers that students struggle if dual communication channels are overloaded or not well-integrated. "It was easier working with the diagram on a piece of paper, but when we watched the video and tried to follow the connections as the wires moved from one component to the next, it became too much and there were so many wires that were being connected that it became confusing" (Student 2). This theory recommends presenting information through dual communication formats, such as pairing narration with relevant images or diagrams. *"I put in for a smart board because I realised this is how it must go. For example, if you are using three types of chain pulleys, students can see it"* (Lecturer A). By creating materials that support both channels without overwhelming them, lecturers formed meaningful connections and reduced confusion. Specific design principles, such as the Coherence Principle (avoiding unnecessary media) and the Modality Principle (utilising multimodal communication), are employed to anticipate and address student responses to cognitive overload. *"With you explaining it step by step with the logic behind it, it created a better understanding for me as a student"* (Student 1). This design approach helped students retain information and reduced comprehension issues.

All three theories (CLT, MLT and DCT) contributed solutions that addressed anticipated challenges students encountered, such as cognitive overload, information retention, and content confusion. *"It was confusing; however, it was better when we got to the practical task. But in the class, watching that video was confusing. I do not think I would have understood it independently if I had done it individually"* (Student 2). Integrating these theories and instructional materials made learning more efficient, engaging, and effective.

5.6.2.2 Adaptability and Flexibility for Effective Teaching Strategies for Diagrams and Illustrations

5.6.2.2.1 Use of Visual Aids in Teaching Electrical Wiring.

Using visuals in teaching electrical wiring enhanced student understanding, retention, and skill acquisition. Electrical wiring involves complex concepts and technical skills that can be difficult to grasp without clear, structured guidance. Graphicacy simplified these concepts, improved comprehension, and provided a firsthand learning experience.

Electrical wiring encompasses abstract concepts such as circuits, current flow, voltage, and grounding, which can be challenging for students to grasp. *"The diagram on the [electronic white] board made it simple, [as] you can picture it in your head if you know what those components are"* (Student 1). Graphicacy made these concepts more concrete by clearly representing how electrical components connect and interact. Presenting information through dual channels improved retention. *"You see clearly how to connect. Without drawing it, we cannot practically connect it. It is easy to connect, looking at the diagram"* (Student B). Colour-coded wiring diagrams and labelled circuit layouts provided multiple ways for students to remember information, strengthening memory and recall. *"A live conductor should have a certain colour, and so to a neutral conductor, another colour, and the strappers should have another colour"* (Lecturer C). These aids served as mental models that students could reference during practical applications or assessments.

Electrical wiring often requires students to process numerous steps, technical terms, and safety protocols. Synesthetic communication reduced the mental load by organising information in an accessible way. *"Drawings can become more complicated as we use more sophisticated and advanced processes"* (Student A). Simplified wiring diagrams with clear labels and step-by-step instructions allowed students to process and understand the material without feeling overwhelmed. *"With you explaining it step by step with the logic behind it, it created a better understanding for me as a student"* (Student 1).

Graphicacy offered step-by-step instructions on wiring tasks when installing circuits, connecting switches, or troubleshooting. This gradual guidance, especially in video or animation format, provided learners with a model to follow, reducing mistakes and enabling them to develop practical skills with confidence and accuracy. Images such as safety icons, warnings, and colour-coding for live, neutral, and earth wires reinforced safety procedures and aided student recall of important precautions. *"Non-operating mode and de-energised are the same thing. So, the students listen to multiple terms, such as non-operating mode, energised, and de-energised. These terms must be explained further and in greater detail as they can be confusing. Remember this switch is in a non-energised state"* (Lecturer F).

Electrical wiring tasks require troubleshooting and diagnosing faults. Images like legend cards trained students to recognise patterns and identify problem areas. *"This process is continuous, especially with new things coming up, new machines being made, new drawings, legend cards and symbols that do eventually change"* (Lecturer A). By working through faults, students learnt systematic troubleshooting approaches for real-world applications.

Graphicacy supported diverse learning styles by presenting information in accessible ways beyond verbal instruction. *"I can see clearly whatever is projected on the screen. You can do things much quicker, explain, and show pictures of things we are doing. It is much clearer to see than compared with classes where the teachers are using whiteboards [only]"* (Student 4). Educators ensured that all students, regardless of learning style, engaged with the material effectively. Synesthetic communication helped students read and understand wiring diagrams, fostering autonomy and better preparing students to tackle independent projects or real-world wiring tasks.

5.6.2.2.2 Student Reactions and Adjustments to Instructional Approaches. During each stage, learners were provided with guided practice, gradually moving towards independence as they built confidence and understanding. The early stages involved direct instruction and worked examples, while the later stages allowed learners to apply their skills in independent problem-solving scenarios. *"It was easy together, but I prefer doing it alone.*

This will show me where I am lacking. With others, you share information about what you are doing, but if you do it independently, you get more experience" (Student B).

Students' reactions and adjustments varied based on learning styles, prior knowledge, and engagement levels when employing instructional approaches. *"We covered the aspect of prior knowledge. Students had to have embedded knowledge before coming to this lesson"* (Lecturer B). Understanding these reactions led to refined methods and optimised learning outcomes.

For lecture-based instruction, students appreciated structured, teacher-led lectures, especially those who preferred guided explanations. *"I think the students started to enjoy the lesson better because the knowledge shared on that day was specific and targeted for that lesson"* (Lecturer C). Others found lectures passive, challenging to follow, or tedious, particularly if they struggled to engage without interaction. To address varying reactions, lecturers incorporated active learning techniques, such as asking questions, encouraging note-taking, or using quick reflective pauses. *"After I completed this lesson, I asked myself why we did two-way switching. I was curious to know what the main purpose of doing these things was. I asked myself why I was doing this"* (Student 3). Adding multimedia, stories, or relatable examples made lectures more engaging and accessible.

Students enjoyed hands-on activities as this allowed for the practical application of concepts and suited kinesthetic learners. *"I did not understand how the components functioned, and how to connect them, but when we started to work with them practically, I started to understand better"* (Student B). However, some students were anxious, especially those uncomfortable with open-ended tasks or who lacked prior experience with the subject matter. *"There are some people who would not take part and they would have not learned anything" (*Student A). Educators scaffolded these experiences by providing clear instructions, modelling tasks first, or grouping students so they could learn collaboratively. *"It was a good idea because for most* *of us this was a new experience. Figuring out everything during the practical together was helpful. Each member of the team contributed to the completion of the task"* (Student 4). Regular check-ins and feedback also helped students feel more confident and engaged.

Social learning thrived in collaborative group settings. *"Figuring it out with fellow students was fun and educational"* (Student 4). However, some students felt frustrated and preferred to work independently or if they perceived that group members were not contributing equally. *"It was easy together, but I prefer doing it on my own. This will show me where I am lacking"* (Student B). Diagrams supported argumentative interaction between students when they discussed ill-defined topics. *"We were able to correct each other as we were reading the diagram"* (Student 3). Lecturers set clear expectations for group roles, established group norms, and offered tools to help students manage tasks fairly. *"We reassigned other parts of the information initially shared to a following lesson and this helped to remove confusing aspects"* (Lecturer C). Assigning roles and rotating them ensured balanced contributions and helped all students participate meaningfully. *"Each member of the team contributed to the completion of the task. If we individually connected the circuit it would have been time consuming"* (Student 4).

Students were highly motivated by project-based learning, allowing them to explore real-world problems, make connections, and take ownership of their learning. *"The atmosphere was good because the students were enjoying the lesson. Especially with the aspect of linking the theory knowledge with the practical. Students were looking forward to going to the next phase"* (Lecturer C). However, some students felt overwhelmed by the open-ended nature of this project, especially those who lacked experience with self-directed learning. *"I didn't understand how the components function. And how to connect them, but when we started to work with them practically I started to understand better"* (Student B). Students were supported by providing structured milestones, checkpoints, templates, self-assessment and asking questions.

Synesthetic communication made multimedia presentations, simulations, and interactive tools engaging. *"We saw a video on how to connect the direct-on-line. That made it much easier to go and do the connection"* (Student 4). Although some students experienced frustration and distraction with technology, lecturers provided practice sessions and endeavoured to keep multimedia elements simple and focused. *"We need to determine how they would assimilate the knowledge and draw that circuit. This is to determine if they can practically construct that circuit in their minds"* (Lecturer C).

5.6.2.2.3 Critique of Over-Reliance on Visual Aids and Cognitive Load Issues.

Over-reliance on graphicacy led to cognitive load issues (Sweller et al., 2019). *"I did at first but as we went further into the video I didn't understand it. Especially the part which showed how the conductors are connecting from one component to the other I didn't understand that"* (Student 3). When too many multimedia elements were used simultaneously, learners experienced cognitive overload. Excessive multimedia resulted in confusion rather than clarity. This was particularly problematic when visuals were complex, densely packed, or presented too rapidly for the learner to process effectively.

An issue arose when learners divided their attention between multiple sources of information, such as images, text, or data. Learners needed to interconnect the external representations and actively construct a coherent mental representation to benefit from multiple representations. *"In the first lesson, you gave us a large wiring diagram. That made it easier for us to see those connections. In the second lesson, you asked us to draw it. And I think this confused us a little bit"* (Student A). When students looked back and forth between a graphic and accompanying text or narration, they experienced the split-attention effect, which strained cognitive resources and reduced learning efficiency. Instead of enhancing understanding, graphicacy unintentionally hindered it when non-aligned with the learning material.

Overuse of images encouraged superficial rather than deep processing of information. *"We also have students who have a lack of thinking, lack of knowledge, lack of ability to solve problems. Students who rely on the lecturer always and who don't take the initiative to go and read and find out things for themselves"* (Lecturer C). Flashy or entertaining images captured attention but distracted from the core content or encouraged learners to remember only surface-level features. This resulted in an aesthetic focus rather than instructional value. *"It confused me a bit. I only did understand the colour coding part. There was too much information on the screen"* (Student 4).

Improperly chosen images were misinterpreted, especially when they lacked clear labels, explanations, or alignment with the subject matter. As the complexity of visual displays increased, cognitive load experienced by learners increased, requiring design techniques that could mitigate the impact of increased complexity. *"The video should have shown a step-by-step process"* (Student 4). Abstract, ambiguous, or stylistically overwhelming graphics misconceptualised rather than reinforced understanding. Deciphering overly complex graphics detracted from higher-order thinking tasks, like synthesis or analysis. *"I think the students could have been given a little bit of time to apply the knowledge. We need to determine how they would assimilate the knowledge and draw that circuit"* (Lecturer C). Synesthetic communication should streamline understanding rather than become a puzzle; otherwise, it impedes rather than enhances learning.

5.6.2.3 Differentiated Instruction's Impact on Declarative Memory and Curriculum Alignment. Lecturers ensured that differentiation was subtle and inclusive, encouraging a classroom culture where learning progressed differently for everyone. Choice and flexibility allowed students to select the best paths without feeling singled out. *"In a class, you can have students who are very bright and can solve problems quickly. However, you do have slower students, and when you group these students, then you will allow the slower students to quickly catch on and learn the techniques required to problem solve"* (Lecturer C).

Differentiation involved offering students multiple ways of taking in and expressing information. Educators examined four key areas: content, process, product, and environment. The goal was to identify where students were in their learning journey and create opportunities for forward movement.

5.6.2.3.1 Enhancing Declarative Memory through Spaced Repetition. The research revealed the importance of mastering basic skills to the point of automaticity, where learners could perform these skills without conscious effort (Feldon, 2007). By automating foundational skills, cognitive resources were freed up for more complex problem-solving. *"I realised why we were duplicating parts of that lesson, and that was to do the connections for the wiring itself. I realised it helped because we connected just the motor the first time, and now we would also include the indicator lights. Doing it the second time reinforced what we had done [in] the first"* (Student A).

5.6.2.3.2. Student Reflections on Retention and Comprehension When Engaging Wiring Diagrams. Student reflections on retention and comprehension when using electrical wiring diagrams revealed insights into how these tools impacted learning, engagement, and understanding. Many students reported that wiring diagrams made complex electrical systems more accessible by graphically representing the layout and connections. *"You see clearly how to connect. Without drawing it, we cannot practically connect it. It is easy to connect looking at the diagram"* (Student B).

This visual format helped students understand how different components interacted, making abstract concepts tangible. *"The diagram on the board made it simple. So you can picture it in your head if you know what those components are"* (Student A). When paths on a diagram were followed, the component's role within the system reinforced comprehension. Students recognised that consistent use of diagrams reinforced retention when concepts, such as circuitry, polarity, and connections, were revisited. *"If you take me to the real world and say connect a two-way switch. Then wake me up at night and say how a two-way switch operates. Then I can tell you because it is already in my mind"* (Lecturer E). Reflection allowed students to observe their progress, recognise recurring patterns, and deepen their familiarity with standard wiring conventions, enhancing long-term retention.

Wiring diagrams bridged theory and practical application, increasing student confidence in handling real-world wiring tasks. *"Students enjoyed the lesson, especially linking the theory knowledge with the practical"* (Lecturer C). This confidence stemmed from understanding that the mirrored actual circuits they would encounter outside the classroom made them feel prepared for practical situations. Working with diagrams required active involvement—tracing lines, identifying components, and diagnosing circuit paths. *"I realised why we were duplicating parts of that lesson, and that was to do the connections for the wiring itself. I realised it helped because we connected just the motor the first time, and now we would include the indicator lights as well"* (Student 1). This hands-on engagement enhanced comprehension and retention, as students were required to think critically and work through real-life issues rather than passively absorb information.

Students mitigated the mental transformation of verbal information that could lead to conceptual misunderstanding. *"We also have students who lack thinking, knowledge, and problem-solving ability"* (Lecturer C). This reliance indicated that, while diagrams were functional, students needed additional practice or instruction to reinforce the underlying principles and apply their knowledge even when a diagram was absent. The data suggested that consistent practice and exposure were crucial to mastering these elements and reducing the time spent decoding symbols instead of understanding circuitry. *"The drawing becomes a communication tool, like how you and I would communicate in English. This is an electrician's language"* (Lecturer F).

Reflections frequently highlighted the benefit of gradually increasing the complexity of wiring diagrams. *"We have different types of students. Some want to construct their ideas compared to what they see according to their understanding. I was unsurprised because they had already been through the first lesson and understood how to connect the components"* (Lecturer C). Students began with basic diagrams, which allowed them to build confidence before advancing to more detailed and complex layouts. This approach supported retention and comprehension, as they could incrementally apply previous learning to more challenging diagrams. *"If the student did not have the embedded knowledge before commencing this lesson, they would have found it very challenging. However, the prior knowledge gap had to be bridged"* (Lecturer B).

5.6.2.4 The Impact of Instructional Design.

The content design should eliminate or minimise unnecessary information or distractions that do not directly support the learning goal. *"I think this is a top way [Lesson Study] of where we target not everything but just the most challenging parts of the syllabus"* (Lecturer A). This ensured learners focused on mastering concepts at each stage without wasting cognitive resources on irrelevant details.

5.6.2.4.1 The Impact of Instructional Design Through Technology and Multimedia

Instructional design through technology and multimedia-enriched educational experiences by enhancing engagement, accessibility, and comprehension. The challenge was to guide learners' cognitive processing during learning without overloading working memory capacity. *"Lesson study starts with the syllabus that you have been given, and as mentioned, this is a transformation in terms of technology because the older syllabuses did not have subject outcomes that learning outcomes"* (Lecturer B).

Multimedia elements, such as simulations, videos, and interactive quizzes, made learning interactive, helping to sustain attention and increase motivation. *"The observing lecturer can also identify the small things that are very important to make that lesson far more impactful"* (Lecturer C). However, visualisation strategies were sometimes necessary to compensate for weaker instructional design, particularly for learners who struggled with abstract concepts.

Technology integration enabled personalised learning paths, with adaptive platforms that adjusted to individual progress, allowing learners to engage at their own pace and skill level. *"Once students have developed a way to do something and if you bring in an alternative method, they will not conflict [their] understanding by mixing both methods"* (Lecturer C). Real-world simulations provided experiential learning in a safe and controlled environment. *"There are different types of electricians, but when you merge as a team, it [impacts] the actual lesson planning"* (Lecturer B). Additionally, multimedia enhanced retention by breaking down complexity into multimodal segments, thereby improving memory retention.

This technology-rich environment promoted self-paced, autonomous learning, encouraging students to take charge of their education. Individual differences in prior knowledge emerged as an important consideration in designing multimedia instruction. Multimedia tools developed thinking and problem-solving skills by presenting students with complex, real-world scenarios. However, multimedia effectiveness depended on mindful instructional design to prevent cognitive overload and ensure alignment with learning goals. *"You must have much knowledge on how to problem solve, and then critical thinking will be married to that"* (Lecturer B). When implemented effectively, multimedia instructional design creates engaging, accessible, and compelling learning experiences suited to the needs of modern learners.

5.6.2.4.2 The Impact of Instructional Design Through Effective Teaching Strategies

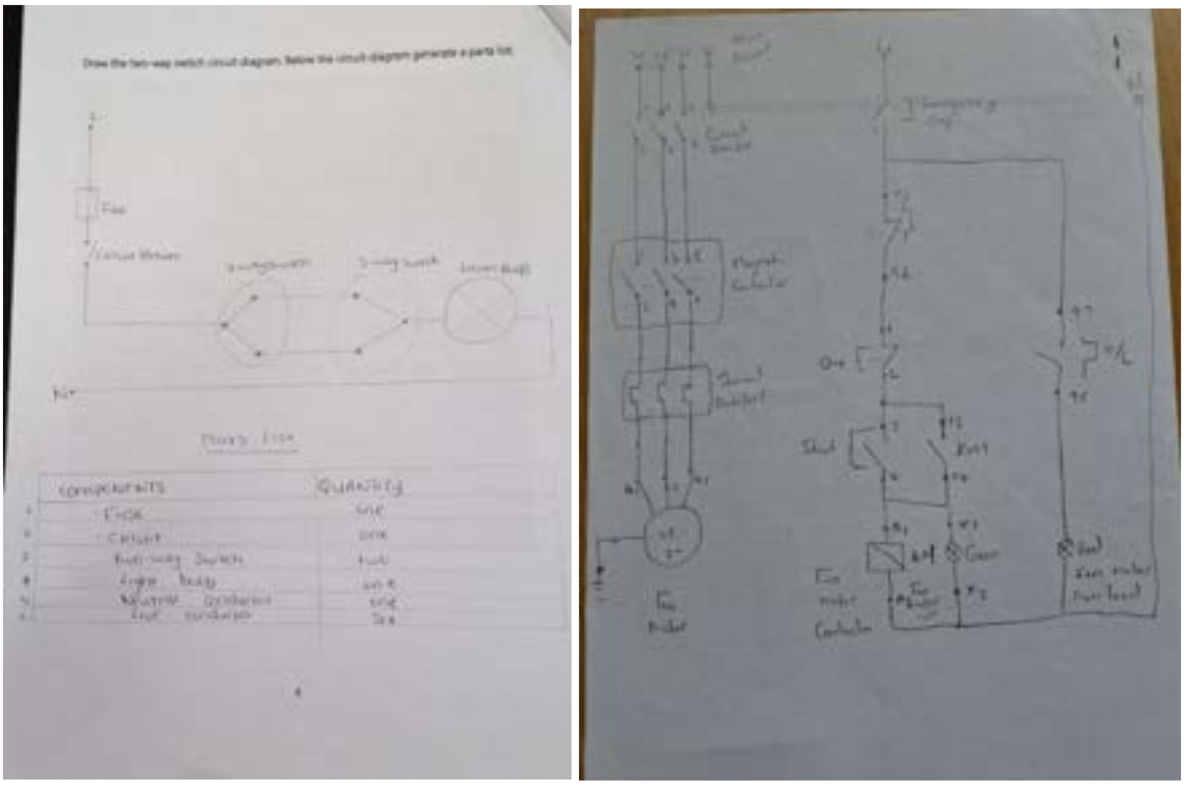
Applying various teaching strategies ensured that students developed a solid foundation, enabling them to build on their knowledge incrementally. *"Everyone brings their best practice and their knowledge. And we sit together. And we develop a lesson plan that everyone can use. For the benefit of the lecturer and the student"* (Lecturer C). Students progressed through complex material without experiencing cognitive overload, resulting in a deeper understanding and long-term retention.

The findings revealed that cognitive load theory informed specific instructional design principles, including considerations of split-attention and redundancy effects, as well as the use of instructional tools and scaffolds (Kirschner et al., 2018). *"You bring more people with knowledge together who complement one another, they can produce a lesson which is not perfect close to perfect, because when they do meet together, you find everyone brings their expertise, and we can take the positives from that and we cancel what is negative from one another,"* (Lecturer C).

5.6.2.5 The Impact of Deep and Surface Learning on Cognition and Instructional Design Specific to Diagrams and Illustrations.

Deep and surface learning represented contrasting approaches that fundamentally affected how learners processed and retained information. Deep learning characterised a robust and intrinsic motivation to understand content meaningfully. *"Even though the second lesson was a lot easier, I still have some questions. I'm curious to know the purpose and why we used this and why we used that?"* (Student 3). These learners engaged with underlying principles and interconnections within the material through critical thinking, active engagement, and application of concepts to real-world situations. *"The two-way switch [diagram] also helped us to develop a parts list"* (Student 1). Deep learners generated a parts list from the diagram, connecting to prior knowledge to understand the why behind the information, promoting long-term retention and the ability to apply knowledge in various contexts.

Figure 15 *Generated parts list and direct online wiring diagram of student 3*



Surface learning, conversely, was often driven by a desire to complete tasks with minimal effort, typically due to external motivations, such as passing examinations. *"He did not have a* *lesson plan. He took a circuit diagram and showed them how to duplicate it. It is like taking a line from here and connecting it to the next point. I told him you should teach them how to connect a battery to a light with a switch. They must switch it on and off, and it must work. Then bring in your transistors and slowly build it up"* (Lecturer F). Surface learners focused on rote memorisation and recall of facts without seeking to understand the material beyond immediate goals. This approach led to quick but shallow retention, where information was stored temporarily but quickly forgotten after assessments. *"From a student's point of view, I am here to learn and not to be shown what to do. I want to know what to do"* (Lecturer F).

Whilst both methods could lead to learning, deep learning fostered intellectual growth through problem-solving, analysis, and adaptability. *"We already had the circuit diagram in front of us showing the actual connections. The video would have been better if it showed the lines going into the contactor"* (Student 3). An interesting surface observation emanated from this student response: *"If students are satisfied with understanding a concept, they can close their minds or block other options"* (PD). Surface learning proved effective for short-term tasks but often lacked the depth needed for complex or long-term learning outcomes. Instructional strategies promoting curiosity, relevance, and active engagement supported deep learning, whilst methods emphasising rote memorisation and limited context encouraged surface learning.

5.6.2.5.1 The Impact of Rigid or Closed Learning on Deep and Surface Learning. Rigid or closed learning environments, characterised by strict structures, limited flexibility, and an emphasis on rote learning or standardised assessments, significantly impact both deep and surface learning, often fostering the latter while inhibiting the former. The focus was typically on content coverage, task completion, and adherence to predefined answers rather than exploring ideas or encouraging open-ended inquiry. *"The other thing you said was that although we used the fuse, we are leaving it out and not discussing it because we are not* *using it in this circuit. What is the purpose of the fuse?"* (Lecturer F). Interestingly, Student B asked, *"The first time, you showed us a fuse, and the second time, it was missing. I want to know why did we not use a fuse?"* With an emphasis on correct answers and standardisation, learners prioritised short-term recall of facts, definitions, and basic procedures over deeper understanding. The rigid structure reduced their opportunity to analyse or connect the material to subjective experiences or other areas of knowledge.

Deep learning flourished when learners explored, questioned, and applied knowledge in diverse contexts, often requiring freedom to make mistakes, experiment, and discover underlying principles. *"I did ask myself, is this three phase. That was the question I had. The picture in my mind was completely different from what I found in the workshop"* (Student 3). However, rigid learning limited opportunities for exploration and curiosity. A lack of autonomy and flexibility reduced intrinsic motivation, causing learners to feel disconnected from the content. *"When you explained about the wires crossing and the dots. I had come across that in the exam and the textbook, and I did not understand what they were all about"* (Student 1). This often resulted in students missing the opportunity to develop critical thinking and problem-solving skills.

5.6.2.5.2 Formulating Mind Pictures Influences Deep and Surface Learning.

Formulating mental images, or mind pictures, significantly influenced deep and surface learning by affecting how learners processed, retained, and retrieved information. *"After I completed this lesson, I asked myself why we did two-way switching. I was curious to know what the main purpose of doing these things is. I asked myself why I am doing this?"* (Student 3). Creating mind pictures enhanced understanding and retention when learners transformed verbal information into pictorial representations. However, learners could incorrectly manipulate information, forming detailed images representing incongruent relationships and processes. *"The picture in my mind was completely different from what I found in the workshop"* (Student 3).

Lecturers also utilised apperception, presenting new concepts and allowing students to associate these with pre-existing knowledge. *"I did not understand how the components function. And how to connect them. but when we started to work with them practically, I started to understand better"* (Student 2). This helped organise information meaningfully, strengthened connections to prior knowledge, and made mental recall easier to apply in different contexts.

In surface learning, mind pictures were more superficial and fragmented, serving primarily as mnemonic aids. *"I also recognised surface learning also emanated from surface teaching"* (PD). *"Then you told the students that when they draw circuit diagrams, they should draw them in non-operating mode. Then you mentioned that when it is energised, it will change. What is non-operating mode, and what is energised? Non-operating mode and deenergised are the same thing. So, the students listen to multiple terms, such as non-operating mode, energised, and de-energised. These terms must be explained further and in greater detail as they can be confusing"* (Lecturer F).

Learners created images to remember facts for tests without connecting them to deeper understanding. These images supported short-term recall but did not foster comprehension of underlying principles. The quality and purpose of mental imagery differed between deep and surface learning. In deep learning, mind pictures were integrated into a learner's mental framework, promoting comprehension and adaptability. They were simple and task-oriented in surface learning, aiding short-term recall but lacking depth for lasting understanding. Encouraging learners to create detailed mental models rather than isolated images enhanced deep learning and prevented reliance on surface-level recall strategies. *"The interaction of them* *writing down the components and visualising it" contributed to student deep learning*" (Lecturer A).

5.6.2.5.3 The Effects of Duplication on Deep and Surface Learning.

Duplication, or repetitive exposure to the same material, had varied effects on deep and surface learning. In surface learning, duplication often reinforced rote memorisation, temporarily allowing learners to remember facts or processes without promoting genuine understanding. Repetition in surface learning focused on mechanical recall, where learners memorised definitions or steps but lacked a deeper grasp of the material's significance. This led to rapid recall, but information was soon forgotten, as it was processed superficially.

In deep learning, duplication reinforced understanding by applying concepts to varied contexts. When repetition was paired with reflection, problem-solving, or exploring different perspectives, it helped strengthen connections between ideas, solidified understanding, and aided long-term retention. *"When I got to the workshop, I realised why we were duplicating parts of that lesson, and that was to make the connections for the wiring itself. I realised it helped because we connected just the motor the first time, and now we would include the indicator lights as well. Doing it the second time reinforced what we had done [in] the first"* (Student 1). This thoughtful duplication allowed learners to refine their mental models and apply knowledge flexibly, making it valuable for complex or abstract subjects. Overall, duplication supported surface learning by enhancing short-term recall, while deep learning benefited from being combined with active engagement and varied applications, promoting lasting understanding and adaptability.

5.6.2.5.4 Imagic Aggregation's Effect on Cognitive Load Theory and Instructional Design Theories Specific to Diagrams and Illustrations. Imagic aggregations utilised graphicacy to facilitate learning and deepen students' comprehension of scientific concepts. Presenting appealing and easily understandable information helped students make connections, recognise patterns, and grasp complex ideas more effectively, fostering active learning. *"The circuit diagram was one of the changes for me. The first time, I felt clueless. The second time, it felt OK. I know the first time you explained it to us, but the second time felt very different from the first. I felt the change was on how to read the diagram the second time"* (Student 3). Multimedia bridged abstract theories and concrete examples, enabling students to conceptualise scientific principles and encouraging them to explore the subject matter with curiosity.

Imagic aggregations were expressed in photographs, illustrations, graphs, flowcharts, and diagrams, which played a crucial role in science learning. They were powerful tools used in this research to convey information, organise data and illustrate scientific processes. *"We saw a video on how to connect the direct-on-line [circuit]. That made it much easier to go and do the connection"* (Student 4). Imagic aggregations captured students' attention and stimulated their interest in the subject, enhancing their overall engagement. Synesthetic communication simplified complex concepts, making them more digestible and easier to comprehend. This enabled a solid foundation of scientific knowledge.

Moreover, imagic aggregations promoted critical thinking and problem-solving skills by encouraging students to analyse, interpret, and draw conclusions from visual information. *"[Interactive smart boards were] very [beneficial]. Firstly, I could see clearly whatever was projected on the screen. You can do things much quicker and then explain and show pictures of things we are doing. It is much clearer to see than with classes where the teachers use whiteboards"* (Student 4). They fostered scientific literacy by familiarising students with scientific literature (Martin & Rose, 2023).

The PLC ensured that graphics were accurate, relevant, and aligned with the learning objectives. Students created visual representations, allowing them to design and draw diagrams, strengthening their understanding of the explored scientific concepts. Imagic aggregations leveraged the power of graphics to enhance learning and comprehension. *"The diagram on the board made it simple. You can picture it if you know what those components are"* (Student 1). Lecturers engaged students, simplified complex concepts, and promoted a deeper understanding of scientific principles through synesthetic communication. This approach nurtured scientific literacy and equipped students with skills for future scientific inquiry and exploration.

5.6.2.6. Collaborative Impact on Contrived Collegiality. Collaboration significantly impacted contrived collegiality, a form of forced or artificial teamwork often resulting from top-down mandates rather than genuine collegial relationships. The initial responses revealed reluctance: *"I want to participate in this approach as long as it is next year and it does not impact my teaching time"* (Lecturer A). Another aspect of contrived collegiality was the expectation that the researcher would complete all administrative tasks. Some participants created the impression that they were participating in the research as a favour to the researcher (PD). However, this observation was not representative of all participants.

For some lecturers, the experience transformed over time. LS participation *"becomes easy because we complement one another. Everyone brings their best practice and knowledge, and we develop a lesson plan that everyone can use to benefit the lecturer and the student"* (Lecturer C). When collaboration was authentic and well-structured, it helped transform contrived collegiality into meaningful, voluntary interactions that fostered trust, respect, and shared purpose. Everyone brought knowledge and best practices, sat together, and developed a lesson plan that benefited both the lecturer and the student. Authentic collaboration allowed colleagues to build genuine relationships and establish trust, shifting the focus from obligatory interactions to productive teamwork.

"It was not just my contribution but the group's contribution because you do not want to use just one person's idea, experience or knowledge. We all know something, and maybe that is something that someone else might not know. Everyone's contribution is counted. It is about how we develop one idea, one method for the lesson that must be delivered" (Lecturer C). This trust allowed individuals to feel more comfortable sharing ideas, providing feedback, and collaborating to achieve shared goals, thereby gradually reducing the sense of contrived collegiality.

Meaningful collaboration promoted a sense of ownership over shared tasks and objectives. This intrinsic motivation encouraged colleagues to view each other as partners rather than participants in a mandated exercise. *"People who are experienced in this field [of] teaching can try and help where you lag or where you have missed out [key aspects]"* (Lecturer E). Colleagues increasingly valued collaborative efforts as growth opportunities rather than mandatory tasks. *"When we sit together... we can ask why is your way different [from mine]. We can thrash it out, and finally, when it is put forward, it is improved"* (Lecturer A). However, forced collaboration often led to resistance or resentment, as colleagues felt their autonomy was restricted.

5.6.2.6.1 The Impact of Extra Work on Lesson Study. The extra work positively and negatively impacted the teaching process. LS required lecturers to collaborate, plan, observe, analyse, and refine lessons on both administrative and psychological levels in a time-intensive and demanding cycle.

On the positive side, LS's reflective and collaborative nature deepened understanding of instructional practices and subject content. Lecturer strategies were refined through collaborative lesson design, yielding new insights and enhancing their effectiveness as educators. *"If someone with the knowledge like yours is sitting in that class to evaluate your [teaching practice], it is good for you and him as well. Moreover, although he is evaluating you, he could be saying I like the way [it is done]. I am not applying this; I am not doing this, or I am not doing that. It is two-way learning for lecturers, the one teaching and the one observing"* (Lecturer C).

This iterative process tailored lessons to student needs, improving engagement and comprehension. *"We can sit down and discuss ... how I teach. This is what I emphasise. This is what the subject outcome requires. Those minor things are things that we tend to look the other way. You are only [engaging] this or that [aspect], and I am [only engaging] this. Let us [focus on] this. Let us get them to [try] this method"* (Lecturer E). This continual refinement improved learning outcomes. Solving instructional challenges built collegiality and strengthened professional relationships, creating a supportive community focused on shared educational goals.

The collaborative challenges of LS included cooperation difficulties, time pressure, tensions, failure to predict student responses, a lack of focus on student learning, inadequate understanding of the proper use of technology, inexperience, stress and anxiety resulting from observing the teaching, reflection, and fatigue. The additional commitment could lead to stress or burnout, particularly when combined with existing teaching responsibilities. Without adequate time, administrative support, and access to resources, lecturers struggled to engage thoroughly, which limited their effectiveness and potentially increased frustration.

A notable observation regarding the effects of additional workload was the role of the team leader. For LS to be effectively implemented, a strong team leader must organise and administrate implementation aspects (PD). With insufficient support or genuine commitment, some lecturers might have gone through the motions without fully engaging, which made the process feel like a formality rather than an impactful practice. This reduced the quality and effectiveness of LS, leading to minimal benefits.

Table 5 below presents a synthesis of the combined codes, phrases, and themes addressing Research Question 3, which examines how teachers' engagement with Lesson Study (LS) and Professional Learning Communities (PLCs) influenced their cognitive processing, conceptual understanding, and multimedia integration in lesson design. Drawing on data from focus groups, interviews, and journal reflections, the table aligns the emergent patterns with Dual Coding Theory (DCT) and Multimedia Learning Theory (MLT) to explain how teachers process, represent, and communicate complex information to learners. The findings reveal that teachers encountered conceptual challenges, such as triple elucidation, semantic incoherence, and infoxication, terms that describe information overload and conceptual misalignment, which hindered learner comprehension. However, these difficulties prompted deeper cognitive engagement, with participants reporting the use of fluid intelligence and inductive reasoning to enhance information sequencing and clarify conceptual understanding. Themes such as temporal contiguity, signalling, and perceptual correlation show how teachers began to align verbal and visual elements more effectively, improving coherence and comprehension in multimedia-supported lessons. Instances of rigid or closed learning and semantic distortion highlight moments where conceptual understanding broke down due to misaligned visual or symbolic representations, reinforcing the importance of integrating images, symbols, and actions meaningfully. The development of declarative memory and comprehension through variation further illustrates teachers' progression toward designing lessons that support both surface and deep learning. Overall, the table demonstrates that through reflective collaboration in LS and PLC contexts, teachers have advanced their ability to manage cognitive load, improve conceptual representation, and apply multimedia principles to enhance the coherence of teaching and learning.

Table 5 *Combined codes and amalgamated themes for research question 3*

Codes/Phrases/ Patterns Focus group	**Codes/Phrases/ Patterns Interviews**	**Codes/Phrases/ Patterns Journal Entries**	**Themes RQ3**	**Conceptual Frameworks**
Triple elucidation	Semantic conceptions of information	Incoherence	***Significant disparity***	***DCT MLT***
Conceptual challenge	Missing information	Conjecture Lesson boredom	***Infoxication***	***DCT MLT***
Fluid Intelligence	Inductive reasoning		***Information sequencing***	***DCT MLT***
Temporal contiguity	Conceptual meaning	Comprehension facilitated action	***Signaling principle***	***DCT MLT***
Rigid or closed learning	Formulating mind pictures		***Semantic distortion***	***DCT MLT***
Formulating mind pictures	Learning symbols	Comprehension facilitated action	***Perceptual correlation***	***DCT MLT***
Conceptual challenge	Rigid or closed learning	Incoherence	***Misaligned multimedia integration***	***DCT MLT***
Declarative memory	Comprehension through variation	Comprehension facilitated action	***Cognition***	***DCT MLT***

5.6.3 Analysis of Research Question 3

How do learners perceive and respond to electrical wiring diagrams that employ principles of dual coding theory and multimedia elements?

5.6.3.1 Significant Disparity of Diagrams with Dual Coding and Multimedia Elements

5.6.3.1.1 Negative Reinforcement and Significant Disparity of Diagrams with Dual Coding and Multimedia Elements.

Negative reinforcement in instructional design refers to removing undesired stimuli to encourage positive learning behaviour. Lecturer F highlighted poor teaching practices that impacted learning when he observed a disorganised educator: *"He did not have a lesson plan. He took a circuit diagram and showed them how to duplicate that circuit diagram, and I asked, how are you going to start teaching them to do it?"* Removing complexity or redundant content when learners answered questions correctly proved effective in mitigating excessive or confusing information. *"We reassigned other parts of the information initially shared to a following lesson, which helped to remove confusing aspects. I think the students started to enjoy the lesson better because the knowledge shared on that day was specific and targeted"* (Lecturer C).

Using diagrams with dual coding and multimedia elements enhanced comprehension by engaging both visual and verbal processing channels. However, significant disparities in these diagrams, such as inconsistencies in content, structure, design quality and terminology, disrupted the intended learning process. These disparities presented conflicting or redundant information, detracting from the benefits of dual coding. To mitigate this, diagrams needed to align consistently with the verbal content. Using consistent style, colour schemes, and structure across diagrams helped prevent cognitive overload. *"A live conductor should have a certain* *colour and neutral another colour, and the strappers should have another colour"* (Lecturer C). When multimedia elements, such as animations or voiceovers, were used in conjunction with diagrams, they needed to complement rather than overwhelm each other.

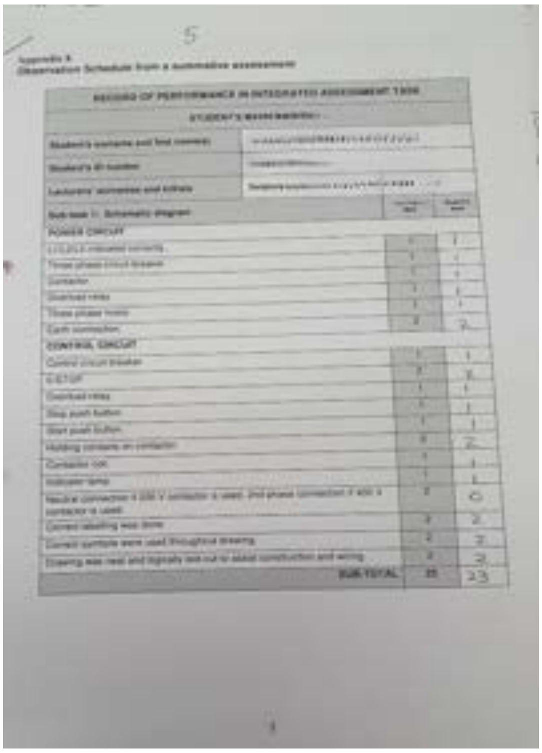
5.6.3.1.2 Elucidation's Impact on Diagrams with Dual Coding and Multimedia Elements. Combining elucidation with dual coding and multimedia elements created a powerful instructional strategy leveraging multiple forms of cognitive engagement. Important elements of correct meaning were mapped onto literal ones, intersecting and working together effectively. *"The terminology energised, non-energised and [de-energised] refers to current flow in the circuit. How do I energise [or de-energise] an emergency stop switch or a start button? You must clarify these aspects"* (Lecturer F). Textual explanations paired with diagrams emphasised the benefits of multimodal communication to enhance memory and understanding. The textual component, paired with carefully designed graphics, created this dual-coding elucidation effect.

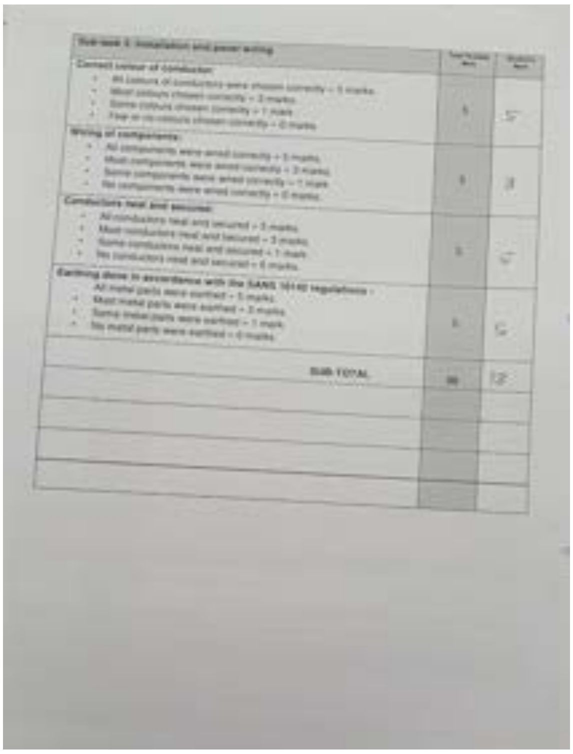
> You told the students that when they draw circuit diagrams, they should be drawn in the non-operating mode. Then you mentioned that when it is energised, it will change. What is a non-operating mode, and what is energised? Non-operating mode and deenergised are the same thing. So, the students listen to multiple terms, such as non-operating mode, energised, and de-energised. These terms must be explained further and in greater detail as they can be confusing (Lecturer F).

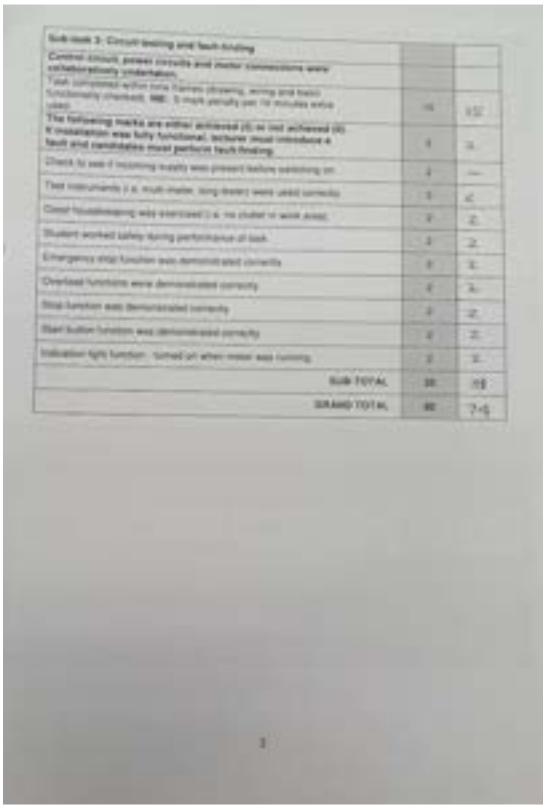
When correctly combined, these elements transformed imagery into dynamic representations, making it easier for learners to understand processes or sequences that changed over time. *"[Students] will recognise that a timer is in that circuit. It is there to activate or deactivate [a component]. These lines get attached to the components, and so the drawing builds"* (Lecturer A). The interactive component in elucidation enabled learners to actively engage with content through simulations or hands-on tasks. *"I did not understand how the components function, and how to connect them. But when we started to work with them practically, I started to understand better"* (Student 1).

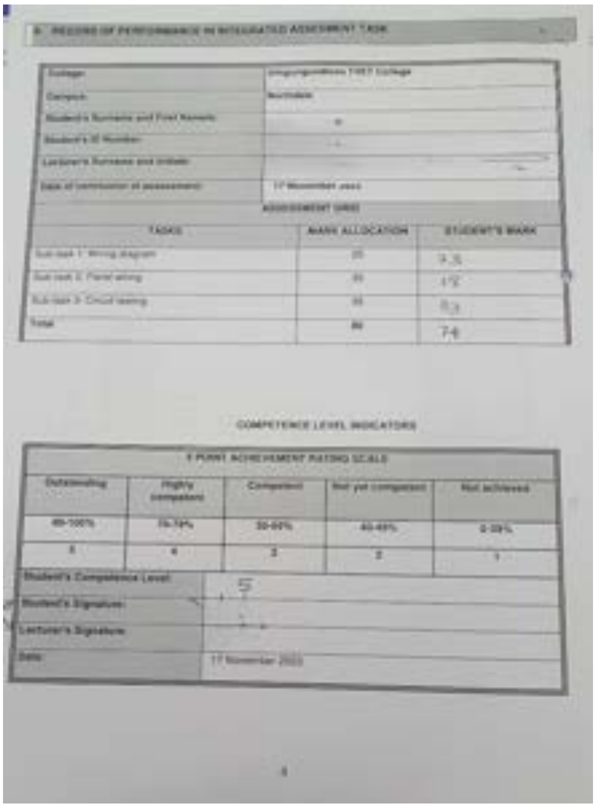
When these elements were harmonised, learners engaged with content through diverse methods that reinforced each other. *"I did not understand how the conductors connect from one component to the other. However, it was easier when we went to do the practical; we could see how it came together"* (Student 3). Multimodal communication promoted information encoding in different forms, making it easier to retrieve and apply. Multimedia elements and interactivity promoted active learning through constructive discussion, planning, practice, observation and feedback, which deepened understanding through engagement and self-explanation. Flexible learning paths accommodated different learning preferences, allowing learners to navigate multimodal elements according to their needs. The observation schedule below indicates the successful student's cognitive engagement with the task.

Figure 16 *Observation schedule for the summative assessment of student 1*









5.6.3.1.3 The Effects of Semantic Conceptions of Information. Students with solid semantic conceptions approached diagrams by seeking meaning and relationships rather than memorising isolated parts. *"We saw a video on how to connect the direct-on-line. That made it much easier to make the connection. I also understand now that circuit diagrams are an international language that electrical engineers or electricians use to understand certain connections"* (Student 4). They interpreted underlying concepts, which helped them see connections between various parts of the diagram and the broader topic. This led to deeper comprehension, as they actively made sense of the diagram rather than passively viewing it.

"The reason why our circuit did not work [was] because it was incomplete. This was due to the information missing from the wiring diagram given to us. When you showed us what to do, we understood what was required" (Student 1). When students clearly understood conceptual information, they were comfortable with complex diagrams, understanding how each component fitted into the larger context. *"I asked myself, is this three-phase? That was the question I had. The picture in my mind was completely different from what I found in the workshop"* (Student 3).

Students with limited semantic understanding found complex diagrams overwhelming or confusing, perceiving them as irrelevant or overly detailed. Diagrams aligned with semantic frameworks, showing relationships, hierarchies or processes, helped students grasp information logically. *"I tell my level 2 students to write on their drawings. Draw or add additional information to your diagram. Do not become concerned if it starts to look untidy. Not only drawing circuit diagrams but also using them. Once they start using them, it becomes easy"* (Lecturer D).

Semantic conceptions helped students filter details and focus on the most meaningful parts of a diagram, reducing cognitive load. Diagrams using clear labelling, logical flow and structured visuals supported processing and memory. *"It is nice that you showed them a legend chart to [indicate component symbols and demonstrate] what a component is and how you draw it. The* *legend is [important] for them to practise in their mind so that if they look at any drawing, even if they do not understand what the drawing is meant to do, they can see that there is a contactor, relay, timer, etc."* (Lecturer A).

Students who understood the semantic value were more likely to benefit from dual coding, as they drew connections between multimodal elements. Lecturer F explained: *"Symbols for the circuit breakers are very similar to the symbols for a contactor and an overload. The contactor switches off 3 [terminals], and the circuit breaker switches off three as well. In explaining the difference, you will tell the students that one works electromagnetically and the other works mechanically."* This combination helped them create a cohesive mental model of the information, improving recall and knowledge transfer.

5.6.3.1.3 Perceptive Incoherence of Diagrams. Perceptive incoherence occurred when students had trouble understanding diagrams due to lack of clarity, logical structure or visual alignment with the information's meaning. *"It was easier working with the diagram on a piece of paper, but when we watched the video and tried to follow the connections as the wires moved from one component to the next, it became too much, and there were so many wires that were being connected that it became confusing"* (Student 2). This incoherence occurred when diagrams failed to convey information aligned with students' mental models, leading to misinterpretation, cognitive overload, or disengagement.

Diagrams lacked clear organisation when they featured unstructured layouts, crowded elements and inconsistent spacing. When elements were not logically arranged, students struggled to identify relationships, sequences or hierarchies within the information, leading to confusion and disengagement. *"Another important observation from the Student 3 interview was when students watched YouTube videos, they perceived this as gaining practical knowledge"* (PD).

"I am also trying to find ways to help me improve my studying abilities. I use YouTube videos to see how I can bring practicality into my own space" (Student 3).

Diagrams that did not align with students' pre-existing knowledge appeared incoherent, as users could not easily connect new information with what they already knew. *"There was too much information. We already had the second diagram in front of us showing the actual connections"* (Student 4). Clear, consistent design choices helped avoid perceptual conflicts, whereas inconsistencies created noise that hindered understanding. Labelled diagrams proved powerful for framing and shaping students' thinking. *"Source supply is normally omitted in most of these schematics. This must be clearly explained. Most textbooks show circuit breakers but do not indicate [the] source. Students get confused [by the lack of this detail]"* (Lecturer D).

Without labels or clarifications, elements within a diagram became ambiguous, leading to different interpretations or misunderstandings about important concepts. *"The whole idea is to have it in their mind as to why I need to do this. I could write an entire paragraph or draw each of these components. Now, think about the complicated diagrams. The drawing becomes a communication tool. We need diagrams and circuit symbols"* (Lecturer F). Diagrams that included too much detail or extraneous information overwhelmed students, creating cognitive overload and perceptual incoherence, making it difficult for students to focus. Simplified, focused diagrams were easier to process, as they directed attention to the most important aspects of the information.

5.6.3.2 The Effect of Infoxication on a Learner's Perception and Response to Electrical Wiring Diagrams

5.6.3.2.1 Perception, Interpretation, and Conceptual Challenges of Infoxication.

Infoxication significantly impacted learners' perception and response to electrical wiring diagrams designed with Dual Coding Theory (DCT) and multimedia principles. Whilst DCT relied on integrating verbal and visual information for effective learning, when excessive multimedia and text were presented simultaneously, the learners became overwhelmed, hindering effective diagram processing. *"It was easier working with the diagram on a piece of paper, but when we watched the video and tried to follow the connections as the wires moved from one component to the next, it became too much, and there were so many wires that were being connected that it became confusing"* (Student 2).

The infoxication led to scattered, unnecessary, or peripheral details dominating learners' attention. *"You showed us the video. To be 100% honest, I did not understand it. I did at first, but as we went further into the video, I did not understand it. Especially the part that showed how the conductors connect one component. I did not understand that"* (Student 3). Overloading learners with multimedia disrupted their ability to form accurate mental models of how electrical systems function, as they struggled to integrate the relevant visual and textual data. This challenge was particularly acute for less capable learners, who found that instructional approaches effective for their more capable peers became counterproductive for them. As Student 1 succinctly stated: *"Too many things at one time."*

5.6.3.2.2 Infoxication Behavioural Response to Missing Information. Learners disengaged when they felt overwhelmed by the volume or complexity of information. Instead of analysing the wiring diagram, learners resorted to guesswork, bypassing the logical reasoning process that dual coding and multimedia elements were intended to support. *"The first part of the video showed us that the connection from the circuit breaker comes out from the top and then goes into the contactor. I found this very confusing because we had* *previously seen how it should have been coming out from the bottom of the circuit breaker and then entering the contactor"* (Student 3).

This study identified a dualistic opposite effect, where lecturers assumed the video showing the wiring connections would improve cognition, but students found it confusing. *"In the class, watching that video was confusing. I do not think I would have understood it on my own if I had done it individually"* (Student 2). However, all lecturer participants believed the video was not confusing and very clear in demonstrating the electrical concepts. Recognising this disconnect between teaching and learning was invaluable (PD). Infoxication delayed learners' ability to interpret and respond to the information in the wiring diagram, particularly in time-sensitive scenarios.

The study revealed that split-attention effects compounded the problem. To mitigate these issues, lecturers simplified the design using minimal yet effective multimedia elements, ensuring that all components directly supported the learning objectives. They broke down wiring diagrams into manageable segments, allowing learners to cognitively process one system part at a time. *"We corrected that in the second [lesson] where we gave them information that was only related specifically to that lesson. We reassigned other parts of the information initially shared to a following lesson, which helped remove confusing aspects"* (Lecturer C).

Visual cues like colour coding or animation were used sparingly to emphasise important aspects of the diagram without overwhelming the learner. Element interactivity influenced the nature of the task, and learner expertise was taken into account, allowing learners to interact with the diagram by toggling layers or components, thereby controlling the flow of information. By carefully managing the amount and complexity of multimedia and textual information, instructional designers reduced infoxication, enabling learners to effectively engage with and understand electrical wiring diagrams.

5.6.3.2.3 Conjecture's Influence on Infoxication Regarding Learner's Perception and Response to Electrical Wiring Diagrams. Conjecture amplified the effects of infoxication on student perception and response to electrical wiring diagrams. *"When you came and fixed our connections, the reason why our circuit did not work was because it was incomplete. The reason why it was incomplete was due to the information that was missing from the wiring diagram given to us"* (Student 1). The assumption by educators that the so-called missing information was addressed in the previous semester and would have been based on prior student knowledge proved problematic (PD). Students mitigated overwhelming information and uncertain details through conjecture.

Lecturer conjecture, characterised by assumptions or oversimplifications in presenting electrical wiring diagrams, strongly influenced learners' perceptions and responses. It rendered diagrams ambiguous or unreliable, leading learners to misinterpret information. "*Lecturers may unintentionally bias learners through unverified assumptions, causing them to focus disproportionately on certain elements and form skewed understandings"* (PD). Maton (2013) clarifies issues of teacher conjecture, where robust knowledge classification indicated clear boundaries, whilst blurred boundaries emanated from weak classification. Strong framing means reasonable teacher control over the learning process, whereas weak instructional framing permits detrimental student autonomy.

Infoxication already strains working memory, but conjecture adds further load. Conjectures made under infoxication created faulty mental models that competed with accurate instructional design, causing learners to misunderstand the system's wiring or sequence. *"Where [the] lines showed the connection from component to component. I already had the* *drawing in front of me, and was shown how the different components were connected. I drifted off there and lost interest"* (Student 4).

By managing the volume and structure of information, instructional designers minimised infoxication and reduced learners' reliance on conjecture. It is not the way courses and programmes are designed in higher education that relates to the quality of student learning but how students experience and understand the design (Chipamaunga, 2015). This approach encouraged accurate, confidence-building interactions with electrical wiring diagrams and supported deeper, more reliable learning outcomes.

5.6.3.3 The Impact of Information Sequencing on Electrical Wiring Diagrams that Employ Principles of Dual Coding Theory and Multimedia Elements

5.6.3.3.1 The Effects of Fluid Intelligence on Information Sequencing. Fluid intelligence, the cognitive ability to reason, solve problems, and process unfamiliar information, significantly influenced how students managed information sequencing in electrical wiring diagrams. Students with high fluid intelligence excelled in recognising patterns and adapted quickly to unconventional or fragmented information. *"Maybe the video can be broken down step by step, showing connections from one component to another"* (Student 4). These students demonstrated the capacity to handle complexity, allowing them to organise disjointed data coherently and dynamically reorder events in their minds to align with logical sequences, even in chaotic scenarios. They effectively troubleshot missing steps in ambiguous situations, filling gaps through problem-solving and reasoning. *"The diagram on the board made it simple. You can picture it in your head if you know what those components are"* (Student 1).

Conversely, students with low fluid intelligence struggled with complex sequences and processing lengthy or intricate information. Their rigid, linear thinking limited their ability to adapt when engaging with information. As Leutner et al. (2009) noted, what was "intended to trigger helpful cognitive processing impose[d] extraneous cognitive load that hinders learning" (p. 288).

These findings revealed crucial implications for teaching and instructional design. *"If you look at student attendance right now, if you look at concentration levels, if you look at all of that, [students] tend to get bored in class. What exciting [or] new thing are you doing? Lecturing right now looks outdated"* (Lecturer F). The research showed that structured sequences with explicit connections facilitated chunking. *"Maybe we needed to find a way to remind them [of prior knowledge] so that everyone can be on the same page when you are discussing the electrical circuit for the lesson"* (Lecturer C).

Generating a parts list emerged as an explicit form of chunking. *"When making a parts list, you prepare them to buy [components and] equipment"* (Lecturer D*). "The diagram could indicate ten red conductors. The student does not need to purchase ten, rather one long piece that can be cut into ten"* (PD). The findings underscored that fluid intelligence enabled students to manage complexity and adapt to new challenges, highlighting the need for tailored instructional strategies that accommodate varying cognitive abilities.

5.6.3.3.2 The Effects of Inductive Reasoning on Information Sequencing. Inductive reasoning is the ability to draw general conclusions from specific observations. This profoundly influenced how learners engaged with electrical wiring diagrams. *"You must start from one side [and ask] if this wire exists. You need to teach them how to check. You noticed that when you wanted to switch on, they [students] moved back. They lack[ed] confidence in knowing the constructed circuit is correct. I tell my level 2 students to write on their drawings. [use it as a work-in-progress document. Draw or add additional information to your diagram. Do not become concerned if it starts to look untidy] Not only drawing circuit* *diagrams but also using them. Once they start using them, [comprehension] becomes easy"* (Lecturer D).

The interplay between inductive, experiential learning and deductive instruction helped expand students' understanding of abstract concepts. *"That is why [students] need to learn diagrams and circuit symbols"* (Lecturer F). Learners with strong inductive reasoning effectively recognised connections and patterns within wiring diagrams, such as repeated symbols and visual cues. This enabled them to infer the overall circuit layout and flow, which was vital for understanding how components interconnected. By examining elements and noting patterns such as colour codes for different wire types, learners confidently derived principles that enhanced their ability to anticipate features in other diagrams.

When learners merged visual clues with inductive reasoning, they constructed accurate mental models of circuit operations necessary for grasping complex sequences like voltage pathways. Lecturers highlighted the importance of exposing students to multiple diagram types. Lecturer F stated, *"You could have shown them [all] three different versions and explained that this is why we chose this way of showing you how to read diagrams. Prior knowledge could also include circuit symbols. Previously, you worked with these symbols, but for the practical task today, these are the ones that you will use."*

Inductive reasoning also enhanced problem-solving skills, empowering learners to predict missing components by recognising familiar structures. Students retained knowledge by spotting inconsistencies and applying patterns to future applications. *"When you explained about the wires crossing and the dots. I had come across that in the exam and textbook and did not understand what they were all about. [Now I do], it helped"* (Student 1). Lecturers who supported inductive reasoning helped students focus on essential elements, allowing them to apply their understanding effectively in practical contexts.

5.6.3.4 Signalling Principle The signalling principle states that students may learn better when cues that highlight the organisation of the material are added. Signalling can be verbal or visual, and when appropriately applied in multimedia courseware, it helps learners more actively select, organise, and integrate incoming information in the learning process.

5.6.3.4.1 Temporal Contiguity and the Signalling Effect. Temporal contiguity in signalling, where related visual and verbal elements are presented simultaneously, significantly impacted learners' perceptions and responses to electrical wiring diagrams. This approach optimised cognitive load and enhanced information processing and integration. The benefits were clear: temporal contiguity improved attention allocation and ensured that signals such as highlights and colour changes aligned closely with verbal explanations.

"You also [mentioned that] the circuit breaker [can be] drawn as a switch. Is it a circuit breaker or a switch? Remember, it can be both. Students must be told that although we use this symbol for a switch, it can also be used as a circuit breaker. This must be clarified" (Lecturer F).

When material is organised into coherent verbal and spatial representations and mentally integrated, the synchronisation minimised distractions. When synesthetic communication coincided, learners quickly formed connections. Reducing the time gap between presenting complementary information helped students retain concepts more effectively, while aligning visual cues with verbal explanations enabled them to construct coherent mental models of electrical circuits.

"The circuit diagram was one of the changes for me. The first time, I felt clueless. The second time, it felt okay. I know you explained it to us the first time, but the second time felt very different from the first. I felt the change was in reading the diagram the second time" (Student 3). This temporal alignment led to improved comprehension and deeper understanding. Reduced cognitive load allowed for focused diagram analysis, whilst simultaneous presentation enhanced long-term retention and recall. Students remained focused, and confusion diminished as temporal mismatches were eliminated.

"It is important to clarify which symbol represents what is drawn. [Students] must know that this is a circuit breaker in a certain application, and in a different application, this could be an MCB" (Lecturer F). This engagement encouraged proactive problem-solving, allowing learners to explore and manipulate diagrams independently.

5.6.3.4.2 Conceptual Meaning and Signalling. Conceptual meaning in signalling employed cues about the structure and function of elements within learning materials.

"You will discover that there are many things that the lecturer who is teaching could be missing. Also, by observing, you develop different views and ideas and easily identify what could be missing from the lesson. It is a good experience. The observing lecturer can also identify the small things that are very important to make that lesson far more impactful" (Lecturer C).

Signalling can be accomplished through typographical cues such as underlining, capitalisation, italics, boldface, and colour variations. Conceptually meaningful signals allowed students to grasp complex information effortlessly, guiding their focus and enhancing comprehension.

When resistors, capacitors, or voltage sources were colour-coded, students were directed to important circuit parts, reducing interpretive time and facilitating swift identification.

When working with complex wiring diagrams that spanned multiple pages, students had to be innovative to improve productivity. Lecturer A explained a simple tick method to quickly identify where the circuit construction had stopped and needed to resume. *"The tick system will [indicate] exactly where they have ended, and they can [return] to that last part they did. Otherwise, you will get lost in the volume of wires, especially for big machines in a factory."*

Arrows indicating current direction or animations showing voltage flow enabled learners to grasp how different circuit parts interacted. *"Electrical diagrams go from top to bottom and from right to left, and that is how current flows"* (Lecturer F).

This clarity helped students construct a robust mental model of the system's dynamics. Conceptual signals reduced cognitive load by minimising the need for mental translation of abstract symbols. When a diagram highlighted conductive pathways whilst the lecturer explained the current flow, students formed a cohesive mental representation, enhancing retention through meaningful associations.

Improved problem-solving emerged as learners quickly detected circuit errors, bolstered by understanding the expected current flow.

"When you came and fixed our connections, our circuit did not work because it was incomplete [due to missing information not being given to us. When you showed us what to do, we understood what was required" (Student A).

Conceptually meaningful signals boosted confidence in troubleshooting, helping learners understand how changes affected the entire system. However, potential pitfalls existed, such as the risk of overwhelming learners with overly complex signals or assuming prior knowledge of conventions, like the use of red arrows to indicate positive voltage.

5.6.3.4.*3 Comprehension Facilitated Action of Signalling*. Educators must select the appropriate tools to design effective teaching methodologies. *"When the students came to me, I also showed them [alternative teaching and] learning [methods]. There was a simulated room [and I included] things like plug and play [demonstrations]"* (Lecturer A).

Signalling provides cues to help students process instructional materials most effectively and efficiently. In educational psychology and instructional design, signalling supported learning by drawing attention to important details and helping learners understand how to process new information. *"In a ladder diagram, you have all these switches here in a ladder format, where your live [conductor] is on this side, like programmable logic controllers. That is where the programmable logic controller ladder diagram comes from. It is a direct replica of this diagram. It is just that they have changed these symbols"* (Lecturer F).

Signalling in multimedia helped learners more actively select, organise, and integrate incoming information, enhancing cognitive development by using intentional cues to direct focus, facilitate learning, and build comprehension skills. When size, colour, or sound effects were changed, these were forms of signalling. A clear signalling aspect was the intentional cue of generating a parts list.

"When [generating] a parts list, you prepare them to buy [components and] equipment" (Lecturer D).

This compelled students to engage the wiring diagram to extract information cognitively. A signalling effect is created whenever contrast or sounds are displayed in a video, deliberately directing learners' attention.

5.6.3.5 The Effects of Semantic Distortion on a Learner's Perception and Response to Electrical Wiring Diagrams that Employ Principles of DCT and Multimedia Elements

5.6.3.5.1 The Impact of Semantic Distortion on Rigid or Closed Learning.

Semantic distortion, where language, symbols, or terminology diverge from established meanings, hindered rigid learners from studying electrical wiring diagrams. These learners often faced confusion over symbolic meanings because they depend on consistent, conventional symbols.

> You did mention that you need to connect one of the strappers from this terminal to the terminal [on the next switch]. However, if you had the physical switch, you [realise] this wire needs to come to this terminal and the other wire to those terminals. This [is] better illustrated [instead of] showing them three dots. This [creates] a picture in their mind [about] what they are looking for when they go to do the practical (Lecturer F).

When symbols deviated from the norm, students struggled to recognise components, leading to misinterpretations and misconceptions, with a diminished understanding of relationships between elements. Furthermore, semantic distortion created a fragmented comprehension of circuit functions. Inconsistent language or symbols prevented rigid learners from forming coherent mental models, causing them to view diagrams as isolated components rather than cohesive circuits.

Semantic understanding *"removes the confusion of people putting neutrals in switches or cutting the neutral. When they [engage] the switch box, they [see] live, neutral and earth and [realise] the neutral is not [required], so [they] cut it. This confusion [must be] eliminated"* (Lecturer D).

This interference complicated their cause-and-effect reasoning, leaving gaps in their understanding. The cognitive strain on these learners was substantial. They often focused excessively on decoding unclear symbols, which hindered higher-level problem-solving and diminished their motivation and confidence. As a result, they struggled with problem-solving and error detection in circuits, limiting their skill development.

5.6.3.5.2 Formulating Mind Pictures to Address Semantic Distortion.

Visualisation, the formation of mental images or mental pictures, was a powerful strategy to address semantic distortion in learning contexts like electrical wiring diagrams. This approach capitalised on the brain's preference for imagery, effectively bridging gaps in understanding caused by unclear symbols. *"The diagram on the board made it simple. So you can picture it in your head if you know what those components are"* (Student 1).

This semantic strategy transformed students' abstract thinking into imagery generation, allowing learners to visualise familiar components and apply their knowledge of physical principles in the real world to simulate how things would appear under actual physical conditions corresponding to the tasks. For example, learners used analogies, such as likening circuit flow to water in pipes, to create explicit mental representations that reduced confusion. Contextual scenarios, like picturing a complete circuit powering a light bulb, reinforced their understanding of the functions of symbols.

Enhancing spatial understanding was also crucial. Learners visualised current paths and imagined assembling components in a layered system, making the overall flow of the circuit more comprehensible. When students combined symbols, relationships between symbols (i.e. grouping, containment and connectivity), and spatial arrangement, it strengthened their learning, allowing them to articulate their mental images confidently.

Addressing potential limitations ensured that simplified imagery accurately represented functions without introducing misconceptions. Student 3 highlighted the following misconception: *"I did ask myself, is this three phase. That was the question I had. The picture in my mind completely differed from what I found in the workshop."*

Instructional techniques, such as guided visualisation and interactive simulations, empowered learners to build vivid mental models while encouraging them to create their own diagrams, thereby reinforcing understanding and clarifying areas that needed further exploration.

5.6.3.6 The Effects of Perceptual Correlation on a Learner's Perception and Response to Electrical Wiring Diagrams that Employ Principles of DCT and Multimedia Elements

5.6.3.6.1 Perceptual Correlation and Its Aid in Formulating Mind Pictures.

Perceptual correlation proved essential for understanding and visualising electrical wiring diagrams, enhancing the formulation of mental images associated with such diagrams. For this study, the correlation between symbols and components facilitated the integration of visual and conceptual information. As Student 1 explained: *"Some of the symbols [used] are found in our textbook [which] we only know [by] name. I think it is better to show students the specific components, whether it is LED's etc. So that when we get to connect them, it is easier."*

Electrical wiring diagrams use standardised symbols for components such as resistors, capacitors, switches, and wires. Perceptual correlation enabled students to recognise these symbols and associate them with real-world counterparts. Understanding spatial relationships between components allowed for an accurate visualisation of wiring configurations while promoting a functional understanding. Grasping each component's role and the flow of electricity within the circuit was crucial. Recognising a switch in a diagram, for instance, aided in comprehending its function in controlling current flow.

Lecturer F emphasised the importance of physical demonstrations: *"You should have concentrated more on the circuit symbols that you used. You mentioned that you need to connect one of the strappers from this terminal to the terminal [on the next switch]. Even though you do not have a switch for each student, because you have demonstrated a physical switch, they already have a picture in their mind as to what they are looking for when they go to do the practical."*

Contextual understanding emerged as another significant factor in interpreting wiring diagrams. The interpretation varied depending on the specific context of use, such as household versus industrial systems. Perceptual correlation helped ensure an accurate understanding based on this context. As Lecturer A noted: *"You can show them pictures, but seeing the real thing is much better."*

When troubleshooting, forming a mental image of the wiring helped identify potential issues. Lecturer C highlighted the importance of mental construction: *"The new circuit could have a two-way switch that controls three or four lights. We must determine how they would assimilate the knowledge and draw that circuit. This determines if they can practically construct that circuit in their minds."*

Engineers and electricians utilise wiring diagrams for planning and designing electrical systems, with perceptual correlation enhancing their ability to visualise the final setup. Additionally, reading and interpreting wiring diagrams is important in electrical engineering education, where perceptual correlation aids students in retaining and understanding the material.

5.6.3.6.2 Perceptual Correlations Impact on Learning Symbols. Diagrams helped students encode, read, and use circuit diagrams to improve cognitive representations. To solve standard paper and pencil circuit problems, students must recognise the symbols used for electrical components, avoid attributing unintended meaning to conventions such as the use of straight, perpendicular lines, and extract information from the diagram about the completeness of the circuits, any elements bypassed by shorts, and series and parallel components. Successful interpretation and creation of circuit diagrams mirrors the understanding of circuit behaviour and is linked to developing a successful problem representation.

Perceptual correlation allowed the brain to connect sensory cues with specific meanings, such as shapes, colours, and patterns. This connection was necessary for learning symbols, enabling learners to form immediate associations between a symbol's appearance and function, which led to intuitive and efficient recognition.

Lecturer A described practical demonstrations that enhanced this correlation: *"When the students came to me, I also showed them [alternative teaching and] learning [methods]. There was a simulated room [and I included] things like plug and play [demonstrations]. This gave the students a chance to see the real-life application of what they are working with."*

Perceptual correlation accelerated recognition and recall. When learners saw a zig-zag symbol representing a resistor, they quickly identified its function without conscious thought, reducing cognitive load and allowing them to focus on understanding circuit operations. Additionally, strong correlations enhanced memory retention. For instance, the ground symbol's three descending lines visually represented earthing, making it easier to remember.

Perceptual correlation improved comprehension through clear associations. Symbols that resembled their real-world counterparts simplified understanding. The diode symbol, like a one-way road sign, conveyed that current flows in one direction. Lecturer F illustrated how different diagram types could initially confuse students: *"This type of wiring diagram show[s] [current flowing] top down and right to left. [A student could say] Sir, but the current is flowing [down the control circuit and back up to the neutral as indicated on the diagram] this way and back up to the top, [indicating that] this is a [different type of] wiring diagram called a ladder diagram. It is just that they have changed these symbols."*

This immediate recognition enabled learners to connect new information to prior knowledge effectively. With its long and short lines, a battery symbol visually represented polarity, eliminating confusion. Visual recognition and verbal association worked together, linking a switch symbol to the phrase 'open/closed circuit', boosting retention.

Lecturer F highlighted the need for clarity in symbol instruction: *"On your symbol chart, you referenced a circuit breaker but said it is drawn as a switch. Is it a circuit breaker or a switch? Students must be told that although we use this symbol for a switch, it can also be used as a circuit breaker."*

Using colour based on function and strategic arrangement in sequences further strengthened understanding (Reisslein et al., 2010). Lastly, strong perceptual correlations enabled learners to generalise and apply their knowledge effectively. Consistent symbol formats, such as an 'M' within a circle for a motor, ensured recognition across contexts.

5.6.3.7 The Effects of Misaligned Multi-Media Integration on a Learner's Perception and Response to Electrical Wiring Diagrams that Employ Principles of DCT and Multimedia Elements

5.6.3.7.1 Conceptual Challenges to Misaligned Multi-Media Integration when Engaging with Electrical Wiring Diagrams. Engaging with electrical wiring diagrams through misaligned multimedia integration created significant conceptual challenges that disrupted learning. Misalignment occurred when multimedia elements, text, diagrams, animations, and audio failed to connect temporally, spatially, or conceptually, leading to confusion and cognitive overload. Student 4 articulated this frustration: *"The video [confused me], especially where those lines showed the connection from component to component. I already had the drawing in front of me, and was shown how the different components were connected. I drifted off there and lost interest."*

The primary issue centred on instructional design that failed to consider how learners process information in multimedia environments. Disconnected modalities made it impossible for learners to link explanations to corresponding diagram components. Lecturer C observed a further complication*: "I have noticed that once students have developed a way to do something, and if you do, bring in an alternative method, they will endeavour not to have a conflict of understanding by mixing both methods. Or even entertaining the second one. They have already decided on a way of doing what needs to be done."* For instance, students struggled to integrate information if a resistor's role was described far from its symbol, leading to knowledge fragmentation. Inconsistent representations led to conflicting mental models; learners were confused when a switch appeared differently in a static diagram compared to an animation.

When corresponding texts and pictures are physically separated rather than integrated, learners struggle to hold both modalities in working memory simultaneously, reducing opportunities for active learning (Jiang et al., 2017). The increased cognitive load further complicated understanding. Misaligned multimedia forced students to expend unnecessary cognitive resources aligning related information. Cognitive overload ensued when animations demonstrated current flow whilst narration described a different aspect of the circuit. Student 4 explained*: "There was too much information. We already had the second diagram in front of us showing the actual connections. Maybe the video can be broken down step-by-step, showing connections from one component to another."* Additionally, repeated or contradictory information created further confusion, detracting from focus on core concepts.

Sequential understanding was also impaired. Temporal misalignment made it challenging to follow the logical flow of the circuit. If narration described one step whilst the animation showed another, learners missed important sequences. Student 2 highlighted this: *"The first time, you showed us a fuse, and the second time, it was missing. I want to know why we did not use a fuse?"* This was especially problematic for wiring diagrams where order is vital, as misaligned elements obscured cause-and-effect relationships.

Misrepresentation of component roles was common. Ambiguous visuals, such as simplified diagrams that omitted important details, led to a poor understanding of the components. Overemphasis on certain parts, such as the battery, while neglecting others, created knowledge gaps. These challenges hindered the formation of accurate mental models and limited the transfer of knowledge. Misaligned multimedia led to shallow learning, making it difficult to apply knowledge to different wiring diagrams and recognise patterns. Lecturer C noted: *"We also have students who have a lack of thinking, lack of knowledge, and lack of ability to solve problems. Students who rely on the lecturer [completely] do not take the initiative to go read and find out things for themselves, creating knowledge gaps."*

Strategies to address these issues included aligning spatial and temporal elements of multimedia. Text and diagrams were presented closely, and animations were synchronised with narration. Consistent representations reinforced understanding, and complex circuits were introduced step-by-step to enhance comprehension. These measures improved the learning experience.

5.6.3.7.2 ***Misaligned Multimedia's Impact on Facilitating Critical Thinking Through Visual Techniques in Response to Electrical Wiring Diagrams.*** Misaligned multimedia caused disconnection and hindered thinking when learners engaged with electrical wiring diagrams. This disconnection prevented practical analysis, interpretation, and problem-solving based on circuit behaviours and relationships. Information fragmentation separated visual elements, like circuit diagrams, from their verbal explanations. Student 3 described this disconnect: *"I did ask myself, is this three phase. That was the question I had. The picture, in my mind, completely differed from what I found in the workshop. I remember when you were telling us about the voltages 230/400V [however] I struggled to understand."*

When complex new concepts are introduced through fragmented multimedia, learners are forced to piece together scattered information, limiting their cognitive capacity for analysing circuit functionality (Fan, 2015). To scaffold this learning, Lecturer C *"encouraged student interaction. In a class, you can have students who are very bright and can solve problems quickly. However, you do have slower students, and when you group these students, then you will allow the slower students to quickly catch on and learn the techniques required to problem solve."* Inconsistent representations in animations and static diagrams created confusion about component roles, while cognitive overload arose when learners had to split their attention between competing elements. This overload impeded their ability to troubleshoot effectively.

Furthermore, misaligned multimedia disrupted problem-solving skills. Learners struggled to recognise patterns, such as distinguishing between parallel and series circuits, and were hindered in error detection. Reduced engagement was also a concern, as distractions from misaligned visuals prevented important analysis. Misleading emphasis on unimportant circuit components skewed the focus and undermined the comprehensive assessment.

Conceptual confusion arose from ambiguous component roles resulting from misaligned visuals, which led to misconceptions. When animations failed to align with verbal explanations, learners found it challenging to construct accurate mental models. Student 4 reiterated: *"The video [confused me], especially where those lines showed the connection from component to component. I already had the drawing in front of me, and was shown how the different components were connected. I drifted off there and lost interest."* This misalignment weakened the link between theory and practical application, impeding their ability to generalise concepts to real-world scenarios.

The impact on higher-order thinking was profound. Student 2 questioned: *"The first time, you showed us a fuse, and the second time, it was missing. I want to know why we did not use a* *fuse?"* Misalignment restricted engagement in what-if scenarios and hindered learners' ability to synthesise visual and conceptual knowledge, reducing their capacity to evaluate solutions creatively. Student 3 revealed this conceptual misalignment: *"How do you connect wires from the bottom when they should be coming from the top? I do not know whether what I am saying makes sense, but I decided not to say it."*

To address these issues, implementing effective strategies was crucial. Ensuring spatial and temporal coherence by presenting diagrams, animations, and text together was crucial, as was the purposeful highlighting of key components. Presenting animations in logical, sequential steps aligned with verbal explanations reinforced understanding and facilitated better critical thinking. Student 4 suggested: *"There was too much information. We already had the second diagram in front of us showing the actual connections. Maybe the video can be broken down step-by-step, showing connections from one component to another."*

5.6.3.8 The Role of Cognition in Learners' Perception and Response to Electrical Wiring Diagrams that Employ Principles of DCT and Multimedia Elements

5.6.3.8.*1 The Role of Cognition in Learners' Perception and Response to Electrical Wiring Diagrams and how this Affects Declarative Memory.* Cognition significantly influenced how learners perceived and responded to electrical wiring diagrams. The interaction between cognitive processes and declarative memory determines how effectively learners encode, store, and retrieve knowledge. *"Your step-by-step explanation, together with the logic behind it, created a better understanding for me as a student"* (Student 4).

Learners interpreted wiring diagrams through visual perception, identifying symbols and patterns within them. *"Some of the symbols [used] are found in our textbook [which] we only know [by] name. I think it is better to show students the specific components, whether it is*

LED's etc. So that when we get to connect them, it is easier" (Student 1). Adequate visual perception encoded declarative memory, such as the meaning of a resistor symbol or the layout of a series circuit. Cognitive attention focused on specific elements; distractions led to incomplete encoding, weakening memory formation. A lack of attention to polarity markers caused learners to overlook important circuit details. *"[The lecturer] took a circuit diagram and showed them how to duplicate that circuit diagram. Take a line from here and connect [it] to the next point there. I told him to connect a battery to a light with a switch. They must switch it on and off, and it must work. Then, bring in your transistors and slowly build them up"* (Lecturer F). Recognising patterns, like the repetition of parallel circuits, helped organise information into coherent mental models.

Complex relationships in wiring diagrams overwhelmed learners, hindering memory formation. Poorly designed diagrams and irrelevant multimedia elements increased cognitive load, making effective encoding difficult. Simplified instructional design, such as breaking diagrams into smaller segments, facilitated a focused understanding of patterns and relationships. Organising components into meaningful chunks, like power sources and switches, reduced cognitive strain and aided memory encoding. Understanding the sequence of a circuit's operations reinforced temporal relationships in memory. *"The first time, you showed us a fuse; the second time, it was missing. I want to know why we did not use a fuse"* (Student 2). When learners retrieved declarative knowledge, such as recognising a fuse symbol, they effectively applied it to wiring diagrams and problem-solving. A strong declarative memory enabled them to identify circuit faults and respond accurately to diagrams, improving efficiency.

However, complex or cluttered diagrams often overwhelm learners and obstruct memory encoding, especially when labelling is unclear. Without sufficient practice, declarative memories faded, making retention difficult. Active learning techniques, such as redrawing diagrams and predicting outcomes, strengthened declarative memory through engagement. *"When I got to the workshop, I realised why we were duplicating parts of that lesson, and that was to make the connections for the wiring itself. I realised it helped because we connected just the motor the first time, and now we were going to include the indicator lights as well. Doing it the second time reinforced what we had done [in] the first"* (Student 1). Well-aligned text, animations, and diagrams minimised cognitive overload. Spaced repetition and retrieval practice reinforced memory by repeatedly activating stored knowledge. *"After completing this lesson, I asked myself why we did two-way switching. I was curious to know the main purpose of doing these things. I asked myself why am I doing this"* (Student 3). Strong declarative memory built a foundation for advanced understanding, allowing learners to analyse complex circuits and apply their knowledge across various contexts, including industrial wiring diagrams and real-world troubleshooting.

5.6.3.8.2 *Comprehension Through Variation's Impact on Cognition in Learners' Perception and Response to Electrical Wiring Diagrams.* Comprehension through variation exposed learners to diverse representations and scenarios related to electrical wiring diagrams. This approach enhanced cognition by improving perception, understanding, and responses to these diagrams. *"In the practical [task], they were using a specific colour, but this was not mentioned in the theory. If you had mentioned this in the theory component, you could have observed during the practical to see whether they had done it as to how you had taught them"* (Lecturer C). By using variation, learners were better equipped to form mental models, recognise patterns, and apply knowledge flexibly.

Variation impacted cognitive perception by improving pattern recognition. Exposure to multiple representations of similar concepts, such as different layouts of a series circuit, helped learners identify consistent features, leading to faster recognition of familiar elements, even though the learning material was very complex and demanding. *"[The student could ask] in this instance, you are using this symbol to indicate a switch [but] not a circuit breaker. Why is this so? [It is important to clarify which symbol represents what is drawn.] They must know that this is a circuit breaker in a certain application, and in a different application, this could be an MCB"* (lecturer F). Novel representations, such as horizontal versus vertical arrangements, kept learners engaged and focused on the important diagram features. Additionally, variation reduced misinterpretation by illustrating the flexibility of component arrangements without changing functionality.

In cognitive processing, exposure to variations in diagram complexity encouraged learners to abstract core principles, such as current flow or voltage relationships, independent of specific features. It also facilitated schema building, allowing learners to identify parallel circuits regardless of diagram orientation. The gradual introduction of complexity helped reduce the cognitive load. *"Your explanation of it step by step, and the logic behind it created a better understanding for me as a student"* (Student 4).

Variations fostered deeper processing by requiring learners to distinguish similarities and differences, enhancing memory encoding and recall. Knowledge acquisition from multiple representations requires learners to create connections between corresponding elements in different representations. *"The current is flowing [down the control circuit and back up to the neutral as indicated on the diagram]. This different type of wiring diagram [is a ladder diagram]. In a ladder diagram, you have different switches in ladder format. It is a [replica] of this [wiring] diagram [with] changed symbols"* (Lecturer F). As they encountered diverse diagrams, they activated memory pathways, strengthening their ability to retrieve and apply knowledge.

Nonetheless, challenges arose from using variation. Introducing too much complexity too early can overwhelm learners and distract them from foundational concepts. *"Although we had given them quality information, maybe it was too much information at one time. It is probably an information overload or close to that. We probably needed to break it into smaller components"* (Lecturer C). To mitigate this, educators employed strategies such as progressively increasing diagram complexity, providing guided comparisons, and utilising interactive tools. *"It is nice to consider [aspects] we never thought about and helps to identify problem areas and [addresses] critical thinking. This process is a continuous one, especially with new things coming up, new machines being made, and new [structural electrical] drawings [developed]"* (Lecturer A). Lecturers related variations to real-world applications and encouraged reflection to reinforce understanding. These variations helped learners become resilient to misinterpretation and improved knowledge transfer, enabling them to apply their learning in different contexts and solve novel problems more effectively.

5.7 Conclusion

This chapter presented the clustered patterns, codes and themes generated from the analysed data. DCT, MLT and PLCs were used as lenses to analyse and interpret the data. Excerpts from the participants were included to lend credibility to the research findings and accurately represent the participants' views.

Data was presented and analysed using lecturer-focused group discussions, questionnaires, structured observations and interviews. A personal reflective journal supplemented and supported the codes and themes, triangulating the data to ensure accuracy in analysing the three research questions. Finally, concepts and themes that emerged after an inductive analysis were tabled. All participants were given pseudonyms to ensure anonymity and were allowed to communicate freely and honestly. The following chapter presents the research findings.

CHAPTER SIX: DISCUSSION, RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

From the conceptual framework, I identified three aspects that structured the perceptual guardrails of this study. The first examined how students learn electrical wiring diagrams. The second examined how cognitive load and instructional design theories improved teaching electrical wiring diagrams. The third examined how learners perceive and respond to electrical wiring diagrams that employ principles of DCT and multimedia elements. Investigating those aspects led to employing a LS professional development approach to examine the factors that affect the reading and interpreting of electrical wiring diagrams in a TVET class. I will now present my findings, considering recent research and theories, as well as the recorded experiences of this TVET college in South Africa. Based on my research and other studies, I offer suggestions on what to consider when implementing LS in a vocational college.

In the previous chapter, the research findings from the generated data were introduced, examined and evaluated. This chapter discusses the data collected from interviews, focus group discussions, questionnaires, a reflective journal, and a structured observation schedule. The chapter begins with the findings, followed by a summary, a discussion, and concludes with recommendations, the study's limitations, and suggestions for further research studies.

The research investigated the impact of LS methodology and explored the integration of cognitive load theory and instructional design theories specific to diagrams and illustrations on the learning of electrical wiring diagrams.

The research questions were answered utilising the following four conceptual frameworks: Professional Learning Communities, Cognitive Load, Dual Coding and Multimedia Learning Theories.

6.2 Findings

The following narrative presents the study's findings.

6.2.1 Analysis of research question 1

How does the implementation of lesson study influence the teaching and learning of electrical wiring diagrams in a South African TVET college?

6.2.1.1 Teacher collaboration encouraged active participation in knowledge construction. The significance of teacher collaboration in promoting active participation and ongoing improvement in education was evident in this research study. Lecturer participants concurred with Ono and Ferreira (2010) that teamwork fostered an enhanced culture of student learning, as exemplified by professional learning communities (PLCs). The study findings revealed that lecturers collaborated on a common goal (Samaras et al., 2008). Defined expectations for collaboration and reflection encouraged continuous improvement. From the study, the PLC created a safe sharing experience; it fostered honest reflection and problem-solving, improving teaching, although the relationship between teaching and learning is complex (Cheung & Wong, 2014). The findings revealed that teacher well-being was crucial in fostering open communication, mutual respect, emotional support, and celebrating achievements.

The study results demonstrated that engaging lessons were necessary to maintain student interest (Samaras et al., 2008). Through this research project, lecturers collaborated to enhance strategies for capturing attention (Farmer, 2010), shared ideas and identified best practices. The study also introduced new research techniques, allowing lecturers to observe and reflect on classroom interactions and management strategies (Samaras et al., 2008). This collaborative approach led to the continuous refinement of classroom culture and practices through planning, implementation, observation, and reflection on lessons. Tacit knowledge, gained through experience and hard to articulate, became explicit. The study demonstrated how lecturers exchanged methods and perceptions through planning sessions, highlighting intuitive teaching aspects (Feldman, 2020; Samaras et al., 2008). The study revealed how feedback and peer review made implicit knowledge explicit, while seasoned educators demonstrated effective practices to less experienced colleagues. Data revealed how a culture of questioning uncovered underlying knowledge utilised in practice (Samaras et al., 2008).

The findings revealed both the challenges and benefits of technology integration and cross-curricular student engagement. Insights from colleagues' past experiences were used to improve the forecasting of student reactions. The research addressed anticipated responses, differentiation and scaffolding to student challenges. The emerging themes revealed that inclusive LS practice promoted knowledge construction. The study underscored the necessity of understanding student diversity to make content culturally relevant and accessible to everyone (Ríos, 2019).

6.2.1.2 Lecturer Development Through Professional Learning Communities (PLC).

The research revealed that a culture of shared learning can be successfully implemented among educators through a PLC. “A highly effective PLC engages in an ongoing process in which educators work under the assumption that continuous job-embedded learning is key to improved student learning” (Eaker & Marzano, 2020, p. 1). The study demonstrated that best practices and new collaborative methods could be utilised to assess the impact on student learning. Three principles for effective PLCs emerged. The first principle focused on a strong commitment to individual student learning, ensuring mastery by breaking skills into manageable parts and providing necessary support. The second principle emphasised a collaborative culture that set shared objectives and promoted accountability. The third principle emphasised a passionate focus on improved learning outcomes for every student. The study assessed progress, analysed data, and reflected on practice. The study revealed that informed PLC decisions resulted in refined approaches to better meet students' diverse needs. The findings revealed that a collegial atmosphere enhanced communication and created a supportive professional community where educators felt empowered to share challenges yet valued every voice (Malcolm, 2015). The study demonstrated a commitment to continuous improvement and reflection when PLCs became dynamic ecosystems for ongoing professional development, encouraging innovation and enhancing educational quality (Owen, 2014). This contributed to a vibrant learning culture prioritising student success (Kitchen et al., 2019).

The study also revealed diverse participant worldviews, which clashed with the institution’s goals, presenting PLC challenges. Lecturers were accustomed to traditional content delivery methods, making adopting this new cognitive teaching strategy complex (Eaker & Marzano, 2020). From the study, the following obstacles to effective PLCs were time, strong leadership, and resource access. Study findings revealed that engagement was vital, and fostered a collective mindset within the team. Time constraints and burnout often came up in discussions. Trust issues emerged from the themes as differing perspectives created friction. Professional judgment tension was palpable yet fundamental to this teaching and learning process. Lecturer C profoundly stated that he recognised that it was not easy to convince others about some of the ideas. Ironically, he said this was good because your contribution should not be readily accepted but should be convincing with strong arguments. The study revealed that evaluation and decisive leadership were imperative to sustain momentum and address shifting priorities (Saif, 2023). Evaluating impact was crucial. The findings indicated that some of the strategies included dedicated PLC meeting times, recognising contributions, and fostering open communication (Brodie & Borko, 2016). Advocating for institutional support and training was paramount (Owen, 2014). The findings also addressed sustainability. To ensure long-term commitment, developing a shared vision, building peer accountability, and celebrating milestones are necessary for ongoing progress (Samaras et al., 2008; Willems & Bossche, 2019).

6.2.1.3 Lesson Study's Impact on Differentiated Instructional Strategies. The study revealed a systematic approach focusing on student learning to connect to student understanding developed instructional strategies. When lecturers observed each other's lessons and engaged in reflective discussions, it enhanced lesson effectiveness. This study showed that support structures helped students build on prior knowledge and deepen their understanding through active learning with student-centred activities.

The themes corroborated that this approach was necessary to select and organise simple to complex instructional strategies. It involved lecturers planning, observing, and refining lessons, enabling them to share diverse perspectives on effectively introducing new concepts and adapting to technological changes. This approach made lessons more engaging for students by starting with simple ideas and gradually increasing complexity, addressing "applied competence" (Bhyat, 2012, p.151).

LS enhanced student thinking by providing a collaborative framework that allowed lecturers to build a knowledge base about student learning and refine instructional strategies. This process focused on deep understanding, active engagement, and continuous improvement as lecturers worked together to create well-planned lessons based on best practices. The study revealed that visualisation supported students' understanding of the nature of science. However, metacognition, self-regulation, and "self-regulated learning were not always explicit" (Dinsmore & Alexander, 2012, p. 501). To address this, lecturers enhanced instructional techniques, clarified definitions, identified measurement types and validated evidence. The PLC had to determine whether the focus was more on teaching processes than on delivering comprehensive content knowledge. However, the findings disclosed that not all students benefited from visual literacy; some found it distracting or confusing. Additionally, certain visuals confused complex concepts and hindered critical thinking.

6.2.1.4 LS Required Strong Institutional Support Through Clearly Established Goals, Professional Development Resources and Administrative Proficiency. This study validated that administrative support was vital in freeing lecturers' time for instructional activities. Collaborative planning and shared ideas reduced workload, enhancing instruction quality (Goldshaft, 2016). Efficient administrative processes and clear policies reduced bureaucratic delays and confusion and improved time management. To create awareness of these issues, three members of the campus management team were included in our lecturer participant group. This was done to eliminate resource constraints and improve institutional support.

The study also revealed that established clear goals, with professional development resources and administrative support, strengthened vocational education. Improving professional development equipped educators and staff with the necessary skills to meet the institution's objectives (Bükki & Fehérvári, 2021, p. 18).

The study also revealed that when everyone understood the institution's direction, it enhanced collective problem-solving. The study findings verified that structured frameworks and effective monitoring enhanced support within educational institutions by providing clarity and consistency (Saif, 2023). Additionally, these frameworks established clear expectations, promoting accountability and encouraging continuous improvement (Jung et al., 2022). This study validated that LS requires strong institutional support through clearly established frameworks, professional development resources and administrative proficiency.

6.2.1.5 Contrived Collegiality Hindered Professional Learning. An interesting observation from this study was that extra work involved in LS positively and negatively impacted educators and the teaching process. LS required lecturers to collaborate, plan, observe, analyse, and refine lessons. As the researcher, I found this research to be the most challenging yet revealing. The participation of the lecturer participants was laboured, an imposition, almost coercion. This was not noticeable from the interviews, but that sense of imposition was noticeable when interviews/focus group discussions and joint lesson plan construction were required. One of the reasons is the lack of allocated time for CPD. It is possible that they only participated as a favour to a colleague. However, the student participation felt genuine and enthusiastic.

6.2.2 Analysis of research question 2

How can cognitive load theory and instructional design theories specific to diagrams and illustrations be integrated to improve the effectiveness of lesson study for teaching electrical wiring diagrams?

6.2.2.1 The Influence of Cognition on Information Processing and the Ability to Process and Construct Knowledge. From this study, the focus on how teachers learn, specifically teachers' learning about pupils' learning, emerged. It examined how LS characterised and operationalised learning to achieve this purpose. Intrinsic cognitive load was the goal of the lesson plan. The emerging themes indicated that the PLC also identified extraneous load, which is the mental effort unrelated to the core learning tasks, such as distracting audiovisuals. Evident from the results were the instructional design theories specific to diagrams and illustrations incorporated into this study, including multimedia elements and supported learning directly related to the content. To manage information effectively, lecturers used schemas, which helped streamline understanding and enabled adaptation to this new experience. The findings displayed that CLT, MLT, and DCT contributed to developing solutions for anticipated student responses and challenges by focusing on how students process, understand, and retain information. Each theory offered strategies to address common learning obstacles, supported comprehension, and facilitated long-term retention.

The study demonstrated that CLT guided educators to design lessons anticipating points of confusion and prevented students from being overwhelmed. CLT emphasised the importance of excluding extraneous information to minimise distractions and cognitive fatigue. The findings showed that the PLC recognised that students often struggled to recall or understand information presented in a single format, like text alone. LS used visual competence to enhance memory by providing multiple retrieval cues. The findings revealed that using images, diagrams, and written explanations accommodated diverse learning preferences and helped clarify abstract concepts.

The findings clarified that MLT demonstrated that students' responses to information depend on its presentation. The lesson plan included well-designed multimedia that enhanced meaningful learning. The study also revealed that the PLC recognised cognitive overload occurs from poorly integrated visual comprehension. By integrating CLT, MLT, and DCT, educators created responsive learning environments that addressed cognitive overload and information retention, making learning more efficient and engaging in teaching electrical wiring diagrams.

6.2.2.2 Engaging Learning Theories and CLT to Develop Adaptable and Flexible Teaching Strategies for Diagrams and Illustrations. The research results indicated that graphicacy greatly enhanced student understanding and skill acquisition in teaching electrical wiring. Given the complexity of concepts like circuits, current flow, and voltage, graphicacy helped clarify these ideas, making them more concrete. The research concluded that DCT acknowledges that dual channels enhanced information retention. Students colour-coded wiring diagrams and labelled circuit layouts during practical tasks. CLT indicated that these aids helped manage the mental load by organising information. Students using materials with text and graphics achieved more accurate solutions (Malhotra & Verma, 2020). Simplified diagrams with clear labels and step-by-step instructions helped learners understand the concepts without feeling overwhelmed. Aids such as videos and demonstrations provided gradual guidance on wiring tasks, enabling learners to develop skills with greater confidence and accuracy.

Data indicated that guided practice helped students become independent during each learning stage, building confidence and understanding (Brown et al., 2013). Students' reactions varied based on learning styles and engagement levels. Some students appreciated structured lectures, while others found them passive or unengaging. To address this, lecturers incorporated active learning techniques and relatable examples (Malhotra & Verma, 2020). The research concluded that students enjoyed hands-on activities and practical application of concepts (Andrews et al., 2009). However, some felt anxious, particularly those uncomfortable with open-ended tasks or lacking prior experience. During the research, educators supported these students through clear instructions, modelling tasks and promoting collaborative learning, while regular check-ins resulted in confidence and engagement. Also noted from this study, social learners thrived by discussing ideas in group settings, leading to deeper understanding (Goldshaft, 2016). However, some students preferred independent work, whereas others, less experienced with self-directed learning, felt overwhelmed by the project's open-ended nature. Visual intelligence allowed tech-savvy students to engage in multimedia presentations and interactive tools. Lecturers facilitated practice sessions and kept multimedia elements simple and focused.

The findings concluded that the over-reliance on graphicacy in learning led to cognitive overload, impairing retention and understanding (Clark & Lyons, 2010; Mayer, 2009). Image overload overwhelmed learners' working memory, causing confusion rather than clarity. This issue was compounded by complex and rapidly presented multimedia. Learners struggled to connect multiple sources of information, resulting in incoherent mental models producing a split-attention effect (Schroeder & Cenkci, 2018). From the findings, misconceptions created from overly abstract or overwhelming multimedia diverted attention from higher-order thinking tasks like synthesis or analysis.

6.2.2.3 Differentiated Instruction's Process and Impact on Declarative Memory Related to Diagrams and Illustrations. The research findings concluded that lecturers ensured that differentiation was subtle and inclusive and encouraged a classroom culture where all students appreciated learning. The differentiation process examined content, process, product and environment. The idea was to determine how students learnt. The study concluded that through CLT, students mastered basic skills to the point of automaticity, meaning the learner could perform these skills without conscious effort (Feldon, 2007). Students found that graphicacy helped improve layouts and connections. This format helped them grasp the interactions between components and the flow of electricity, making abstract concepts more tangible. Data demonstrated that reading and interpreting diagrams correctly reinforced retention, allowing students to revisit important concepts like circuitry and connections. Students tracked their progress, recognised patterns, and improved their understanding of standard wiring conventions for better long-term retention. As students developed diagram comprehension, problem-solving processes improved, complex problems were simplified, and understanding was enhanced. Wiring diagrams helped bridge the gap between theory and practice, boosting student confidence in real-world tasks since they resembled actual circuits. The research concluded that students found active diagram engagement —tracing lines, identifying components, and troubleshooting circuit paths—promoted better comprehension and retention (Martin, 2017; Preston, 2019). From the data, some students focused more on images than conceptual understanding. While diagrams were helpful, students needed extra practice to grasp the underlying principles without them. Consistent practice mastered these concepts and reduced the time spent decoding symbols. Additionally, students recommended starting with basic diagrams to build confidence before progressing to more complex layouts, as this approach enhanced retention and comprehension (Reisslein et al., 2010). Differentiated Instruction positively impacted declarative memory related to diagrams and illustrations.

6.2.2.4 The Impact of Instructional Design Through Cognitive Load Theory and Instructional Design Theories. The research also revealed that the PLC recognised that good content design eliminated or minimised unnecessary information or distractions that did not directly support the learning goal. This ensured learners focused on mastering concepts at each stage without wasting cognitive resources on irrelevant details. Instructional design using technology and multimedia improved educational experiences. The findings disclosed that multimedia elements like simulations and videos fostered interactivity, sustaining attention and motivation. Technology integration allowed personalised learning paths. Furthermore, multimedia improved retention by simplifying complex concepts and reducing cognitive load.

The study findings revealed that this technology-rich environment promoted self-paced, autonomous learning and encouraged students to take charge of their education. Multimedia tools like simulations improved critical thinking and problem-solving skills by presenting students with complex, real-world scenarios. However, the study findings also cautioned that the effectiveness of multimedia depends on mindful instructional design to prevent cognitive overload and ensure alignment with learning goals. Evidenced was how thoughtful integration of technology and multimedia in instructional design created engaging, accessible, and compelling learning experiences suited to the needs of modern learners (Sweller et al., 2019). The findings also indicated that lecturer oversight and presumption of prior knowledge led to overfitting lessons that worked in limited contexts. This created gaps that students found difficult to close, resulting in infoxication. Also, when multimedia elements were distracting, too complex, or rapidly moved from one sequence to the next, information overload led to students' minds wandering.

6.2.2.5 The Impact of Deep and Surface Learning on Cognition and Instructional Design Specific to Diagrams and Illustrations. Data analysis also confirmed that deep and surface learning were contrasting approaches, affecting learners' processing and retaining information. Deep Learning was evidenced by a robust and intrinsic motivation to understand content meaningfully. The summative assessment revealed that deep learners generated a parts list from the diagram when they connected to prior knowledge and sought to understand the why behind the information. This resulted in a solid, flexible understanding that promoted long-term retention and the ability to apply knowledge in various contexts.

The research concluded that surface learners focused on rote memorisation, recall of facts, and adherence to basic requirements without seeking to understand the material beyond what was necessary for immediate goals. The research confirmed that while both methods led to learning, in the deep-achieving approach, students were motivated by intrinsic interest and high marks and approached work through an organised and strategic search for meaning. Deep learning flourished as students explored, questioned, and applied knowledge in diverse contexts. The emerging themes confirmed that formulating mental images, or mind pictures, crucially impacted deep and surface learning by influencing how learners processed, retained, and retrieved information. Collected evidence acknowledged that deep learning created mind pictures that enhanced understanding and retention. However, visual incompetence represented incongruent relationships and processes within the content. Study observations indicated that deep and surface learning impacted cognition and instructional design specific to diagrams and illustrations.

6.2.3 Analysis of Research Question 3

How do students perceive and respond to electrical wiring diagrams that employ principles of dual coding theory and multimedia elements?

6.2.3.1 Significant Disparities' Effect on Diagrams with Dual Coding and Multimedia Elements. One of the important findings was how diagrams with dual coding and multimedia elements strategically enhanced comprehension through dual processing channels. However, it also emerged that significant disparities in these diagrams—such as inconsistencies in content, structure, or design quality— disrupted the intended learning process. Disparities confused students by presenting conflicting or redundant information, which detracted from the benefits of dual coding (Hayikaleng, 2019; Liu et al., 2020). The study revealed that alignment improvement was accomplished through consistency—diagrams matched the verbal content consistently. The colour scheme and structure across diagrams helped prevent cognitive overload. Combining elucidation with dual coding and multimedia elements created a powerful instructional strategy. The emerging themes revealed that dual-channel information and visuals enhanced memory and understanding (Vagg et al., 2020). This resulted in the dual coding elucidation effect. The study results confirmed that interactive or kinesthetic components in elucidation enabled students to actively engage with the content, often through simulations or hands-on tasks. Multimodal encoding allowed text, visuals, and interactive elements to encode information differently. The study demonstrated that flexible learning paths accommodated different learning preferences, allowing students to navigate between text, visuals, and hands-on elements according to their needs.

When students understood the conceptual information in a subject area, they were more comfortable with complex diagrams, as they could see how each component fitted into the larger context. The study also revealed that students with limited semantic understanding found complex diagrams overwhelming or confusing, perceiving them as irrelevant or overly detailed. The emerging themes showed that diagrams aligned with semantic frameworks—such as showing relationships, hierarchies, or processes—helped students grasp information logically and reasonably.

The study findings also revealed that perceptive incoherence occurred when students experienced confusion or difficulty understanding a diagram due to a lack of clarity, logical structure, or alignment with the information's meaning. This incoherence occurred when the diagram did not convey information aligned with students' expectations or mental models, leading to misinterpretation, cognitive overload, or disengagement.

6.2.3.2 The Effect of Infoxication on a Learner's Perception and Response to Electrical Wiring Diagrams. The study concluded that infoxication, "the issue of information overload," impacted students' perception and response to electrical wiring diagrams designed with DCT and multimedia principles (Benito-Ruiz, 2009, p. 60). Students faced perception challenges due to cognitive overload. When excessive multimedia elements like animations, images, and text were presented simultaneously, students' working memory became overwhelmed, hindering their ability to process the wiring diagrams effectively (Nigel, 2020). Infoxication made it harder for students to focus on important diagram aspects, such as wire paths, connections, or annotations. Instead, their attention was scattered across unnecessary or peripheral details. A plausible reason is "that instructional approaches that are effective for the more capable students may be less effective or even counterproductive for the less capable ones" (Jiang et al., 2017, p. 739). DCT suggests that students benefit from processing multimodal communication. However, study results showed that infoxication diluted this advantage when students could not distinguish between necessary and unnecessary elements. From the findings, avoidance occurred when students disengaged altogether when overwhelmed by the volume or complexity of information. Instead of analysing the wiring diagram, students resorted to guesswork, bypassing the logical reasoning process that dual coding and multimedia elements were intended to support. To mitigate these issues, lecturers simplified the design using minimal yet effective multimedia elements. They broke down wiring diagrams into manageable segments. Colour coding or animation was used sparingly to emphasise diagram aspects without overwhelming the learner. Student conjecture amplified the effects of infoxication.

The findings also indicated that lecturer conjecture, characterised by assumptions or oversimplifications in presenting electrical wiring diagrams, strongly influenced learners' perceptions and responses (Goldshaft, 2016). It rendered diagrams ambiguous or unreliable, leading learners to misinterpret information. *"Lecturers may unintentionally bias learners through unverified assumptions, causing them to focus disproportionately on certain elements and form skewed understandings"* (PD). The study conclusions indicated that a strong framing means reasonable teacher control over the learning process, whereas weak instructional framing permits detrimental student autonomy.

6.2.3.3 The Impact of Information Sequencing on Electrical Wiring Diagrams that Employed Principles of DCT and Multimedia Elements. The abstraction of cognitive ability from cognitive complexity significantly influenced how information sequencing was managed. The results indicated that students with high fluid intelligence excelled in recognising patterns and adapting quickly to unconventional or fragmented information using "technology [to unravel] complexity" (Kandaga et al., 2021, p. 2). The capacity to handle complexity allowed them to organise disjointed data coherently. The findings indicated that students effectively troubleshot missing or unclear steps in ambiguous situations. Conversely, also evident was that students with lower fluid intelligence struggled with complex sequences, finding it challenging to process long or intricate information without solid contextual cues. The results indicated that structured sequences with explicit connections led to chunking. Students chunked information processes by organising and grouping sequential inputs. When students chunked, they reordered or recognised patterns easily.

Another emerging theme was inductive reasoning. The ability to draw general conclusions from specific observations influenced how students engaged with electrical wiring diagrams that utilised DCT and multimedia elements. The emerging themes confirmed that students recognised connections and patterns within wiring diagrams, such as repeated symbols and synesthetic communication, allowing them to infer the overall circuit layout and flow (Chang & Shieh, 2018). This comprehension was vital to understanding how various components are interconnected.

The research findings indicated that when students merged synesthetic clues with inductive reasoning, they constructed accurate mental models of circuit operations, necessary for grasping complex sequences like voltage pathways (Engelhardt & Beichner, 2004). Inductive reasoning also improved problem-solving skills, empowering students to predict missing components by recognising familiar structures (Bhyat, 2012). When students relied on inferred patterns to guide their exploration of new diagrams, they quickly spotted inconsistencies and retained knowledge for future applications.

6.2.3.4 Students' Perception and Response to the Signalling Principle Influenced by Temporal Contiguity. Another study finding was that temporal contiguity in signalling, where related bimodal information was presented simultaneously, significantly impacted students' perceptions and responses to electrical wiring diagrams that used DCT and multimedia elements. The temporal contiguity principle (TCP) states that corresponding words and pictures or narration and animation should be presented simultaneously rather than successively. The findings demonstrated that this approach optimised cognitive load and enhanced information processing and integration. Temporal contiguity improved attention allocation and ensured that signals such as highlights and colour changes aligned closely with verbal explanations and prompted students to focus on relevant parts of the diagram, minimising distractions (Mayer, 2014).

Study conclusions also revealed that reducing the time gap between presenting complementary information helped students retain electrical circuit concepts better and allowed for focused diagrams (Mayer, 2014). This promoted independent student exploration and manipulation of diagrams. Conceptually meaningful signals allowed students to grasp complex information effortlessly, guiding their focus and enhancing comprehension (Ozcelik et al., 2010). From the study, when resistors, capacitors, or voltage sources were colour-coded, students were directed to specific circuit components, reducing interpretive time and facilitating swift identification. Arrows for current direction or animations for voltage flow enabled students to grasp how different circuit parts interacted. The results indicated that when a diagram highlighted conductive pathways while an instructor explained the current flow, students could form a cohesive mental representation, enhancing retention through meaningful associations (Chang & Shieh, 2018).

6.2.3.5 The Effects of Semantic Distortion on Learning Electrical Wiring Diagrams.

Observations from the study revealed that semantic distortion, where language, symbols, or terminology diverged from established meanings, hindered rigid learners from studying electrical wiring diagrams. When symbols deviated from the norm, students struggled to recognise components, leading to misconceptions and misrepresentations. Semantic distortion created fragmented comprehension of circuit functions, causing students to view diagrams as isolated components rather than cohesive circuits. The study highlighted how this interference complicated their cause-and-effect reasoning, leaving gaps in their understanding (Egan & Schwartz, 1979). The findings revealed that the cognitive strain on students was substantial. They often focused excessively on decoding unclear symbols, hindering higher-level problem-solving and diminished their motivation and confidence. As a result, they struggled with problem-solving and error detection in circuits.

Another emerging study theme was visualisation. During the study, the PLC recognised this as a powerful strategy to address semantic distortion for electrical wiring diagrams, effectively bridging gaps in understanding caused by unclear symbols. This semantic strategy transformed students' "abstract thinking to achieve imagery generation and used their knowledge of physical principles in the real world to simulate how things would appear under actual physical conditions corresponding to the tasks" (Belardinelli et al., 2009, p. 198). When students combined "symbols, relationships between symbols (i.e. grouping, containment and connectivity), and spatial arrangement, all contributed to meaning," (Lank, 2003, p. 5).

6.2.3.6 Perceptual Correlation Related to Electrical Wiring Diagrams that Employ Principles of DCT and Multimedia Elements. The findings revealed that perceptual correlation was necessary to comprehend electrical wiring diagrams, enhancing the formulation of mental images associated with such diagrams. It aided in visual cognition and conceptualisation (Mayer, 2014). This study used standardised electrical symbols for components such as resistors, capacitors, switches, and wires. Perceptual correlation enabled students to recognise these symbols and associate them with real-world counterparts (Mackay

& Hobden, 2012). The study demonstrated that understanding spatial relationships between components allowed for accurate visualisation of wiring configurations. Perceptual correlation promoted functional understanding. It was crucial to grasp each component's role and the flow of electricity within the circuit (Lank, 2003). During the study, when students recognised a switch in a diagram, it aided in comprehending current flow. Contextual understanding was another key factor in interpreting wiring diagrams. The interpretation varied depending on contextual use (Gates, 2018). When troubleshooting, forming a mental image of the wiring assisted in identifying potential issues (Winn & Sutherland, 1989). The study revealed that perceptual correlation connected sensory cues with specific meanings, such as shapes, colours, and patterns. This connection was necessary to learn symbols, allowing students to form immediate associations between a symbol's appearance and function, leading to intuitive and efficient recognition (Egan & Schwartz, 1979). Perceptual correlation accelerated recognition and recall. When students saw a zig-zag symbol representing a resistor, they quickly identified its function without conscious thought, reducing cognitive load and allowing them to focus on understanding circuit operations. The study also revealed that perceptual correlation improved comprehension through clear associations (Kasturi et al., 1990). Symbols that resembled their real-world counterparts simplified understanding. The results demonstrated that this immediate recognition allowed students to connect new information to prior knowledge effectively.

6.2.3.7 The Influence of Misaligned Multi-Media Integration on Electrical Wiring Diagrams that Employ Principles of DCT and Multimedia Elements. An emerging theme from this study was how the use of misaligned multimedia integration to comprehend electrical wiring diagrams conceptually challenged and disrupted learning (Kassen, 1998). The findings confirmed that misalignment occurred when multimedia elements, such as text, diagrams, animations, and audio, failed to connect temporally, spatially, or conceptually, leading to confusion and cognitive overload. The research displayed that disconnected modalities made it impossible for students to link explanations to corresponding diagram components. For instance, students struggled to integrate the information if a resistor's role was described far from its symbol. The findings corroborated that this led to the fragmentation of knowledge. Inconsistent representations caused conflicting mental models; students were confused if a switch appeared differently in a static diagram versus an animation.

The results proved that the increased cognitive load due to misalignment further complicated understanding. Cognitive overload ensued when animations demonstrated current flow while narration described a different aspect of the circuit. Additionally, the findings validated that repeated or contradictory information created further confusion, detracting from the focus on core concepts and impairing sequential understanding. During the study, temporal misalignment made it challenging to follow the logical flow of the circuit. If narration described a step while the animation showed a different one, students missed important sequences. This was especially problematic for wiring diagrams, where order is vital (Mayer, 2014).

Also emerging from the findings was that overemphasising certain parts, like the battery, while neglecting others, created notable gaps in knowledge. This hindered the formation of accurate mental models and limited knowledge transfer (Sweller et al., 2019). The study findings showed that misaligned multimedia led to shallow learning, making knowledge application and pattern recognition of different wiring diagrams difficult. Spatial and temporal alignment of multimedia elements were implemented to address these issues (Jiang et al., 2017). Bimodal fragmentation forced students to piece together scattered information, limiting their cognitive capacity for analysing circuit functionality.

6.2.3.8 The Role of Cognition in Student Perception and Response to Electrical Wiring Diagrams that Employ Principles of DCT and Multimedia Elements. The study revealed that cognition significantly influenced how students perceived and responded to electrical wiring diagrams, affecting their ability to process, understand, and retain information (Marshall, 2008). The interaction between cognitive processes and declarative memory determined how effectively students encoded, stored, and retrieved knowledge. Students, through synesthetic perception, identified symbols and patterns (Peppler & Glosson, 2013). Cognitive perception encoded details into declarative memory, such as the meaning of a resistor symbol or the layout of a series circuit. The study revealed that cognitive attention focused on specific elements; distractions led to incomplete encoding, weakening memory formation. A lack of attention to polarity markers caused students to overlook important circuit details (Peppler & Glosson, 2013).

The findings ratified that complex relationships in wiring diagrams overwhelmed students. Breaking diagrams into smaller segments facilitated a focused understanding of patterns and relationships (Braun & Clarke, 2006). Organising components into meaningful chunks, like power sources and switches, reduced cognitive strain and aided memory encoding. Understanding the sequence of a circuit's operations reinforced temporal relationships in memory (Mayer, 2014). The results demonstrated that when students retrieved declarative knowledge, such as recognising a fuse symbol, they effectively applied it to wiring diagrams and problem-solving (Winn, 1988). Emerging findings also showed that complex or cluttered diagrams often overwhelmed students, especially when labelling was unclear (Pearson et al., 2015). Active learning techniques, such as redrawing diagrams and predicting outcomes, strengthened declarative memory through engagement (Mor et al., 2014). Spaced repetition and retrieval practice reinforced memory by repeatedly activating stored knowledge (Paivio, 2014).

Another important theme was comprehension through variation. It exposed students to diverse representations and scenarios related to electrical wiring diagrams. The findings revealed that by using variation, students were better equipped to form mental models, recognise patterns, and apply knowledge flexibly. Variation improved pattern recognition (Sadoski & Paivio, 2012). The study authenticated exposure to representations of similar concepts, such as different layouts of a series circuit, helped students identify consistent features, leading to faster recognition of familiar elements. Unlike horizontal versus vertical arrangements, novel representations kept students engaged and focused on important diagram features. The study concluded that variation reduced misinterpretation by illustrating the flexibility of component arrangements without changing functionality (Jiang et al., 2017).

The findings ratified that deeper processing required students to distinguish similarities and differences (Seufert, 2003). As they encountered diverse diagrams, they activated memory pathways, strengthening their ability to retrieve and apply knowledge. Challenges arose from using variation. Too much complexity early overwhelmed students and distracted them from foundational concepts (Paivio, 2014). To mitigate this, the PLC used strategies like progressively increasing diagram complexity, providing guided comparisons, and employing interactive tools. The results revealed that these variations helped students become resilient to misinterpretation and improved knowledge transfer, enabling them to apply their learning in different contexts and solve novel problems more effectively.

6.3 Summary of the Key Findings

6.3.1 The Following Key Findings Emanated from Research Question 1

How does the implementation of LS influence the teaching and learning of electrical wiring diagrams in a South African TVET college?

- Teacher collaboration encouraged active participation in knowledge construction.

- Lecturer development improved through professional learning communities (PLC).
- LS was positively impacted through differentiated instructional strategies.
- LS required strong institutional support through clearly established goals, professional development resources and administrative support.
- Contrived collegiality hindered professional development.

6.3.2 The Following Key Findings Emanated from Research Question 2

How can cognitive load theory and instructional design theories specific to diagrams and illustrations be integrated to improve the effectiveness of LS for teaching electrical wiring diagrams?

- The influence of cognition on information processing and the ability to process and construct knowledge.
- Engaging learning theories and CLT helped develop adaptable and flexible teaching strategies for diagrams and illustrations.
- The impact of differentiated instruction on declarative memory related to diagrams and illustration.
- The impact of instructional design through cognitive load theory and instructional design theories.
- The impact of deep and surface learning on cognition and instructional design specific to diagrams and illustrations.

6.3.3 The Following Key Findings Emanated from Research Question 3

How do students perceive and respond to electrical wiring diagrams that employ principles of dual coding theory and multimedia elements?

- Significant disparity’s effect on diagrams with dual coding and multimedia elements.

- The effect of infoxication on a learner's perception and response to electrical wiring diagrams.
- The impact of information sequencing on electrical wiring diagrams that employed principles of DCT and multimedia elements.
- Students' perception and response to the signalling principle are influenced by temporal contiguity.
- The effects of semantic distortion on learning electrical wiring diagrams.
- Perceptual correlation related to electrical wiring diagrams that employed principles of DCT and multimedia elements.
- The influence of misaligned multimedia integration on electrical wiring diagrams that employed principles of DCT and multimedia elements.
- The role of cognition in student perception and response to electrical wiring diagrams that employed principles of DCT and multimedia elements.

6.4 Discussion

While the study's findings are based on a single TVET college with a limited participant pool, the insights provided a valuable starting point for exploring the scalability and adaptability of LS in a diverse vocational education setting. The following findings respond directly to the overarching research questions. The first research question revealed notable divergence in the levels of engagement and the sustained momentum and effectiveness of the PLC process. Disparities in participation and persistent challenges such as time constraints, heavy workloads, and shifting priorities consistently hindered and negatively impacted the PLC's progress. Maintaining the momentum and effectiveness of PLCs over time proved challenging. This highlights the necessity for participants to bring substantial expertise for the LS model to be genuinely effective. The intensive time commitment for collaborative activities posed logistical challenges, and the approach did not always yield immediate or generalisable results. LS became the catalyst of professional learning; however, the speed versus sophistication paradox was apparent. LS aimed at highly sophisticated, perfected lessons through careful iteration conflicted with teachers' need to make rapid, in-the-moment decisions during actual lesson delivery. A meticulously planned lesson can become too rigid to accommodate real-time adaptations. As Lecturer (A) mentioned, "Teachers have their own way of delivery and know *how to adapt it."* This study underscored the inherent tension between collegiality and strong leadership within the context of LS implementation. While collegiality emphasises collaborative decision-making, mutual respect, and valuing diverse perspectives, effective LS implementation requires decisive leadership. This study revealed that successful LS implementation required a decisive team leader possessing a clear vision, strong communication and interpersonal skills, high emotional intelligence, a commitment to inclusivity, and resilient perseverance. Furthermore, the study revealed an important constraint: lecturers consistently reported insufficient time to dedicate to the additional administrative tasks associated with LS implementation. Another important finding was professional judgment tension that revealed creative conflict. Lecturer C stated that convincing others about some ideas was difficult. Ironically, he said this was good because your contribution should not be readily accepted but convinced with strong arguments.

This study also weighed the impact of instructional design. This addressed the second research question of how cognitive load theory and instructional design theories specific to diagrams and illustrations can be integrated to improve the effectiveness of LS for teaching electrical wiring diagrams. Thoughtful integration of technology and multimedia in instructional design created engaging, accessible, and compelling learning experiences suited to the needs of modern learners. Effective content design rigorously eliminated or minimised unnecessary information and distractions that did not directly support the intended learning objective. By presenting information through diverse modalities – visual, auditory, and kinesthetic – educators ensured all students could effectively access and comprehend the content.

Another finding was relevance versus irrelevance, referred to as the relevance gap emanating from conjecture. When lecturers omitted or relegated an aspect of teaching, students identified the missing information as vital for understanding. These findings emanated from the third research question: How do students perceive and respond to electrical wiring diagrams that employ principles of DCT and multimedia elements? The study revealed the difference in perception between teachers and students regarding the importance or relevance of a particular concept or topic. Recognising this disconnect between teaching and learning was invaluable. Lecturer conjecture, characterised by assumptions or oversimplifications when presenting electrical wiring diagrams, strongly influences learners' perceptions and responses. Abstraction versus granularity tension was another finding emanating from research question 3. Lecturer oversight and presumption of prior knowledge led to overfitting lessons that worked in limited contexts. This created gaps that students found difficult to close. This disconnect led to confusion and frustration among students as they struggled to bridge the gap between the high-level concepts being presented and the foundational knowledge required to comprehend them fully. When lecturers assumed that students already possessed expertise or familiarity with the subject, they inadvertently skipped over key explanations. They failed to address the building of an understanding of the nuances. Striking a balance between abstraction and granularity was important. While abstraction helps convey overarching ideas and principles, granularity was necessary to ground those ideas in concrete examples, real-world applications, or step-by-step problem-solving.

With these notable arguments for this pedagogical approach, it is important to view the challenges by balancing convergent and divergent thinking as a scientific process when discussing the paradoxes of the three research questions. However, the successful completion of the distinct steps of the LS process acted as a conditional factor that could either foster or hinder the initiative's effectiveness. Despite the many positive classroom experiences and sufficient evidence of the effectiveness of LS from numerous research studies, there is still a lack of significant evidence on the successful implementation in a technical vocational context. It can be implemented successfully if the challenges raised are adequately addressed. The paradoxes suggest that LS is most valuable when balanced with opportunities for teachers to develop their adaptive expertise and professional judgment rather than being treated as a complete solution for instructional design.

6.5 Methodological Contributions of Action Research

The research design shaped this study's findings and ensured a strong foundation (Newsome, 2016). This AR study examined how LS functioned as an alternative teaching and learning method to enhance students' ability to read, understand, and interpret electrical wiring diagrams. AR provided a structured framework for addressing the challenges of conceptual learning and improving instructional strategies (Coghlan & Brannick, 2014). Given the lack of curriculum saliency, lecturers developed and adapted teaching strategies to better support student learning. This study is the first empirical evaluation of LS in a South African TVET college, highlighting its significance for vocational education. The findings contribute to best practices, offering insights that can be applied to improve pedagogy and professionalism in technical training.

AR facilitated the professionalisation of teaching by promoting systematic, reflective practice. By collecting empirical data on my pedagogy, I refined my instructional methods, leading to continuous professional growth and improved student learning outcomes. Reflective research on practice strengthened my ability to guide students toward achieving learning objectives (Dreyer, 2015). Integrating PLCs, CLT, DCT, and MLT established a structured approach to knowledge acquisition, application, and critical reflection. Combining practical tasks with LS strategies reduced knowledge gaps and improved conceptual understanding.

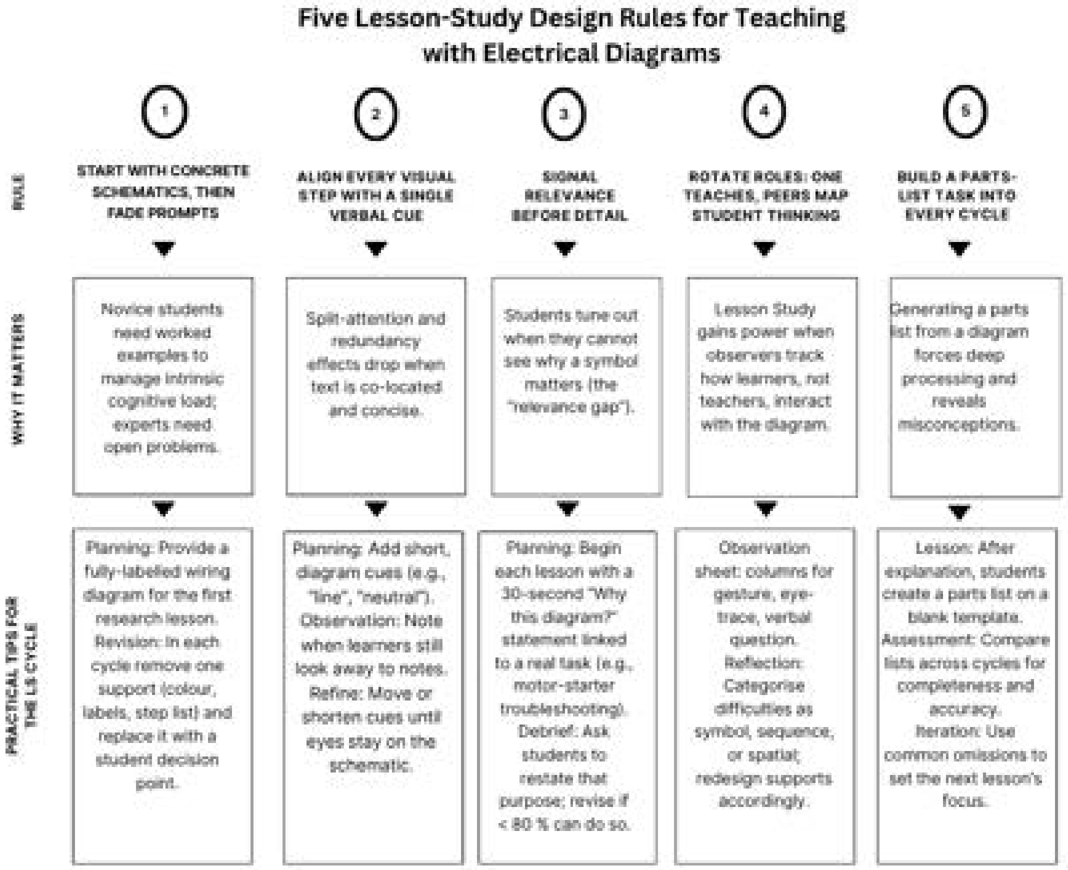
Beyond individual professional development, AR fostered a collaborative culture among educators. Faculty members collectively addressed educational challenges by engaging in AR projects and improving instructional practices and teamwork (Elliot, 1991). Collaboration within PLCs enabled lecturers to share research findings, develop cohesive teaching strategies, and transform professional practice. The structured nature of AR—identifying challenges, designing interventions, implementing changes, and reflecting on outcomes—enhanced motivation and efficacy among educators (Kemmis, 2006; Jugoo, 2014). Meaningful data on effective teaching practices provided a strong basis for improving instructional strategies and balancing self-efficacy with student learning outcomes (Craig, 2009).

This study also demonstrated how AR and LS facilitated students' transition from rote memorisation to conceptual learning. Through structured activities, participants engaged in comprehension, application, analysis, evaluation, and knowledge creation. Teaching electrical schematics with appropriate conceptual tools encouraged participatory learning and improved multisensory perception of complex numbering systems (Kind, 2009). Integrating practical tasks with LS strategies addressed misconceptions, deepened understanding, and enhanced cognitive processing (Lave & Wenger, 1991).

AR contributed to a clearer understanding of student learning challenges and strategies for overcoming them. By scaffolding knowledge from simple to complex concepts, students developed schemas and mental models that improved their cognitive processing (Fan, 2015).

AR helped identify and address misconceptions, ensuring that knowledge was structured logically for effective transfer. Mastery of concepts within one context allowed students to apply their understanding across multiple settings, reinforcing cognitive development (Mohler, 2007). Active student participation in learning empowered learners and educators, fostering a shift from passive reception to engaged knowledge construction (Mor et al., 2014). Cognitive progression from knowledge acquisition to higher-order thinking skills—application, analysis, and evaluation—resulted in conceptual change and intellectual emancipation (Tempelman & Pilot, 2011). By challenging inaccurate beliefs and fostering self-directed learning, AR contributed to a transformative educational experience. Figure 17 illustrates a practical account of the Lesson Study flow chart emanating from this research that will aid in implementation in VET. An implementation checklist should commence with a 5-cycle (identify the problem-plan-teach-observe-reflect) in a single term. Prepared artefacts should include annotated diagrams, observer sheets and a blank parts-list template. Rotating roles should be assigned to lecturer participants. Lecturer participants must have a teacher, two observers, and one data scribe. Collect evidence from student diagrams, parts lists, and observer tallies. Review evidence after each cycle and apply the five rules in Figure 17 to adjust the next lesson. Applying these five rules will help TVET lecturers translate Lesson Study insights into concrete, repeatable improvements in diagram-based teaching.

Figure 17 *Lesson Study flowchart emanating from this research.*



6.6 Limitations of the Study

This study was conducted at a single TVET college with a limited sample of 26 students and six lecturers, making the findings context-specific rather than representative of all TVET institutions in South Africa. The participants were selected from one of 52 colleges, and their unique characteristics may have influenced the results. The cohort may have consisted of high-achieving students and experienced lecturers, potentially limiting the applicability of the findings to broader or more diverse educational settings. Consequently, the study's internal validity may differ if conducted with a different group in another institution.

An important contribution of this study is its originality in applying LS to enhance the cognitive processes involved in reading, understanding, and interpreting electrical wiring diagrams. Given the scarcity of empirical research on diagram comprehension in vocational education, further studies are needed to explore its broader impact. While the study was designed to ensure dependability, credibility, confirmability, and transferability to similar contexts, the findings cannot be generalised.

Additionally, the potential influence of the Hawthorne effect must be acknowledged, as participants were aware of being observed, which may have affected their engagement. As both the teacher and researcher, my involvement in the study introduced a degree of subjectivity, which may have influenced the research outcomes despite efforts to minimise bias.

6.7 Recommendations for Further Research

The following two issues require further research and could unravel invaluable information about how students learn. The first is the misconception that the existing way you understand a concept could be the easiest or best, and if you engage in an alternative, it could be confusing.

"If students are satisfied with understanding a concept, they can close their minds or block other options" (PD). This surface strategy describes "how students organise the temporal and spatial contexts surrounding the task" (Henning, 2006, p. 23) *"[when we watched] the video [the animated] lines showed the connection from component to component. I already had the drawing in front of me and was now shown how the different components were connected. I drifted off there and lost interest"* (Student 4). *"I have noticed that once students have developed a way to do something, if you bring in an alternative method, they will endeavour not to have a conflict of understanding by mixing both methods. Alternatively, even entertaining the second one. They have already decided on a way of doing what needs to be done"* (Lecturer C).

Why do students have this prevailing mentality, and how can this misconception be deconstructed?

The second important consideration for further research is whether YouTube videos are an authentic avenue to gain practical knowledge.

"Another important observation from Student 3's interview was when students watched YouTube videos, they perceived this as gaining practical knowledge" (PD*). "I am also trying to find ways to help me improve my studying abilities. I use YouTube videos to see how I can bring practicality into my own space"* (Student 3)

These videos are available on various topics and are often free, making knowledge widely accessible by creating step-by-step tutorials and demonstrations. The unique insights make the platform a rich source of diverse learning experiences. However, not all creators are experts, and some videos might oversimplify or omit important details, leading to gaps in understanding and disjointed learning.

Engaging this study repeatedly will highlight other important emerging aspects; however, stopping here is inconclusive, but the most important thing about research is knowing when to stop. "One must stop before one has finished; otherwise, one will never stop and never finish" (Tuchman, 1983, p. 20).

6.8 Conclusion

A rapidly changing, increasingly complex world demands more from education to prepare students for an uncertain future. Lecturer's knowledge and professionalism have changed accordingly. This study revealed that LS is a transformative professional development tool for South African TVET lecturers, fostering collaborative learning, improved instructional strategies, and deeper student engagement. It addresses challenges in teaching electrical wiring diagrams through a structured approach integrating cognitive and multimedia learning theories. LS unravelled into practitioner scholarship. Our TVET campus requires inquiry-based science instruction. Transformation must begin with lecturer beliefs. This focus on beliefs led me to explore LS. A professional learning community was formed from which we gained a common, more nuanced understanding of our challenges. We became more intentional in our lesson planning. Through honesty and reflection, we confronted and overcame a pressing problem of practice. We worked and learned together. In the end, all transformed together. Through LS, we became students of our practice.

References

Abdella, A., & Reddy, C. (2021). *Implementing lesson study in middle schools: Benefits and challenges*. *3*, 85–104.

Abdulrahaman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N. T., Olawoyin, L. A., Mejabi, O. V., Imam-Fulani, Y. O., Fahm, A. O., & Azeez, A. L. (2020). Multimedia tools in the teaching and learning processes: A systematic review. *Heliyon*, *6*(11), e05312. https://doi.org/10.1016/j.heliyon.2020.e05312

Abrahams, I., Reiss, M. J., & Sharpe, R. M. (2013). The assessment of practical work in school science. *Studies in Science Education*, *49*(2), 209–251. https://doi.org/10.1080/03057267.2013.858496

Acosta, C. (2006). The Frame(s) Problem and the physical and emotional basis of human cognition. *Technoetic Arts*, *4*(2), 151–165. https://doi.org/10.1386/tear.4.2.151_1

Adams, E. (2017). Thinking Drawing. *International Journal of Art & Design Education*, *36*(3), 244–252. https://doi.org/10.1111/jade.12153

Adams, J. W. (2013). A case study: Using lesson study to understand factors that affect teaching creative and critical thinking in the elementary classroom [Ed.D., Drexel University]. In *ProQuest Dissertations and Theses*. https://www.proquest.com/docview/1356692081/abstract/16331EF88E8D4EAAPQ/1

Adelman, C. (1993). Kurt Lewin and the Origins of Action Research. *Educational Action Research*, *1*(1), 7–24. https://doi.org/10.1080/0965079930010102

Agarwal, P. K., Bain, P. M., & Chamberlain, R. W. (2012). The Value of Applied Research: Retrieval Practice Improves Classroom Learning and Recommendations from a Teacher, a Principal, and a Scientist. *Educational Psychology Review*, *24*(3), 437–448. https://doi.org/10.1007/s10648-012-9210-2

Agustin, A. (2019). Reflective Journal as a Self-Directed and Sustainable Professional Development Tool for Pre-Service Teachers: A Case Study in English Language Education Study Program. *Scholaria: Jurnal Pendidikan Dan Kebudayaan*, *9*(2), Article 2. https://doi.org/10.24246/j.js.2019.v9.i2.p103-110

Ainsworth, S., Prain, V., & Tytler, R. (2011). Drawing to Learn in Science. *Science*, *333*(6046), 1096–1097. http://www.jstor.org/stable/27978521

Akinyode, B. F., & Khan, T. H. (2018). Step by step approach for qualitative data analysis. *International Journal of Built Environment and Sustainability*, *5*(3). https://doi.org/10.11113/ijbes.v5.n3.267

Akoojee, S. (2016). Developmental TVET Rhetoric In-Action: The White Paper for Post-School Education and Training in South Africa. *International Journal for Research in Vocational Education and Training*, *3*(1), Article 1. https://doi.org/10.13152/IJRVET.3.1.1

Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I., Shlomo, A., Ishikawa, S., Silverstein, M., Ishikawa, S., & Silverstein, M. (1977). *A pattern language: Towns, buildings, construction*. Oxford University Press. http://catdir.loc.gov/catdir/enhancements/fy1311/74022874-t.html

Al-Saadi, H. (2014). *Demystifying Ontology and Epistemology in Research Methods*.

Altricher, H., Feldman, A., Posch, P., & Somekh, B. (2005). *Teachers Investigate Their Work: An Introduction to Action Research across the Professions*. Routledge. https://doi.org/10.4324/9780203978979

Aminoff, E. M., & Tarr, M. J. (2015). Associative Processing Is Inherent in Scene Perception. *PLOS ONE*, *10*(6), e0128840. https://doi.org/10.1371/journal.pone.0128840

Anderson, J. R. (1990). *Cognitive psychology and its implications, 3rd ed* (pp. xvi, 519). W H Freeman/Times Books/ Henry Holt & Co.

Andrews, M., Vigliocco, G., & Vinson, D. (2009). Integrating Experiential and Distributional Data to Learn Semantic Representations. *Psychological Review*, *116*, 463–498. https://doi.org/10.1037/a0016261

Arcangeli, M. (2014). Anežka Kuzmičová, Mental Imagery in the Experience of Literary Narrative: Views from Embodied Cognition. *Estetika*, *51*(1), 149–154. https://doi.org/10.33134/eeja.120

Ates, S. (2005). The Effects of Learning Cycle on College Students' Understanding of Different Aspects in Resistive DC Circuits. *The Electronic Journal for Research in Science & Mathematics Education*. https://ejrsme.icrsme.com/article/view/7737

Babaci-Wilhite, Z. (2017). A rights-based approach to science literacy using local languages: Contextualising inquiry-based learning in Africa. *Int Rev Educ International Review of Education: Journal of Lifelong Learning*, *63*(3), 381–401.

Baldwin, L., & Crawford, I. (2010). Art Instruction in the Botany Lab: A Collaborative Approach. *Journal of College Science Teaching*, *40*(2), 26–31. https://doi.org/10.2505/3/jcst10_040_02

Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin*, *128*(4), 612–637. https://doi.org/10.1037/0033-2909.128.4.612

Bates, A. W. (Tony). (2015). *Teaching in a Digital Age*. Tony Bates Associates Ltd. https://opentextbc.ca/teachinginadigitalage/

Bedwin, M. M. (2012). *Challenges Faced by Lecturers in the Implementation of National Certificate Vocational Curriculum at Mopani South East FET College*. 118.

Belardinelli, M., Palmiero, M., Sestieri, C., Nardo, D., Di Matteo, R., Londei, A., D'Ausilio, A., Ferretti, A., Del Gratta, C., & Romani, G. L. (2009). An fMRI investigation on image generation in different sensory modalities: The influence of vividness. *Acta Psychologica*, *132*(2), 190–200. https://doi.org/10.1016/j.actpsy.2009.06.009

Benito-Ruiz, E. (2009). Infoxication 2.0. In *Handbook of Research on Web 2.0 and Second Language Learning* (pp. 60–79). https://dx.doi.org/10.4018/978-1-60566-190-2.ch004

Benjamin, R., Ewell, P. T., Miller, M. A., Rhodes, T. L., & Banta, T. (2012). *The Seven Red Herrings About Standardized Assessments in Higher Education*. https://www.semanticscholar.org/paper/The-Seven-Red-Herrings-About-Standardized-in-Higher-Benjamin-Ewell/20327582653ab15840b6d36d43635577349b444c

Bennedsen, J. (2006). The dissemination of pedagogical patterns. *Computer Science Education*, *16*(2), 119–136. https://doi.org/10.1080/08993400600733590

Bertram, C., & Christiansen, I. (2014). *Understanding Research: An Introduction to Reading Research: Vol. First edition*. Van Schaik Publishers. https://ukzn.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=1243049&site=ehost-live&scope=site

Bhyat, F. (2012). *From the particularities of practice to the generalisation of theory.* Doctoral dissertation, University of Witwatersrand [Thesis]. http://wiredspace.wits.ac.za/handle/10539/11370

Biggs, J. B., & Collis, K. F. (2014). *Evaluating the Quality of Learning: The SOLO Taxonomy (Structure of the Observed Learning Outcome)*. Academic Press.

Billett, S. (2013). Vocational education: Purposes, traditions and prospects. *Journal of Vocational Education & Training*.

https://www.academia.edu/16918283/Vocational_education_purposes_traditions_and_prospects

Bowden, J. A., & Green, P. (2005). *Doing developmental phenomenography*. RMIT University Press.

Bowden, J. A., & Walsh, E. (2000). *Phenomenography*. RMIT University Press.

Bower, M. (2017). *Design of Technology-Enhanced Learning: Integrating Research and Practice*. Emerald Publishing Limited. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=4717043

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How People Learn: Brain, Mind, Experience, and School*. National Academies Press. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=3375627

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bright, D., McKay, A., & Firth, K. (2024). How to be reflexive: Foucault, ethics and writing qualitative research as a technology of the self. *International Journal of Research & Method in Education*, *47*(4), 408–420. https://doi.org/10.1080/1743727X.2023.2290185

Brodie, K., & Borko, H. (2016). *Professional learning communities in South African schools and teacher education programmes*. HSRC Press.

Brown, B., Eaton, S. E., Jacobsen, D. M., Roy, S., & Friesen, S. (2013). Instructional Design Collaboration: A Professional Learning and Growth Experience. *Journal of Online Learning and Teaching*, *9*(3), 439. https://www.proquest.com/docview/1499024409/abstract/1AB611AF1CCC485CPQ/1

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, *18*(1), 32–42. https://doi.org/10.3102/0013189X018001032

Bruce, C., & Ladky, M. (2011). *What's Going on Backstage? Revealing the Work of Lesson Study with Mathematics Teachers* (pp. 243–249). https://doi.org/10.1007/978-90-481-9941-9_19

Buckley, P. J., Chapman, M., Clegg, J., & Mattos, H. G.-D. (2014). A Linguistic and Philosophical Analysis of Emic and Etic and their Use in International Business Research. *Management International Review*, *54*(3), 307–324. https://doi.org/10.1007/s11575-013-0193-0

Bükki, E., & Fehérvári, A. (2021). How do teachers collaborate in Hungarian VET schools? A quantitative study of forms, perceptions of impact and related individual and organisational factors. *Empirical Research in Vocational Education and Training*, *13*(1), 2. https://doi.org/10.1186/s40461-020-00108-6

Buncick, M. C., Betts, P. G., & Horgan, D. D. (2001). Using Demonstrations as a Contextual Road Map: Enhancing Course Continuity and Promoting Active Engagement in Introductory College Physics. *International Journal of Science Education*, *23*(12), 1237–1255.

Bunniss, S., & Kelly, D. R. (2010). Research paradigms in medical education research. *Medical Education*, *44*(4), 358–366. https://doi.org/10.1111/j.1365-2923.2009.03611.x

Calikli, G., & Bener, A. (2015). Empirical analysis of factors affecting confirmation bias levels of software engineers. *Software Quality Journal*, *23*(4), 695–722. https://doi.org/10.1007/s11219-014-9250-6

Cañas, A. J., & Novak, J. D. (2010). The theory underlying concept maps and how to construct and use them. *Práxis Educativa*, *5*(1), 9–29. http://www.revistas2.uepg.br/index.php/praxiseducativa/article/view/1298/944

Carlstedt, B., Gustafsson, J.-E., & Ullstadius, E. (2000). Item Sequencing Effects on the Measurement of Fluid Intelligence. *Intelligence*, *28*(2), 145–160. https://doi.org/10.1016/S0160-2896(00)00034-9

Carstensen, A.-K. (2013). *Connect: Modelling learning to facilitate linking models and the real world through lab-work in electric circuit courses for engineering students*. https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=3328034

Caulfield, J. (2019, September 6). *How to Do Thematic Analysis | Step-by-Step Guide & Examples*. Scribbr. https://www.scribbr.com/methodology/thematic-analysis/

Cavanagh, T., & Kiersch, C. (2022). Using commonly-available technologies to create online multimedia lessons through the application of the Cognitive Theory of Multimedia Learning. *Educational Technology Research and Development*, *71*. https://doi.org/10.1007/s11423-022-10181-1

Caviglioli, O. (2019). *Dual Coding with Teachers*. John Catt Educational, Limited. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=6461839

Cerbin, B. (2011). *Lesson study: Using classroom inquiry to improve teaching and learning in higher education* (1st ed, 1–1 online resource (xiv, 149 pages)). Stylus. http://site.ebrary.com/id/10545782

Cerulo, K. A. (1988). What's Wrong with This Picture? Enhancing Communication through Distortion. *Communication Research*, *15*(1), 93–101.

Chang, W. (2011). Integrating electrostatics with demonstrations and interactive teaching. *American Journal of Physics*, *79*(2), 226–238. https://doi.org/10.1119/1.3533342

Chang, W., & Shieh, R. S. (2018). A study of the conceptual comprehension of electric circuits that engineer freshmen display. *European Journal of Physics*, *39*(4), 045705. https://doi.org/10.1088/1361-6404/aab6e1

Cheung, W. M., & Wong, W. Y. (2014). Does Lesson Study work?: A systematic review on the effects of Lesson Study and Learning Study on teachers and students. *International Journal for Lesson and Learning Studies*, *3*(2), 137–149. https://doi.org/10.1108/IJLLS-05-2013-0024

Chi, M. T. H. (2009). Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. *Topics in Cognitive Science*, *1*(1), 73–105. https://doi.org/10.1111/j.1756-8765.2008.01005.x

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, *5*(2), 121–152. https://doi.org/10.1207/s15516709cog0502_2

Chipamaunga, S. R. (2015). *How students develop the ability to integrate learning—A phenomenographic study* Doctoral dissertation, University of Witwatersrand [Thesis]. http://wiredspace.wits.ac.za/handle/10539/19961

Chisholm, L., & Leyendecker, R. (2008). Curriculum reform in post-1990s sub-Saharan Africa. *International Journal of Educational Development*, *28*(2), 195–205. https://doi.org/10.1016/j.ijedudev.2007.04.003

Clark, R. C., & Lyons, C. (2010). *Graphics for Learning: Proven Guidelines for Planning, Designing, and Evaluating Visuals in Training Materials*. Center for Creative Leadership. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=624441

Clark, R. C., & Mayer, R. E. (2016). *E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*. John Wiley &

Sons, Incorporated. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=4418752

Cochrane, B. A., & Milliken, B. (2019). Imagined event files: An interplay between imagined and perceived objects. *Psychonomic Bulletin & Review*, *26*(2), 538–544. https://doi.org/10.3758/s13423-019-01572-2

Coghlan, D., & Brannick, T. (2014). *Doing Action Research in Your Own Organization*. SAGE Publications Ltd. https://doi.org/10.4135/9781529682861

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education, 6th ed* (pp. xviii, 638). Routledge/Taylor & Francis Group.

Collins, A., Brown, J., & Holum, A. (1991). COGNITIVE APPRENTICESHIP: MAKING THINKING VISIBLE. *American Educator: The Professional Journal of the American Federation of Teachers*. https://www.semanticscholar.org/paper/Cognitive-Apprenticeship. Making-Thinking-Visible-Collins-Brown/712a1b8a88040d80db28f2751288b5a45d702014

Cox, R., & Brna, P. (2016). Twenty Years on: Reflections on “Supporting the Use of External Representations in Problem Solving” …. *International Journal of Artificial Intelligence in Education*, *26*(1), 193–204. https://doi.org/10.1007/s40593-015-0054-z

Craig, D. V. (2009). *Action Research Essentials* (1st edition). Jossey-Bass.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed). SAGE Publications.

Creswell, J. W., & Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications.

de Hevia, M. D., & Spelke, E. S. (2010). Number-space mapping in human infants. *Psychological Science*, *21*(5), 653–660. https://doi.org/10.1177/0956797610366091 de Jong, T. (2010). Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science*, *38*(2), 105–134. https://doi.org/10.1007/s11251-009-9110-0

Dehaene, S., Meyniel, F., Wacongne, C., Wang, L., & Pallier, C. (2015). The Neural Representation of Sequences: From Transition Probabilities to Algebraic Patterns and Linguistic Trees. *Neuron*, *88*(1), 2–19. https://doi.org/10.1016/j.neuron.2015.09.019

Deregowski, J. B., & Dziurawiec, S. (1986). Some Aspects of Comprehension of Technical Diagrams: An Intercultural Study. *Le Travail Humain*, *49*(1), 43–60. https://www.jstor.org/stable/40657386

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, *32*(1), 5–8. https://doi.org/10.3102/0013189X032001005

Desjardins, C. D. (2010). *Dissertation research quality and doctoral attrition: A mixed methods study* [Doctoral dissertation, University of Southern California].

Dinsmore, D., & Alexander, P. (2012). A Critical Discussion of Deep and Surface Processing: What It Means, How It Is Measured, the Role of Context, and Model Specification. *Educational Psychology Review*, *24*(4), 499–567. https://doi.org/10.1007/s10648-012-9198-7

Dobelli, R. (2014). *The Art of Thinking Clearly: The Secrets of Perfect Decision-Making* (N. Griffin, Trans.). Hodder And Stoughton Ltd.

Dreyer, L. M. (2015). Reflective journaling: A tool for teacher professional development. *Africa Education Review*, *12*(2), 331–344. https://doi.org/10.1080/18146627.2015.1108011

Dudley, P. (2013). Teacher learning in Lesson Study: What interaction-level discourse analysis revealed about how teachers utilised imagination, tacit knowledge of teaching, and fresh evidence of pupils' learning, to develop practice knowledge and so enhance their pupils' learning. *Teaching and Teacher Education*, *34*, 107–121. https://doi.org/10.1016/j.tate.2013.04.006

Dudley, P., Xu, H., Vermunt, J. D., & Lang, J. (2019). Empirical evidence of the impact of lesson study on students' achievement, teachers' professional learning and on institutional and system evolution. *European Journal of Education*, *54*(2), 202–217. https://doi.org/10.1111/ejed.12337

DuFour, R., & Reason, C. (2015). *Professional Learning Communities at Work TM and Virtual Collaboration: On the Tipping Point of Transformation*. Solution Tree. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=4537421

DuFour, R., DuFour, R., Eaker, R., Many, T. W., & Mattos, M. (2016). *Learning by doing: A handbook for Professional Learning Communities at Work* (3rd ed.). Solution Tree Press.

Dunkelberger, N., Sullivan, J. L., Bradley, J., Manickam, I., Dasarathy, G., Baraniuk, R., & O'Malley, M. K. (2021). A Multisensory Approach to Present Phonemes as Language Through a Wearable Haptic Device. *IEEE Transactions on Haptics*, *14*(1), 188–199. IEEE Transactions on Haptics. https://doi.org/10.1109/TOH.2020.3009581

Dunlap, J. C. (2006). Using Guided Reflective Journaling Activities to Capture Students' Changing Perceptions. *TechTrends*, *50*(6), 20–26. https://doi.org/10.1007/s11528-006-7614-x

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving Students' Learning With Effective Learning Techniques: Promising

Directions From Cognitive and Educational Psychology. *Psychological Science in the Public Interest*, *14*(1), 4–58. https://doi.org/10.1177/1529100612453266

Dunn, W. R., Lyman, S., & Marx, R. (2003). Research methodology. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, *19*(8), 870–873. https://doi.org/10.1016/S0749-8063(03)00705-9

Dupin, J.-J., & Johsua, S. (1987). Conceptions of french pupils concerning electric circuits: Structure and evolution. *Journal of Research in Science Teaching*, *24*(9), 791–806. https://doi.org/10.1002/tea.3660240903

Eaker, R., & Marzano, R. J. (2020a). *Professional Learning Communities at Work®and High-Reliability Schools: Cultures of Continuous Learning (Ensure a Viable and Guaranteed Curriculum)*. Solution Tree. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=6036729

Eaker, R., & Marzano, R. J. (2020b). *Professional Learning Communities at Work®and High-Reliability Schools: Cultures of Continuous Learning (Ensure a Viable and Guaranteed Curriculum)*. Solution Tree. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=6036729

Egan, D. E., & Schwartz, B. J. (1979). Chunking in recall of symbolic drawings. *Memory & Cognition*, *7*(2), 149–158. https://doi.org/10.3758/BF03197595

Eklund-Myrskog, G. (1997). Students' Views of Learning in Vocational Education. *Scandinavian Journal of Educational Research*, *41*(2), 179–188. https://doi.org/10.1080/0031383970410205

Elliot, J. (1991). *Action Research for Educational Change*. McGraw-Hill Education (UK).

Emerson, R. W. (2021). Convenience sampling revisited: Embracing its limitations through thoughtful study design. Journal of Visual Impairment & Blindness, 115(1), 76–77. https://doi.org/10.1177/0145482X20987707

Engelhardt, P. V., & Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics*, *72*(1), 98–115. https://doi.org/10.1119/1.1614813

Entwistle, N. (1997). *Contrasting Perspectives on Learning*. 11.

Euchner, J. (2019). Problem Framing. *Research-Technology Management*, *62*(2), 11–13. https://doi.org/10.1080/08956308.2019.1563433

Evagorou, M., Erduran, S., & Mäntylä, T. (2015). The role of visual representations in scientific practices: From conceptual understanding and knowledge generation to 'seeing' how science works. *International Journal of STEM Education*, *2*(1), 11. https://doi.org/10.1186/s40594-015-0024-x

Fakhrunnisaa, N., & Munadi, S. (2019). Relevance of Multimedia Expertise Competency in Vocational Schools toward the needs of Business/Industrial World. *Journal of Educational Science and Technology (EST)*, *5*, 58. https://doi.org/10.26858/est.v5i1.6923

Fan, J. E. (2015). Drawing to learn: How producing graphical representations enhances scientific thinking. *Translational Issues in Psychological Science*, *1*(2), 170–181. https://doi.org/10.1037/tps0000037

Farmer, L. (2010). *Fostering online communities of practice in vocational education*.

Fay, N., Garrod, S., Roberts, L., & Swoboda, N. (2010). The Interactive Evolution of Human Communication Systems. *Cognitive Science*, *34*(3), 351–386. https://doi.org/10.1111/j.1551-6709.2009.01090.x

Feldman, J. (2020). The role of professional learning communities to support teacher development: A social practice theory perspective. *South African Journal of Education*, *40*(1), 1–8. https://doi.org/10.15700/saje.v40n1a1668

Feldon, D. F. (2007). Cognitive Load and Classroom Teaching: The Double-Edged Sword of Automaticity. *Educational Psychologist*, *42*(3), 123–137. https://doi.org/10.1080/00461520701416173

Fernandez, C., & Yoshida, M. (2004). *Lesson Study: A Japanese Approach to Improving Mathematics Teaching and Learning*. Taylor & Francis Group. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=234239

Fernández, E. (1998). *Building systems using analysis patterns*. https://doi.org/10.1145/288408.288418

Fleay, J. J. (2018). Moral realism versus moral relativism in the postmodern myth. *Educational Philosophy and Theory*, *50*(14), 1354–1355. https://doi.org/10.1080/00131857.2018.1501944

Fox, A., & Poultney, V. (2020). *Professional learning communities and teacher enquiry: Evidence-based teaching for enquiring teachers* (1–1 online resource). Critical Publishing. https://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=2409196

Galantucci, B., Fowler, C. A., & Turvey, M. T. (2006). The motor theory of speech perception reviewed. *Psychonomic Bulletin & Review*, *13*(3), 361–377. https://doi.org/10.3758/BF03193857

Gamma, E., Helm, R., Johnson, R., & Vlissides, J. (1993). Design Patterns: Abstraction and Reuse of Object-Oriented Design. In O. M. Nierstrasz (Ed.), *ECOOP' 93—Object-Oriented Programming* (pp. 406–431). Springer. https://doi.org/10.1007/3-540-47910-4_21

Garg, R. (2016). Methodology for research I. *Indian Journal of Anaesthesia*, *60*(9), 640–645. https://doi.org/10.4103/0019-5049.190619

Garrod, S., Fay, N., Lee, J., Oberlander, J., & MacLeod, T. (2007). Foundations of Representation: Where Might Graphical Symbol Systems Come From? *Cognitive Science*, *31*(6), 961–987. https://doi.org/10.1080/03640210701703659

Gates, P. (2018). The Importance of Diagrams, Graphics and Other Visual Representations in STEM Teaching. In R. Jorgensen & K. Larkin (Eds.), *STEM Education in the Junior Secondary: The State of Play* (pp. 169–196). Springer. https://doi.org/10.1007/978-981-10-5448-8_9

Gebre, E. H., & Polman, J. L. (2016). Developing young adults' representational competence through infographic-based science news reporting. *International Journal of Science Education*, *38*(18), 2667–2687. https://doi.org/10.1080/09500693.2016.1258129

Gernsbacher, M. A. (1984). Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of Experimental Psychology. General*, *113*(2), 256–281. https://doi.org/10.1037//0096-3445.113.2.256

Gilovich, T. (1991). *How We Know What Isn't So: The Fallibility of Human Reason in Everyday Life*. https://www.semanticscholar.org/paper/How-We-Know-What-Isn't-So%3A-The-Fallibility-of-Human-Gilovich/586da3e95ff8fcbbc640e9466c20c8c56477d179

Gleason, B. L., Peeters, M. J., Resman-Targoff, B. H., Karr, S., McBane, S., Kelley, K., Thomas, T., & Denetclaw, T. H. (2011). An Active-Learning Strategies Primer for Achieving Ability-Based Educational Outcomes. *American Journal of Pharmaceutical Education*, *75*(9), 186. https://doi.org/10.5688/ajpe759186

Goldshaft, B. (2016). *A Case Study of Lesson Study—How could Lesson Study contribute to collaborative professional learning in Norwegian schools?* [Master thesis, NTNU]. https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2687142

González, G., Villafañe-Cepeda, W., & Hernández-Rodríguez, O. (2023). Leveraging prospective teachers' knowledge through their participation in lesson study. *Journal of Mathematics Teacher Education*, *26*(1), 79–102. https://doi.org/10.1007/s10857-021-09521-4

Gupta, R., Duff, M. C., Denburg, N. L., Cohen, N. J., Bechara, A., & Tranel, D. (2009). Declarative memory is critical for sustained advantageous complex decision-making. *Neuropsychologia*, *47*(7), 1686–1693. https://doi.org/10.1016/j.neuropsychologia.2009.02.007

Gustafsson, J. (2017). Single case studies vs. multiple case studies: A comparative study. *Academy of Business, Engineering and Science*, Halmstad University. http://www.diva-portal.org/smash/get/diva2:1064378/FULLTEXT01.pdf

GURR, C. A. (1999). Effective Diagrammatic Communication: Syntactic, Semantic and Pragmatic Issues. *Journal of Visual Languages and Computing*, *10*(4), 317–342. https://doi.org/10.1006/jvlc.1999.0130

Gyselinck, V., De Beni, R., Pazzaglia, F., Meneghetti, C., & Mondoloni, A. (2007). Working memory components and imagery instructions in the elaboration of a spatial mental model. *Psychological Research*, *71*(3), 373–382. https://doi.org/10.1007/s00426-006-0091-1

Hammond, B. (2004). Ontology. *Psychological Perspectives*, *47*(1), 147–147. https://doi.org/10.1080/00332920408407136

Han, F., & Ellis, R. A. (2019). Using Phenomenography to Tackle Key Challenges in Science Education. *Frontiers in Psychology*, *10*. https://www.frontiersin.org/articles/10.3389/fpsyg.2019.01414

Hattie, J., & Zierer, K. (2019). *Visible learning insights*. Routledge.

Hayikaleng, N. (2019). *The Effects of Using Dual-Coding Theory in Teaching English Reading Comprehension among Vocational Students at Narathiwat Technical College*.

Henning, L. A. (2006). *Using phenomenography to explore the relationship between students perceptions of the learning context of their first-year engineering course and their approaches to learning.* Doctoral dissertation, University of Witwatersrand [Thesis]. http://wiredspace.wits.ac.za/handle/10539/1469

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, *292*, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Holmes, V. M., & Langford, J. (1976). Comprehension and recall of abstract and concrete sentences. *Journal of Verbal Learning and Verbal Behavior*, *15*(5), 559–566. https://doi.org/10.1016/0022-5371(76)90050-5

Horn, I. S., & Little, J. W. (2010). Attending to problems of practice: Routines and resources for professional learning in teachers' workplace interactions. *American Educational Research Journal*, *47*(1), 181–217. https://doi.org/10.3102/0002831209345158

Horridge, G. A. (1990). A Template Theory to Relate Visual Processing to Digital Circuitry. *Proceedings of the Royal Society of London. Series B, Biological Sciences*, *239*(1294), 17–33. http://www.jstor.org/stable/49506

Hubbs, D. L., & Brand, C. F. (2005). The Paper Mirror: Understanding Reflective Journaling. *Journal of Experiential Education*, *28*(1), 60–71. https://doi.org/10.1177/105382590502800107

Hupet, M., & Chantraine, Y. (1992). Changes in repeated references: Collaboration or repetition effects? *Journal of Psycholinguistic Research*, *21*(6), 485–496. https://doi.org/10.1007/BF01067526

Isoda, M., & Olfos, R. (Eds.). (2021). *Teaching Multiplication with Lesson Study: Japanese and Ibero-American Theories for International Mathematics EducationForeword by Abraham Arcavi*. Springer International Publishing. https://doi.org/10.1007/978-3-030-28561-6

Jaakkola, T., Veermans, K. and Nuutinen, P. (2017). 'Effect of a diagram on primary students' understanding about electric circuits', *Research in Science Education,* 49(1), pp. 111–129. doi:10.1007/s11165-017-9662-y.

Jiang, D., Renandya, W. A., & Zhang, L. J. (2017). Evaluating ELT multimedia courseware from the perspective of cognitive theory of multimedia learning. *Computer Assisted Language Learning*, *30*(7), 726–744. https://doi.org/10.1080/09588221.2017.1359187

Johannesson, P. (2022). Development of professional learning communities through action research: Understanding professional learning in practice. *Educational Action Research*, *30*(3), 411–426. https://doi.org/10.1080/09650792.2020.1854100

Jones, D. (1999). Patterns: Using proven experience to develop online learning. *Proceedings of ASCILITE*. https://www.academia.edu/2665035/Patterns_using_proven_experience_to_develop_online_learning

Jung, E., Lim, R., & Kim, D. (2022). A Schema-Based Instructional Design Model for Self-Paced Learning Environments. *Education Sciences*, *12*, 271. https://doi.org/10.3390/educsci12040271

Kahneman, D. (2011). *Thinking, fast and slow* (p. 499). Farrar, Straus and Giroux.

Kajee, L., & Balfour, R. (2011). Students' access to digital literacy at a South African university: Privilege and marginalisation. *Southern African Linguistics and Applied Language Studies*, *29*, 187–196. https://doi.org/10.2989/16073614.2011.633365

Kalyuga, S., & Singh, A.-M. (2016). Rethinking the boundaries of cognitive load theory in complex learning. *Educational Psychology Review*, *28*(4), 831–852. https://doi.org/10.1007/s10648-015-9352-0

Kandaga, T., Dahlan, T., Gardenia, N., Darta, & Saputra, J. (2021). A lesson study to foster prospective teachers' disposition in STEM education. *Journal of Physics: Conference Series*, *1806*(1), 012107. https://doi.org/10.1088/1742-6596/1806/1/012107

Kanellopoulou, C., Kermanidis, K. L., & Giannakoulopoulos, A. (2019). The Dual-Coding and Multimedia Learning Theories: Film Subtitles as a Vocabulary Teaching Tool. *Education Sciences*, *9*(3), Article 3. https://doi.org/10.3390/educsci9030210

Kanellopoulou, E.-M. D., & Darra, M. (2019). Benefits, Difficulties and Conditions of Lesson Study Implementation in Basic Teacher Education: A Review. *International Journal of Higher Education*, *8*(4), 18–35. https://eric.ed.gov/?id=EJ1220925

Kassen, M. A. (1998). The Multiple Challenges of Multimedia: Development, Implementation, and Evaluation. In *Texas Papers in Foreign Language Education* (Vol. 3, Issue 3). https://eric.ed.gov/?id=ED427524

Kasturi, R., Bow, S. T., El-Masri, W., Shah, J., Gattiker, J. R., & Mokate, U. B. (1990). A system for interpretation of line drawings. *IEEE Transactions on Pattern Analysis and*

Machine Intelligence, *12*(10), 978–992. IEEE Transactions on Pattern Analysis and Machine Intelligence. https://doi.org/10.1109/34.58870

Kemmis, S., McTaggart, R., & Nixon, R. (2014). *The Action Research Planner: Doing Critical Participatory Action Research*. Springer. https://doi.org/10.1007/978-981-4560-67-2

Khaled, A., Meer, M., Bükki, E., & Gyori, J. (2021). *LS4VET Model: Developing A Lesson Study Model for Vocational Education & Training*.

King, R. B., & McInerney, D. M. (2019). Family-support goals drive engagement and achievement in a collectivist context: Integrating etic and emic approaches in goal research. *Contemporary Educational Psychology*, *58*, 338–353. https://doi.org/10.1016/j.cedpsych.2019.04.003

Kirk, J. (2009). CHAPTER SEVEN: Starting With the Self: Reflexivity in Studying Women Teachers' Lives in Development. *Counterpoints*, *357*, 115–126. https://www.jstor.org/stable/42980341

Kirschner, P. A., & van Merriënboer, J. J. G. (2013). Do learners really know best? Urban legends in education. *Educational Psychologist*, *48*(3), 169–183. https://doi.org/10.1080/00461520.2013.804395

Kirschner, P. A., Sweller, J., Kirschner, F., & Zambrano R., J. (2018). From Cognitive Load Theory to Collaborative Cognitive Load Theory. *International Journal of Computer-Supported Collaborative Learning*, *13*(2), 213–233. https://doi.org/10.1007/s11412-018-9277-y

Kivunja, C. (2018). Distinguishing between theory, theoretical framework, and conceptual framework: A systematic review of lessons from the field. *International Journal of Higher Education*, *7*(6), 44–53. https://doi.org/10.5430/ijhe.v7n6p44

Kjeldsen, J. E. (2015). The Study of Visual and Multimodal Argumentation. *Argumentation*, *29*(2), 115–132. https://doi.org/10.1007/s10503-015-9348-4

Koba, S., & Tweed, A. (2009). *Hard-to-teach Biology Concepts: A Framework to Deepen Student Understanding*. NSTA Press.

Koenderink, J. J. (1984). The structure of images. *Biological Cybernetics*, *50*(5), 363–370. https://doi.org/10.1007/BF00336961

Konovalov, A., & Krajbich, I. (2018). Neurocomputational Dynamics of Sequence Learning. *Neuron*, *98*(6), 1282-1293.e4. https://doi.org/10.1016/j.neuron.2018.05.013

Koshy, E., Koshy, V., & Waterman, H. (2010). *Action Research in Healthcare*. SAGE.

Koshy, V. (2005). Action Research for Improving Practice: A Practical Guide. In *Paul Chapman Publishing*. Paul Chapman Publishing, A SAGE Publications Company, Customer Care: 2455 Teller Road, Thousand Oaks, CA 91320.

Kraft, & Papay, J. P. (2014). Can Professional Environments in Schools Promote Teacher Development? Explaining Heterogeneity in Returns to Teaching Experience. *Educational Effectiveness and Policy Analysis*, *36*(4), 476–500.

Kuhn, T. S. (1994). *The structure of scientific revolutions* (2. ed., enlarged, 21. print). Univ. of Chicago Press.

Kumar, A. A. (2021). Semantic memory: A review of methods, models, and current challenges. *Psychonomic Bulletin & Review*, *28*(1), 40–80. https://doi.org/10.3758/s13423-020-01792-x

Lank, E. H. (2003). A retargetable framework for interactive diagram recognition. *Seventh International Conference on Document Analysis and Recognition, 2003. Proceedings.*, 185–189 vol.1. https://doi.org/10.1109/ICDAR.2003.1227656

Larkin, J. H., & Simon, H. A. (1987). Why a Diagram is (Sometimes) Worth Ten Thousand Words. *Cognitive Science*, *11*(1), 65–100. https://doi.org/10.1016/S0364-0213(87)80026-5

Larssen, D. L. S., Cajkler, W., Mosvold, R., Bjuland, R., Helgevold, N., Fauskanger, J., Wood, P., Baldry, F., Jakobsen, A., Bugge, H. E., Næsheim-Bjørkvik, G., & Norton, J. (2018). A literature review of lesson study in initial teacher education. *International Journal for Lesson and Learning Studies*, *7*(1), 8–22. https://doi.org/10.1108/IJLLS-06-2017-0030

Laynor, G. (2023). Are Spaced Repetition Study Tools Changing Health Professions Education? *Journal of Electronic Resources in Medical Libraries*, *20*(2–3), 94–97. https://doi.org/10.1080/15424065.2023.2244364

Le Deist, F. D., & Winterton, J. (2005). What Is Competence? *Human Resource Development International*, *8*(1), 27–46. https://doi.org/10.1080/1367886042000338227

Ledwith, M. (2007). On being critical: Uniting theory and practice through emancipatory action research. *Educational Action Research*, *15*(4), 597–611. https://doi.org/10.1080/09650790701664021

Lee, C. J., Sugimoto, C. R., Zhang, G., & Cronin, B. (2013). Bias in peer review. *Journal of the American Society for Information Science and Technology*, *64*(1), 2–17. https://doi.org/10.1002/asi.22784

Lee, J. F. K. (2008). A Hong Kong case of lesson study—Benefits and concerns. *Teaching and Teacher Education*, *24*(5), 1115–1124. https://doi.org/10.1016/j.tate.2007.10.007

Lehner, P. E., Adelman, L., Cheikes, B. A., & Brown, M. J. (2008). Confirmation Bias in Complex Analyses. *Trans. Sys. Man Cyber. Part A*, *38*(3), 584–592. https://doi.org/10.1109/TSMCA.2008.918634

Lench, H. C., Flores, S. A., & Bench, S. W. (2011). Discrete emotions predict changes in cognition, judgment, experience, behavior, and physiology: A meta-analysis of experimental emotion elicitations. *Psychological Bulletin*, *137*(5), 834–855. https://doi.org/10.1037/a0024244

Leutner, D., Leopold, C., & Sumfleth, E. (2009). Cognitive load and science text comprehension: Effects of drawing and mentally imagining text content. *Computers in Human Behavior*, *25*(2), 284–289. https://doi.org/10.1016/j.chb.2008.12.010

Lewis, C. (2002). *Lesson Study: A handbook of teacher-led instructional change*. Research for Better Schools.

Lewis, C., Perry, R., & Murata, A. (2006). How Should Research Contribute to Instructional Improvement? The Case of Lesson Study. *Educational Researcher*, *35*, 3–14. https://doi.org/10.3102/0013189X035003003

Liévin, V., Deckers, N. and Chettaoui, A. (2024) 'Digitizing images of electrical-circuit schematics', *APL Machine Learning,* 2(1), 016109. doi:10.1063/5.0176184.

Liu, X., Liu, C.-H., & Li, Y. (2020). The Effects of Computer-Assisted Learning Based on Dual Coding Theory. *Symmetry (20738994)*, *12*(5), 701. https://doi.org/10.3390/sym12050701.

Lockyer, L., Bennett, S., Agostinho, S., & Harper, B. (2008). Handbook of research on learning design and learning objects: Issues, applications and technologies. In *Distance Education—DISTANCE EDUC* (Vol. 30).

Lombard, E. H., & Simayi, A. (2019). Academic engagement of Eastern Cape Grade 8 township learners with depictive representations of simple electric circuits: A focus on low-achieving learners with limited science self-confidence. *African Journal of Research in Mathematics, Science and Technology Education*, *23*(1), 40–51. https://doi.org/10.1080/18117295.2019.1587248

Longhitano, M. E. (2021). *High School Mathematics Lesson Study, Curriculum Design, and Teacher Practice Through the Lens of Danielson's Framework for Teaching* [Ed.D., Teachers College, Columbia University]. https://www.proquest.com/docview/2640072365/abstract/6CDBBE4A813847F5PQ/1

Louis, K. S., Hord, S. M., & Von Frank, V. (2016). *Reach the Highest Standard in Professional Learning: Leadership* (1–1 online resource (109 pages)). SAGE Publications. https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=5603518

Macdonald-Ross, M. (1979). Scientific Diagrams and the Generation of Plausible Hypotheses: An Essay in the History of Ideas. *Instructional Science*, *8*(3), 223–234. https://www.jstor.org/stable/23368223

MacIntyre, C. (2000). *The Art of Action Research in the Classroom*. Routledge.

Mackay, J., & Hobden, P. (2012). Using circuit and wiring diagrams to identify students' preconceived ideas about basic electric circuits. *African Journal of Research in Mathematics, Science and Technology Education*, *16*(2), 131–144. https://doi.org/10.1080/10288457.2012.10740735

Mackay, J., & Parkinson, J. (2009). "My very own mission impossible": An appraisal analysis of student teacher reflections on a design and technology project. *Text & Talk*, *29*(6), 729–753.

Makinae, N. (2019). The Origin and Development of Lesson Study in Japan. In R. Huang, A. Takahashi, & J. P. da Ponte (Eds.), *Theory and Practice of Lesson Study in Mathematics: An International Perspective* (pp. 169–181). Springer International Publishing. https://doi.org/10.1007/978-3-030-04031-4_9

Makole, K. R. (2015). *The implementation of the National Certificate Vocation Programme at Tswane North FET College* Doctoral dissertation, University of Witwatersrand [Thesis]. http://wiredspace.wits.ac.za/handle/10539/18747

Malhotra, R., & Verma, N. (2020). An Impact of Using Multimedia Presentations on Engineering Education. *Procedia Computer Science*, *172*, 71–76. https://doi.org/10.1016/j.procs.2020.05.011

Maltitz, V., & Lindsay, D. (2018). *Apprentice to artisan trials and tribulations of apprentices in a dual system apprenticeship programme in South Africa* Doctoral dissertation, University of Witwatersrand [Thesis]. http://wiredspace.wits.ac.za/handle/10539/27170

Mariano, G. (2014). Breaking It Down: Knowledge Transfer in a Multimedia Learning Environment. *International Journal of Teaching and Learning in Higher Education*, *26*(1), 1–11. https://eric.ed.gov/?id=EJ1043012

Maries, A., & Singh, C. (2017). Do students benefit from drawing productive diagrams themselves while solving introductory physics problems? The case of two electrostatics problems. *European Journal of Physics*, *39*(1), 015703. https://doi.org/10.1088/1361-6404/aa9038

Marschark, M., & Cornoldi, C. (1991). Imagery and Verbal Memory. In C. Cornoldi & M. A. McDaniel (Eds.), *Imagery and Cognition* (pp. 133–182). Springer US. https://doi.org/10.1007/978-1-4684-6407-8_5

Marsh, D. M., & Hanlon, T. J. (2007). Seeing What We Want to See: Confirmation Bias in Animal Behavior Research. *Ethology*, *113*(11), 1089–1098. https://doi.org/10.1111/j.1439-0310.2007.01406.x

Marshall, J. (2008). *Students' Creation and Interpretation of Circuit Diagrams*.

Martin, T. (2017). How to Read Wiring Diagrams. *Motor Age*, *136*(2), 22–30. https://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=121280141&site=ehost-live

MARTON, F. (1981). PHENOMENOGRAPHY — DESCRIBING CONCEPTIONS OF THE WORLD AROUND US. *Instructional Science*, *10*(2), 177–200. http://www.jstor.org/stable/23368358

Marton, F., & Booth, S. (1997). *Learning and Awareness*. Routledge. https://doi.org/10.4324/9780203053690

Marton, F., & Pang, M. F. (2006). On Some Necessary Conditions of Learning. *The Journal of the Learning Sciences*, *15*(2), 193–220. http://www.jstor.org/stable/25473516

Maton, K. (2013). Making semantic waves: A key to cumulative knowledge-building. *Linguistics and Education*, *24*(1), 8–22. https://doi.org/10.1016/j.linged.2012.11.005

Mayer, R. E. (2009). *Multimedia learning* (2nd ed). Cambridge University Press. http://swbplus.bsz-bw.de/bsz306340151inh.htm

Mayer, R. E. (2014). Cognitive Theory of Multimedia Learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (2nd ed., pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Mayer, R. E. (2021). *Multimedia learning* (3rd ed.). Cambridge University Press.

Mazhinye, R. (2018). *A critical investigation into vocational curriculum alignment to the needs of industry: A case of national certificate (Vocational) hospitality studies at a technical and vocational education and training college in Gauteng* Doctoral dissertation, University of Witwatersrand [Thesis]. http://wiredspace.wits.ac.za/handle/10539/26955

McCoy, J. D., & Ketterlin-Geller, L. R. (2004). Rethinking Instructional Delivery for Diverse Student Populations: Serving All Learners with Concept-Based Instruction. *Intervention in School and Clinic*, *40*(2), 88–95. https://doi.org/10.1177/10534512040400020401

McGrath, S., & Akoojee, S. (2009). Vocational education and training for sustainability in South Africa: The role of public and private provision. *International Journal of Educational Development*, *29*(2), 149–156. https://doi.org/10.1016/j.ijedudev.2008.09.008

McKenney, S., & Reeves, T. C. (2012). *Conducting educational design research*. Routledge.

McKernan, J. (2013). *Curriculum Action Research: A Handbook of Methods and Resources for the Reflective Practitioner*. Routledge. https://doi.org/10.4324/9781315041742

Medelyan, A. (2020). *Understanding Qualitative Data Coding: A Comprehensive Guide | Course Hero*. https://www.coursehero.com/file/185771911/Medelyan-2020-Coding-Qualitative/

Mega, C., Ronconi, L., & De Beni, R. (2014). What Makes a Good Student? How Emotions, Self-Regulated Learning, and Motivation Contribute to Academic Achievement. *Journal of Educational Psychology*, *106*, 121. https://doi.org/10.1037/a0033546

Mentzer, N., Becker, K., & Sutton, M. (2015). Engineering Design Thinking: High School Students' Performance and Knowledge. *Journal of Engineering Education*, *104*(4), 417–432.

Mertens, D. M. (2012). What Comes First? The Paradigm or the Approach? *Journal of Mixed Methods Research*, *6*(4), 255–257. https://doi.org/10.1177/1558689812461574

Merton, R. K. (1975). Thematic Analysis in Science: Notes on Holton's Concept. *Science*, *188*(4186), 335–338. https://www.jstor.org/stable/1739319

Mesuwini, J. (2015). *An exploration of the skills set required for sustainable employability of Technical Vocational Education and Training (TVET) engineering graduates: The case of Majuba TVET college, Newcastle, KwaZulu-Natal.* Doctoral dissertation, University of KwaZulu-Natal [Thesis]. https://researchspace.ukzn.ac.za/handle/10413/13920

Mewald, C. (2021). Lesson Study in Vocational Education and Training: The status quo in four European countries. *R&E-SOURCE*. https://doi.org/10.53349/resource.2021.i16.a998

Mezei, A. (1972). [Review of *Review of Imagery and Verbal Processes*, by A. Paivio]. *Leonardo*, *5*(4), 359–360. https://doi.org/10.2307/1572599

Moalosi, R., Letsholo, P., Matake, B., & Ollyn, M. (2021). Enhancing Graduate Attributes through Work- Integrated Learning: Students' Perspective. *International Journal of Educational Development in Africa*, *6*(1), 1–23. https://doi.org/10.25159/2312-3540/9696

Mohler, J. L. (2007). An Instructional Strategy for Pictorial Drawing. *Journal of Industrial Teacher Education*, *44*(3), 5–26. https://eric.ed.gov/?id=EJ830482

Mor, Y., Mellar, H., Warburton, S., & Winters, N. (Eds.). (2014). *Practical Design Patterns for Teaching and Learning with Technology*. SensePublishers. https://doi.org/10.1007/978-94-6209-530-4

Morrison, K. (2019). *The implications of using lesson study as a professional development model to support graphical literacy in second grade*. https://www.semanticscholar.org/paper/The-implications-of-using-lesson-study-as-a-model-Morrison/76b8309a24e33a21a3073c38f0cb859dc9bd60fe

Mortaki, S. (2012). The definition and aims of vocational education and training (VET). *International Journal of Humanities and Social Science*, *2*(24), 8.

Mortari, L. (2015). Reflectivity in Research Practice: An Overview of Different Perspectives. *International Journal of Qualitative Methods*, *14*(5), 1609406915618045. https://doi.org/10.1177/1609406915618045

Muijs, D. (2006). Measuring teacher effectiveness: Some methodological reflections. *Educational Research and Evaluation*, *12*(1), 53–74. https://doi.org/10.1080/13803610500392236

Munneke, L., van Amelsvoort, M., & Andriessen, J. (2003). The role of diagrams in collaborative argumentation-based learning. *International Journal of Educational Research*, *39*(1), 113–131. https://doi.org/10.1016/S0883-0355(03)00076-4

Mutch-Jones, K., Puttick, G., & Minner, D. (2012). Lesson study for accessible science: Building expertise to improve practice in inclusive science classrooms. *Journal of Research in Science Teaching*, *49*(8), 1012–1034. https://doi.org/10.1002/tea.21034

Mutemeri, J., & Chetty, R. (2011). An examination of university-school partnerships in South Africa. *South African Journal of Education*, *31*(4), 505–517. https://doi.org/10.10520/EJC32300

Newsome, B. O. (2016). *An Introduction to Research, Analysis, and Writing: Practical Skills for Social Science Students*. SAGE Publications, Inc. https://doi.org/10.4135/9781071909829

Ngubane, Y. P. (2013). *Effectiveness of the performance management and development system at the South African Social Security Agency.* http://hdl.handle.net/10413/12360

Nigel, T. (2020, July 1). *Mental Imagery > Conceptual Issues in Dual Coding Theory (Stanford Encyclopedia of Philosophy/Summer 2020 Edition)*.

https://plato.stanford.edu/archIves/sum2020/entries/mental-imagery/dual-coding-theory.html

Nolen, A. L., & Putten, J. V. (2007). Action Research in Education: Addressing Gaps in Ethical Principles and Practices. *Educational Researcher*, *36*(7), 401–407. https://doi.org/10.3102/0013189X07309629

Nongxa, L. (2010). *Tertiary institutions ignore primary lessons at their peril*. TimesLIVE. https://www.timeslive.co.za/sunday-times/lifestyle/2010-08-01-tertiary-institutions-ignore-primary-lessons-at-their-peril/

Norwich, B., Benham-Clarke, S., & Goei, S. L. (2021). Review of research literature about the use of lesson study and lesson study-related practices relevant to the field of special needs and inclusive education. *European Journal of Special Needs Education*, *36*(3), 309–328. https://doi.org/10.1080/08856257.2020.1755929

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, *16*(1), 1609406917733847. https://doi.org/10.1177/1609406917733847

Nundkumar, A. (2016). *Risk management: A case study in a KwaZulu-Natal technical and vocational education and training college.* Doctoral dissertation, University of KwaZulu-Natal [Thesis]. https://researchspace.ukzn.ac.za/handle/10413/15565

O'Connell, T. S., & Dyment, J. E. (2011). The case of reflective journals: Is the jury still out? *Reflective Practice*, *12*(1), 47–59. https://doi.org/10.1080/14623943.2011.541093

Olmos-Vega, F. M., Stalmeijer, R. E., Varpio, L., & Kahlke, R. (2023). A practical guide to reflexivity in qualitative research: AMEE Guide No. 149. *Medical Teacher*, *45*(3), 241–251. https://doi.org/10.1080/0142159X.2022.2057287

Ono, Y., & Ferreira, J. (2010). A case study of continuing teacher professional development through lesson study in South Africa. *South African Journal of Education*, *30*(1), 59–

74. http://www.scielo.org.za/scielo.php?script=sci_abstract&pid=S0256-01002010000100005&lng=en&nrm=iso&tlng=en

Owen, S. (2014). Teacher professional learning communities: Going beyond contrived collegiality toward challenging debate and collegial learning and professional growth. *Australian Journal of Adult Learning*, *54*(2), 54–77. https://www.proquest.com/docview/1547708625/abstract/3C7366E210614326PQ/1

Ozcelik, E., Arslan-Ari, I., & Cagiltay, K. (2010). Why does signaling enhance multimedia learning? Evidence from eye movements. *Computers in Human Behavior*, *26*(1), 110–117. https://doi.org/10.1016/j.chb.2009.09.001

Paivio, A. (2006). Dual coding theory and education. *Pathways to Literacy Achievement for High Poverty Children*, *14*, 1–20.

Paivio, A. (2013). *Imagery and Verbal Processes*. Psychology Press.

Paivio, A. (2014). Intelligence, dual coding theory, and the brain. *Intelligence*, *47*, 141–158. https://doi.org/10.1016/j.intell.2014.09.002

Palmiero, M., Belardinelli, M. O., Nardo, D., Sestieri, C., Di Matteo, R., D'Ausilio, A., & Romani, G. L. (2009). Mental imagery generation in different modalities activates sensory-motor areas. *Cognitive Processing*, *10 Suppl 2*, S268-271. https://doi.org/10.1007/s10339-009-0324-5

Pearson, J., Naselaris, T., Holmes, E. A., & Kosslyn, S. M. (2015). Mental Imagery: Functional Mechanisms and Clinical Applications. *Trends in Cognitive Sciences*, *19*(10), 590–602. https://doi.org/10.1016/j.tics.2015.08.003

Peppler, K., & Glosson, D. (2013). Stitching Circuits: Learning About Circuitry Through E-textile Materials. *Journal of Science Education and Technology*, *22*(5), 751–763. http://www.jstor.org/stable/24019816

Pintrich, P. R. (2000). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. *Journal of Educational Psychology*, *92*(3), 544–555. https://doi.org/10.1037/0022-0663.92.3.544

Plass, J. L., Moreno, R., & Brünken, R. (Eds.). (2010). *Cognitive load theory*. Cambridge University Press.

Prain, V., & Tytler, R. (2012). Learning Through Constructing Representations in Science: A framework of representational construction affordances. *International Journal of Science Education*, *34*(17), 2751–2773. https://doi.org/10.1080/09500693.2011.626462

Preston, C. (2019). Effect of a Diagram on Primary Students' Understanding About Electric Circuits. *Research in Science Education*, *49*. https://doi.org/10.1007/s11165-017-9662-y

Preston, C., Hubber, P., Bondurant-Scott, M., & Gunesekere, I. (2020). A Representation Construction Approach to Learning About Electrical Energy in Year 6. *Teaching Science: The Journal of the Australian Science Teachers Association*, *66*(2), 5–19. http://ezproxy.uct.ac.za/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=146405564&site=ehost-live

Preston, C. M. (2019). Effect of a Diagram on Primary Students' Understanding About Electric Circuits. *Research in Science Education*, *49*(5), 1433–1456. https://doi.org/10.1007/s11165-017-9662-y

Probst, B. (2015). The Eye Regards Itself: Benefits and Challenges of Reflexivity in Qualitative Social Work Research. *Social Work Research*, *39*. https://doi.org/10.1093/swr/svu028

Pule, S. (2012). Students' versatility with resistor-capacitor circuits. *International Journal of Electrical Engineering Education*, *49*(4), 419–444. https://doi.org/10.7227/IJEEE.49.4.5

Putnam, R. T., & Borko, H. (2000). What Do New Views of Knowledge and Thinking Have to Say About Research on Teacher Learning? *Educational Researcher*, *29*(1), 4–15. https://doi.org/10.3102/0013189X029001004

Quillin, K., & Thomas, S. (2015). Drawing-to-learn: A framework for using drawings to promote model-based reasoning in biology. *CBE Life Sciences Education*, *14*(1), es2. https://doi.org/10.1187/cbe.14-08-0128

Ramnarain, U., & Ramaila, S. (2012). Mentoring as a viable and sustainable form of professional development for physical science teachers. *Education as Change*, *16*(2), 255–268. https://doi.org/10.1080/16823206.2012.745754

Reisslein, M., Moreno, R., & Ozogul, G. (2010). Pre-college Electrical Engineering Instruction: The Impact of Abstract vs. Contextualized Representation and Practice on Learning. *Journal of Engineering Education*, *99*(3), 225–235. https://www.proquest.com/docview/744366750/abstract/16C5FA654E1B41C5PQ/1

Ríos, R. (2019). *Mindful Practice for Social Justice: A Guide for Educators and Professional Learning Communities*. Taylor & Francis Group. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=5742445

Rosengrant, D., Van Heuvelen, A., & Etkina, E. (2009). Do students use and understand free-body diagrams? *Physical Review Special Topics - Physics Education Research*, *5*(1), 010108. https://doi.org/10.1103/PhysRevSTPER.5.010108

Ruiz, P., Dorronsoro, B., & Mora, M. B. (2018). A New CAD Tool to Assist Industrial Design Engineering Students in the Implementation of Electrical Diagrams – CADDI.

2018 International Symposium on Computers in Education (SIIE), 1–5. https://doi.org/10.1109/SIIE.2018.8586772

Rumelhart, D. E. (1980). Schemata: The Building Blocks of Cognition. In *Theoretical Issues in Reading Comprehension*. Routledge.

Saad, S., Dandashi, A., Aljaam, J. M., & Saleh, M. (2015). The Multimedia-Based Learning System Improved Cognitive Skills and Motivation of Disabled Children with a Very High Rate. *Educational Technology & Society*, *18*(2), 366–379. https://research.ebsco.com/linkprocessor/plink?id=0bb87b59-5ce0-3ba3-a6b6-d1634a63819e

Sadoski, M., & Paivio, A. (2012). *Imagery and Text: A Dual Coding Theory of Reading and Writing*. Taylor & Francis Group. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=1108613

Safik, M., Hobri, Yuianti, N., Sarjono, W., & Sa'id, I. A. (2021). The development of science, technology, engineering, art, and mathematics learning devices – lesson study for learning community to improve students' creative thinking skill. *Journal of Physics: Conference Series*, *1839*(1), 012019. https://doi.org/10.1088/1742-6596/1839/1/012019

Saif, M. (2023, May 26). A Conceptual Paper on the Roles of Vocational Education Instructors in Professional Learning Communities (PLC). *TVET Journal*. https://tvetjournal.com/tvet-tools/a-conceptual-paper-on-the-roles-of-vocational-education-instructors-in-professional-learning-communities-plc/

Samaras, A. P., Freese, A. R., Kosnik, C. M., & Beck, C. (2008). *Learning communities in practice*. Springer Verlag.

Sarowardy, M. H., & Halder, D. P. (2019). The Issues and Challenges of Using Multimedia at a District Level, Specialized Girls' College in Bangladesh. *Creative Education*, *10*(07), Article 07. https://doi.org/10.4236/ce.2019.107110

Schieltz, K. M., Wacker, D. P., Suess, A. N., Graber, J. E., Lustig, N. H., & Detrick, J. (2019). Evaluating the Effects of Positive Reinforcement, Instructional Strategies, and Negative Reinforcement on Problem Behavior and Academic Performance: An Experimental Analysis. *Journal of Developmental and Physical Disabilities*, *32*(2), 339–363. https://doi.org/10.1007/s10882-019-09696-y

Schifferstein, R. (2008). Comparing Mental Imagery Across the Sensory Modalities. *Imagination, Cognition and Personality*, *28*, 371–388. https://doi.org/10.2190/IC.28.4.g

Schipper, T. M., van der Lans, R. M., de Vries, S., Goei, S. L., & van Veen, K. (2020). Becoming a more adaptive teacher through collaborating in Lesson Study? Examining the influence of Lesson Study on teachers' adaptive teaching practices in mainstream secondary education. *Teaching and Teacher Education*, *88*, 102961. https://doi.org/10.1016/j.tate.2019.102961

Schipper, T. M., Willemse, T. M., & Goei, S. L. (2022). Supporting teacher educators' professional learning through lesson study. *Journal of Education for Teaching*, *48*(3), 316–331. https://doi.org/10.1080/02607476.2021.1988825

Schroeder, N. L., & Cenkci, A. T. (2018). Spatial Contiguity and Spatial Split-Attention Effects in Multimedia Learning Environments: A Meta-Analysis. *Educational Psychology Review*, *30*(3), 679–701. https://doi.org/10.1007/s10648-018-9435-9

Schrueder, R. (1997). *An action research study of cooperative learning in a pre-service natural science course.* http://hdl.handle.net/10413/3614

Schuiling, G. J., & Vermaak, H. (2017). Four contexts of action research: Crossing boundaries for productive interplay. *International Journal of Action Research*, *13*(1), 5–23. https://doi.org/10.3224/ijar.v13i1.02

Schwartz, D. L. (1995). The Emergence of Abstract Representations in Dyad Problem Solving. *The Journal of the Learning Sciences*, *4*(3), 321–354. https://www.jstor.org/stable/1466735

Schwarz, C. V., Ke, L., Lee, M., & Rosenberg, J. M. (2021). Literature reviews, theoretical frameworks, and conceptual frameworks: An introduction for new biology education researchers. *CBE—Life Sciences Education*, *20*(3), fe3. https://doi.org/10.1187/cbe.21-05-0134

Scoppetta, J. A. (2015). Undergraduate students' attempts to initiate and maintain writing center-facilitated writing groups: A narrative and self-reflexive study [Ed.D., Teachers College, Columbia University]. In *ProQuest Dissertations and Theses*. https://www.proquest.com/docview/1687150690/abstract/6BF14F788A3247EBPQ/1

Scott, L. (2014). 'Digging deep': Self-study as a reflexive approach to improving my practice as an artist, researcher and teacher. *Perspectives in Education*, *32*(2), 69–88. https://www.proquest.com/docview/1566320885/abstract/E29549CD8F1143E6PQ/1

Seddon, G. M., Adeola, A., el Farra, A. O., & Oyediji, S. I. (1984). The responsiveness of students to pictorial depth cues and the understanding of diagrams of three-dimensional structures. *British Educational Research Journal*, *10*(1), 49–62. https://doi.org/10.1080/0141192840100104

Sekao, D., & Engelbrecht, J. (2022). South African Primary Mathematics Teachers' Experiences and Perspectives About Lesson Study. *International Journal of Science* *and Mathematics Education*, *20*(7), 1431–1453. https://doi.org/10.1007/s10763-021-10214-w

Seleznyov, S. (2019). Lesson study: Exploring implementation challenges in England. *International Journal for Lesson and Learning Studies*, *9*(2), 179–192. https://doi.org/10.1108/IJLLS-08-2019-0059

Serra, M. J., & Dunlosky, J. (2010). Metacomprehension judgements reflect the belief that diagrams improve learning from text. *Memory*, *18*(7), 698–711. https://doi.org/10.1080/09658211.2010.506441

Seufert, T. (2003). Supporting coherence formation in learning from multiple representations. *Learning and Instruction*, *13*(2), 227–237. https://doi.org/10.1016/S0959-4752(02)00022-1

Sherman, R. O. (2016). Wicked Problems. *Nurse Leader*, *14*(6), 380–381. https://doi.org/10.1016/j.mnl.2016.08.009

Shermer, M. (2008, December 1). *Patternicity: Finding Meaningful Patterns in Meaningless Noise*. Scientific American. https://www.scientificamerican.com/article/patternicity-finding-meaningful-patterns/

Shimizu, Y., & Kang, H. (2022). Discussing students' thinking and perspectives for improving teaching: An analysis of teachers' reflection in post-lesson discussions in lesson study cycles. *ZDM – Mathematics Education*, *54*(2), 419–431. https://doi.org/10.1007/s11858-022-01371-5

Shuilleabhain, A. N. (2013). Lesson Study in a Community of Practice: A model of in-school professional development. *Trinity Education Papers*. https://www.academia.edu/4220476/Lesson_Study_in_a_Community_of_Practice_A_model_of_in_school_professional_development

Sibisi, N. (2019). *Lecturers' experiences in the implementation of the National Certificate (Vocational) Engineering curriculum in a selected Technical Vocational Education and Training college*. https://www.academia.edu/66098981/Lecturers_experiences_in_the_implementation_of_the_National_Certificate_Vocational_Engineering_curriculum_in_a_selected_Technical_Vocational_Education_and_Training_college

Sithole, M. D., Wissink, H., & Chiwawa, N. (2022). Enhancing the Management Systems and Structures of Technical Vocational Education and Training Colleges in South Africa. *Administratio Publica*, *30*(3), 86–105. https://doi.org/10.10520/ejc-adminpub_v30_n3_a7

Skott, C. K., & Møller, H. (2020). Adaptation of lesson study in a Danish context: Displacements of teachers' work and power relations. *Teaching and Teacher Education*, *87*, 102945. https://doi.org/10.1016/j.tate.2019.102945

Smith, & Fortin. (1963). Diagrams – An Organized Approach to System Understanding. *IEEE Transactions on Aerospace*, *1*(2), 1459–1468. IEEE Transactions on Aerospace. https://doi.org/10.1109/TA.1963.4319522

Sobh, R., & Perry, C. (2006). Research design and data analysis in realism research. *European Journal of Marketing*, *40*(11–12), 1194–1209. https://doi.org/10.1108/03090560610702777

Sprenger, M. (2003). *Differentiation through Learning Styles and Memory*. Corwin Press, Inc., 2455 Teller Road, Thousand Oaks, CA 91320-2218 (paperback: ISBN-0-7619-3942-3, $27.95; hardback: ISBN-0-7619-3941-5, $61.95). Tel: 800-818-7243 (Toll Free); Fax: 800-417-2466; e-mail: order@corwinpress.com; Web site: http://www.corwinpress.com.

Srivastava, S., & Arora, R. K. (1998). Multimedia in Education and Training. *Electronics Information and Planning*, *25*, 337–348.

Stålne, K., Kjellström, S., & Utriainen, J. (2016). Assessing complexity in learning outcomes – a comparison between the SOLO taxonomy and the model of hierarchical complexity. *Assessment & Evaluation in Higher Education*, *41*(7), 1033–1048. https://doi.org/10.1080/02602938.2015.1047319

Stankov, L. (2000). Complexity, Metacognition, and Fluid Intelligence. *Intelligence*, *28*(2), 121–143. https://doi.org/10.1016/S0160-2896(99)00033-1

Stanovich, K. E., & West, R. F. (2007). Natural myside bias is independent of cognitive ability. *Thinking & Reasoning*, *13*(3), 225–247. https://doi.org/10.1080/13546780600780796

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420. https://doi.org/10.1177/030631289019003001

Stigler, J., & Hiebert, J. (1999). The teaching gap: Best ideas from the world’s teachers for improving education in the classroom. New York, NY: The Free Press. *Http://Lst-Iiep.Iiep-Unesco.Org/Cgi-Bin/Wwwi32.Exe/ [In=epidoc1.in]/?T2000=011347/(100)*.

Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. *Journal of Educational Change*, *7*(4), 221–258. https://doi.org/10.1007/s10833-006-0001-8

Strain, E., Patterson, K., & Seidenberg, M. S. (1995). Semantic effects in single-word naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(5), 1140–1154. https://doi.org/10.1037/0278-7393.21.5.1140.

Stringer, E. T. (2014). *Action research* (4th ed.). Sage Publications.

Stuart, T. S., Heckmann, S., Mattos, M., & Buffum, A. (2018). *Personalized Learning in a PLC at Work TM: Student Agency Through the Four Critical Questions (Develop Innovative PLC- and RTI-Based Personalized Learning Programs)*. Solution Tree. http://ebookcentral.proquest.com/lib/ukzn-ebooks/detail.action?docID=5358240

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive Load Theory*. Springer. https://doi.org/10.1007/978-1-4419-8126-4

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. *Educational Psychology Review*, *31*(2), 261–292. https://doi.org/10.1007/s10648-019-09465-5

Takahashi, A., & McDougal, T. (2016). Collaborative lesson research: Maximizing the impact of lesson study. *ZDM Mathematics Education*, *48*(4), 513–526. https://doi.org/10.1007/s11858-015-0752-x

Tavory, I., & Timmermans, S. (2025). The reliance on conceptual frameworks in qualitative research: A way forward. *BMC Medical Research Methodology*, *25*(1), 31. https://doi.org/10.1186/s12874-025-02461-0

Tennyson, R. D. (2002). Linking Learning Theories to Instructional Design. *Educational Technology*, *42*(3), 51–55. https://www.jstor.org/stable/44428751

Thalmann, M., Souza, A. S., & Oberauer, K. (2019). How does chunking help working memory? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *45*(1), 37–55. https://doi.org/10.1037/xlm0000578

Thompson, J. J., Hagenah, S., McDonald, S., & Barchenger, C. (2019). Toward a practice-based theory for how professional learning communities engage in the improvement of tools and practices for scientific modeling. *Science Education*, *103*(6), 1423–1455. https://doi.org/10.1002/sce.21547

Tuchman, B. W. (1983). *Practising history*. Macmillan.

Uesaka, Y., Manalo, E., & Ichikawa, S. (2007). What kinds of perceptions and daily learning behaviors promote students' use of diagrams in mathematics problem solving? *Learning and Instruction*, *17*(3), 322–335. https://doi.org/10.1016/j.learninstruc.2007.02.006

Uffen, I., de Vries, S., Goei, S. L., van Veen, K., & Verhoef, N. (2022). Understanding teacher learning in lesson study through a cultural–historical activity theory lens. *Teaching and Teacher Education*, *119*, 103831. https://doi.org/10.1016/j.tate.2022.103831

Urama, M. S., & Ndidi, O. (2012). Manpower development in technical and vocational education (TVE) a pre-requisite for the technological development of Nigeria. *Knowledge Review*, *4*, 7.

Urban-Woldron, H. (2023) 'Effect of a STEM approach on students' cognitive structures about electrical circuits', *International Journal of STEM Education,* 10(1), 9. doi:10.1186/s40594-022-00393-5.

Vagg, T., Balta, J. Y., Bolger, A., & Lone, M. (2020). Multimedia in Education: What do the Students Think? *Health Professions Education*, *6*(3), 325–333. https://doi.org/10.1016/j.hpe.2020.04.011

Van Meter, P. (2001). Drawing construction as a strategy for learning from text. *Journal of Educational Psychology*, *93*(1), 129–140. https://doi.org/10.1037/0022-0663.93.1.129

Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2020). The distinctions between theory, theoretical framework, and conceptual framework. *Academic Medicine*, *95*(7), 989–994. https://doi.org/10.1097/ACM.0000000000003075.

Vasileiou, K., Barnett, J., Thorpe, S., & Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: Systematic analysis of qualitative health research over 15 years. *BMC Medical Research Methodology*, *18*(1), Article 148. https://doi.org/10.1186/s12874-018-0594-7

Vavra, K. L., Janjic-Watrich, V., Loerke, K., Phillips, L., Norris, S., & Macnab, J. (2011). *Visualization in Science Education*. https://www.semanticscholar.org/paper/Visualization-in-Science-Education-Vavra-Janjic-Watrich/cc10afbb532e55d1e5f2ae664af6250120c64cbb

Vescio, V., Ross, D., & Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education*, *24*(1), 80–91. https://doi.org/10.1016/j.tate.2007.01.004

Vigliocco, G., Vinson, D. P., Woolfe, T., Dye, M. W. G., & Woll, B. (2005). Language and imagery: Effects of language modality. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1574), 1859–1863. https://doi.org/10.1098/rspb.2005.3169

Voss, J. L., Gonsalves, B. D., Federmeier, K. D., Tranel, D., & Cohen, N. J. (2011). Hippocampal brain-network coordination during volitional exploratory behavior enhances learning. *Nature Neuroscience*, *14*(1), 115–120. https://doi.org/10.1038/nn.2693

Vrikki, M. (2019). Lesson Study Approaches in Teacher Education. In M. A. Peters (Ed.), *Encyclopedia of Teacher Education* (pp. 1–6). Springer. https://doi.org/10.1007/978-981-13-1179-6_54-1

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wammes, J. D., Meade, M. E., & Fernandes, M. A. (2016). The drawing effect: Evidence for reliable and robust memory benefits in free recall. *Quarterly Journal of Experimental Psychology (2006)*, *69*(9), 1752–1776. https://doi.org/10.1080/17470218.2015.1094494

Weaver, K., & Olson, J. K. (2006). Understanding paradigms used for nursing research. *Journal of Advanced Nursing*, *53*(4), 459–469. https://doi.org/10.1111/j.1365-2648.2006.03740.x

Weigel, T., Mulder, M., & Collins, K. (2007). The concept of competence in the development of vocational education and training in selected EU member states. *Journal of Vocational Education & Training*, *59*(1), 53–66. https://doi.org/10.1080/13636820601145549

Welcome, S. E., Paivio, A., McRae, K., & Joanisse, M. F. (2011). An electrophysiological study of task demands on concreteness effects: Evidence for dual coding theory. *Experimental Brain Research*, *212*(3), 347–359. https://doi.org/10.1007/s00221-011-2734-8

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.

Wenger, E., McDermott, R. A. (Richard A., Snyder, W., McDermott, R. A., & Snyder, W. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Harvard Business School Press. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=79094

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Harvard University Press.

Widjaja, W., Vale, C., Groves, S., & Doig, B. (2017). Teachers' professional growth through engagement with lesson study. *Journal of Mathematics Teacher Education*, *20*(4), 357–383. https://doi.org/10.1007/s10857-015-9341-8

Willems, I., & Bossche, P. V. den. (2019). Lesson Study effectiveness for teachers' professional learning: A best evidence synthesis. *International Journal for Lesson and Learning Studies*, *8*(4), 257–271. https://doi.org/10.1108/IJLLS-04-2019-0031

Williams, M., & May, T. (1996). *Introduction to the Philosophy of Social Research*. University College London Press.

Willis, J. (2007). Review of Research: Brain-Based Teaching Strategies for Improving Students' Memory, Learning, and Test-Taking Success. *Childhood Education*, *83*(5), 310–315. https://doi.org/10.1080/00094056.2007.10522940

Winberg, C., & Hollis-Turner, S. (2021). Practical subjects in the vocational curriculum: A critical review of the literature. *Journal of Education*, *85*, 1–22. https://doi.org/10.17159/2520-9868/i85a01

Winch, C. (2013). Three Different Conceptions of Know-How and their Relevance to Professional and Vocational Education. *Journal of Philosophy of Education*, *47*(2), 281–298. https://doi.org/10.1111/1467-9752.12025

Winn, W. (1982). The role of diagrammatic representation in learning sequences, identification and classification as a function of verbal and spatial ability. *Journal of Research in Science Teaching*, *19*(1), 79–89. https://doi.org/10.1002/tea.3660190110

Winn, W. (1983). Perceptual Strategies Used with Flow Diagrams Having Normal and Unanticipated Formats. *Perceptual and Motor Skills*, *57*(3), 751–762. https://doi.org/10.2466/pms.1983.57.3.751

Winn, W. (1988). Recall of the pattern, sequence, and names of concepts presented in instructional diagrams. *Journal of Research in Science Teaching*, *25*(5), 375–386. https://doi.org/10.1002/tea.3660250505

Winn, W. (1991). Learning from maps and diagrams. *Educational Psychology Review*, *3*(3), 211–247. https://doi.org/10.1007/BF01320077

Winn, W. D., & Sutherland, S. W. (1989). Factors influencing the recall of elements in maps and diagrams and the strategies used to encode them. *Journal of Educational Psychology*, *81*(1), 33–39. https://doi.org/10.1037/0022-0663.81.1.33

Wong, K. M., & Samudra, P. G. (2019). L2 Vocabulary Learning from Educational Media: Extending Dual-Coding Theory to Dual-Language Learners. In *Grantee Submission*. https://doi.org/10.1080/09588221.2019.1666150

Wu, Y., Chen, Y., Wang, L., Ye, Y., Liu, Z., Guo, Y., & Fu, Y. (2019). *Large Scale Incremental Learning*. 374–382. https://openaccess.thecvf.com/content_CVPR_2019/html/Wu_Large_Scale_Incremental_Learning_CVPR_2019_paper.html

Wutich, A., Beresford, M., & Bernard, H. R. (2024). Sample sizes for 10 types of qualitative data analysis: An integrative review, empirical guidance, and next steps. *International Journal of Qualitative Methods*, *23*, Article 16094069241296206. https://doi.org/10.1177/16094069241296206

Yadiannur, M., & Supahar. (2017). Mobile Learning Based Worked Example in Electric Circuit (WEIEC) Application to Improve the High School Students' Electric Circuits Interpretation Ability. *International Journal of Environmental and Science Education*, *12*(3), 539–558. https://eric.ed.gov/?id=EJ1141565

Yasak, Z., & Alias, M. (2017). Designing learning materials in TVET: Application of the learning hierarchy technique. *2017 IEEE 9th International Conference on Engineering Education (ICEED)*, 180–185. https://doi.org/10.1109/ICEED.2017.8251189

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Sage Publications.

Zhao, F., Ahmed, F., Iqbal, M. K., Mughal, M. F., Qin, Y. J., Faraz, N. A., & Hunt, V. J. (2020). Shaping Behaviors Through Institutional Support in British Higher

Educational Institutions: Focusing on Employees for Sustainable Technological Change. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.584857

Zungu, Z. N. (2016). *Curriculum and competence: Exploring the relationship between competence development and the curriculum : a comprehensive case of two TVET institutions in South Africa.* http://hdl.handle.net/10413/12937

Appendices

Appendix A

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

18 October 2023

Mark Sanjeevy (213569811)
School Of Education
Pietermaritzburg Campus

Dear M Sanjeevy,

Protocol reference number: HSSREC/00006259/2023
Project title: Implementing lesson study to influence the teaching and learning of electrical wiring diagrams in a South African technical vocational education and training college
Degree: PhD

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 20 September 2023 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted FULL APPROVAL.

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

This approval is valid until 18 October 2024.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

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

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 8350/4557/3587 **Email:** hssrec@ukzn.ac.za **Website:** http://research.ukzn.ac.za/Research-Ethics

Appendix B: Letter to Participant.

[redacted]
Pietermaritzburg
3201
10 July 2023

Dear Participant
REQUEST FOR PARTICIPATION IN RESEARCH PROJECT

My name is Mark Sanjeevy (Student No. 213569811) a PhD student in the School of Education at the University of KwaZulu Natal. As part of the requirement for this degree, I am required to conduct a research project. The title of my research study is: **Implementing Lesson Study to influence the teaching and learning of electrical wiring diagrams in a South African TVET college.**

The aim and purpose of this research study are to understand how students learn wiring diagrams. This study is expected to use 14 participants who are learners in NCV Level 4 and four lecturers who will participate in a lesson study research project. Students will be observed during lessons as a data generation method. Students and educators will be required to complete questionnaires and participate in focus group discussions, over 20 to 40 minutes. Follow-up discussions including surveys and semi-structured interviews will be conducted. All discussions will be voice-recorded. The lesson will be conducted over 2 weeks. This study will not involve any risks or discomfort to learners and the institution and will not provide direct benefits to the institution or participants. Students will be video recorded while undertaking their practical tasks.
In the event of any problems or concerns/questions you may contact me, my supervisor or the Ukzn Ethics Committee, contact details are as follows:

My contact details
Email: [redacted] Cell: 0[redacted]
Supervisor
Professor Wayne Hugo
Email address: hugow@ukzn.ac.za
Telephone:033-2605879
UKZN Research Office

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

Participation in this research study is voluntary, and learners may withdraw participation at any point. In the event of refusal/withdrawal of participation, learners will not be penalised. There are no consequences to learners if they withdraw from the study. Learners will incur no costs, for participating in the study, and there are no incentives or reimbursements for participation in the study. Institutional and participants'

names will be changed, and pseudonyms will be used so that participants remain anonymous. Information provided by learners will remain confidential and will not be shared with anyone else. Data generated through lesson observations, questionnaires and focus group discussions will be stored at Ukzn for five years, and after that destroyed.
Thank you for your cooperation.
Yours in Education
Mark Sanjeevy

DECLARATION OF CONSENT

I, ____ (Name of participant) have been informed about the study entitled: Implementing Lesson Study to influence the teaching and learning of electrical wiring diagrams in a South African TVET College. by Mark Sanjeevy

I understand the purpose and procedures of the study.
I have been allowed to ask questions about the study and have had answers to my satisfaction.
I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.
If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher at ([redacted]).
If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers, then I may contact the University of Kwa-Zulu Natal.

Additional consent, where applicable
I hereby provide consent to (Please circle response)

Observe lessons and classroom activities	YES / NO
Video and audio-record the research	YES / NO
Complete questionnaires	YES / NO
Take photographs	YES / NO
Participate in semi-structured interviews, questionnaires, focus group discussions.	YES / NO

______________________ ______________________

Signature of Participant **Date**

Appendix C

Institutional Consent

higher education & training
Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

UMGUNGUNDLOVU TVET COLLEGE

Thank you for your cooperation.

Yours in Education

Mark Sampeery

DECLARATION OF CONSENT

I **Andile Frank Simelane** (Full names of the campus manager) have been informed about the study entitled: **Implementing Lesson Study to influence the teaching and learning of electrical wiring diagrams in a South African TVET college.**

I understand the purp [redacted] cedures of the study and do consent.

SIGNATURE OF CAMPUS MANAGER

17/07/2023
DATE

UMGUNGUNDLOVU TVET COLLEGE
2023 -07- 17

Appendix D: Lecturer Interview (PRE-Lesson Study)

Name ____

Discipline____________________________________

Class Level________________________ Date________________________________

1. Tell me about yourself (background, education, specialisation, length of teaching experience.)
2. In what sorts of activities do students engage in your classroom?
3. What instructional approaches, methods or strategies do you use in the classroom?
4. What is your definition of creativity as it relates to teaching?
5. What do you do to promote creative thinking and problem-solving in students?
6. How important is the teaching of creative and critical thinking skills?
7. How does your own creativity influence your teaching?
8. How does the climate of the school impact the teaching of creative and critical thinking skills?
9. How would you describe your experiences of teaching?
10. What is your definition of Lesson Study as it relates to teaching?
11. Describe the effectiveness of the Lesson Study Approach as a professional development tool.

Appendix E:

Interview Questions.

1. Lesson planning

1.1 Describe your contribution to this phase.

1.2 How did the group decide on the targets for the LS (Lesson Study)?

1.3 Did you share ideas with the others?

1.4 Did you get new ideas from the others?

1.5 How did you choose the research lesson?

1.6 Which lesson, grade, class and why?

1.7 How was the process of planning the pedagogical content?

1.8 Did you have lesson targets? Learning targets? Were these clarified with students?

1.9 How were the pupils prepared for the research lesson?

1.10 What were the decided time frames?

1.11 Did you receive enough support from the school leadership? Explain.

2. Experience with the research lesson

2.1 How did the class react to the observing teachers and video camera?

2.2 Answer the following questions depending on which role you had during the research lesson. (2.2.1 & 2.2.2) Instructor, (2.2.3 &2.2.4) Observer:

2.2.1 What was it like being a teacher in a room with so many other teachers present?

2.2.2 Did you manage to carry out the lesson exactly as the group had agreed? Did you change any of the instructions? If you made any changes, why?

2.2.3 How did you ensure you stayed focused on the key points?

2.2.4 How would you describe the experience of being a passive observer? Did you note enough relevant observations?

3. post-lesson experience

3.1 Did you interview any pupils? If so, what did they say?

3.2.1 What was the atmosphere like in the group after the research lesson?

3.2.2 Could everyone contribute with relevant observation data?

3.2.3 Did everyone agree on what had worked well in the lesson?

3.2.4 What was the students' reaction to instructions?

3.2.5 Did you see any evidence of learning?

3.3 What type of weaknesses were discovered?

3.4 What revisions were suggested?

3.5 Did you feel that it was ok to suggest revisions to the group?

4. Experience of the revised research lesson and consequent post-lesson discussion.

4.1 What was it like to carry out a revised lesson?

4.2 Were there any surprises?

4.3 What did you discuss afterwards?

4.4 What have you written down during the process? Logs? Observation notes? Lesson plans? Reflection notes?

5. Evaluation of the process

5.1 When you look back at the entire process, what has had a positive impact on your professional development?

5.2 Did anything surprise you?

5.3 What has been the most negative thing you have experienced?

5.4 Would you consider participating in a new round of lesson study? On what conditions?

Appendix F: Lesson Study Observation Checklist

Purpose: to record observed teacher performance during the lesson study observations

Date:	Observation:	Observer:	Educator observed:
Topic of Observed Lesson:			
Core Subject Area of Observed Lesson:			Start time:
Grade level of Observed Lesson:			End time:

Use the scale below to record teacher performance during the lesson study observation.

No evidence.	Not observed during the lesson.	0
Very little evidence.	Observed 1 time during the lesson.	1
Some evidence	Observed 2 times during the lesson	2
Much evidence	Observed 3 times during the lesson	3
Considerable evidence.	Observed 4 or more times during the lesson	4

Part One: Learning and Thinking Skills

Demonstrates knowledge of a wide range of instructional practices, approaches, methods, technologies, and curriculum to support learning and improve thinking skills.

		Times observed (tally)	Notes	Total
	The teacher provides for student activities that allow for:			
1.1	Critical thinking that leads to Problem-solving.			
1.2	Creative and innovative learning.			
1.3	Collaborative learning.			
1.4	Appropriate and relevant activities.			
	The teacher employs instructional strategies, media, and materials that foster:			
1.5	Critical thinking and problem Solving.			
1.6	Creativity and innovation			
1.8	Collaboration			
1.9	Information about students' interests			
1.10	Apply information about students' cultural and experiential backgrounds			
	Learning and Thinking Skills Total: (0-36)			

Part Two: Core Subjects

Provides for effective instruction in the core subject being observed.

		Times observed (tally)	Notes	Total
	The teacher applies current scholarly knowledge related to:			
2.1	Developmental stages.			
2.2	Learning and cognition.			
	The teacher uses a variety of:			
2.3	Technologies/media to support instruction.			
2.4	Strategies/ methods to support instruction.			
2.5	Materials to support instruction.			
2.6	Information about students' interests			
2.7	Apply information about students' cultural and experiential backgrounds.			
2.8	Formal and informal assessments to inform instruction for multi-level groups and individuals.			
	Core Subjects Total: (0-24)			

Part Three: The use of current assessments.

Integrates knowledge of assessment and evaluation to create a data-driven environment that advances achievement and academic attainment.

		Times observed (tally)	Notes	Total
	The teacher uses:			
3.1	Modern technologies to increase The efficiency of assessment.			
3.2	A variety of assessments to inform Instruction.			
3.3	Performance assessment to measure mastery of content or skills.			
3.4	Rubric assessment to inform students of progress toward performance criteria.			
	Current Assessments Total: (0-16)			

Part Four: Life Skills

Evidence of instruction characterized by experiences that build skills needed to thrive in, a global society.

		Times	Notes	Total

		observed (tally)		
	The teacher creates opportunities for the development of:			
4.1	Leadership			
4.2	Ethical decision making			
4.3	Personal productivity			
4.4	Personal responsibility			
4.5	People skills			
4.6	Self-direction			
4.7	Social responsibility			
	Life Skills Total: (0-28)			

Appendix G: Likert rating scale questionnaire (Evaluation Tool)

Please rate yourself on the following attributes for using creative and critical thinking instructional strategies. Base your answers on the most recent lessons that you have taught. This information will not be shared by name or in the report in any way that can be traced back to you.

Ratings: Use the Likert rating scale to self-assess on a scale of 1-5

1 – Rarely (less than 20% of the time)

2 – Occasionally (between 20%-40% of the time)

3 – Sometimes (between 40%-60% of the time)

4 – Often (between 60%-80% of the time)

5- Mostly (more than 80% of the time)

		QUESTION CATEGORIES	1	2	3	4	5
		CM = Classroom Management/Learning Atmosphere (8)					
CM	1	Encouraged and called for excellence in students' work.					
CM	2	Challenged students' thinking in a non-threatening manner.					
CM	3	Continuously sought to build trust with students.					
CM	4	Organized materials, lectures, and information presented.					
CM	5	Remained flexible and open-minded.					
CM	6	Ensured information was presented clearly.					
CM	7	Students processed information successfully.					
CM	8	Continuously encouraged group participation, classroom participation, and/or individual interactions.					

		QUESTION CATEGORIES	1	2	3	4	5
		SE = Support of Exploration and Experimentation (8)					
SE	1	Provided chances for students to think, learn, and discover.					
SE	2	Fostered self-initiated learning.					
SE	3	Helped students examine issues from different points of view.					
SE	4	Engaged students to learn by exploring, manipulating, experimenting, risking, testing, and modifying ideas.					
SE	5	Discouraged conformity and allowed students to explore.					
SE	6	Encouraged students to use a variety of approaches to solving problems and produce many ideas.					
SE	7	Encouraged fact-finding and information-gathering.					
SE	8	Provided verbal and visual elements in learning					
		QUESTION CATEGORIES	1	2	3	4	5
		SI = Support of different Ideas and Divergent thinking (8)					
SI	1	Supported students' ideas.					
SI	2	Rewarded creative thinking.					
SI	3	Respectful of unusual questions and opposing ideas.					
SI	4	Encouraged and called for original work, self-initiated					

		projects and experimentation.					
SI	5	Encouraged opinions and expression of ideas.					
SI	6	Encouraged academic controversy.					
SI	7	Encouraged independent, productive thinking.					
SI	8	Considered students' views about subject matter.					

QUESTION CATEGORIES			1	2	3	4	5
		LO = Lesson Organization and Content (8)					
LO	1	Encouraged synthesis and analysis using text, images, audio, and video.					
LO	2	Provided idea-time for students to think.					
LO	3	Used numerous learning tools and instructional approaches to present information and design effective instructional materials.					
LO	4	Captured students' attention.					
LO	5	Related subject content to real-world problems.					
LO	6	Provided student-centred instruction.					
LO	7	Used verbal and visual elements in learning and memory.					
LO	8	Used open-ended, probing questions in class.					
		verbal and visual elements in learning and memory					

Question Category Key

CM = Classroom Management/Learning Atmosphere (8)

LO = Lesson Organization and Content (8)

SE = Support of Exploration and Experimentation (8)

SI = Support of different Ideas and Divergent thinking (8)

Appendix H Lesson Plan

Appendix H **LESSON PLAN**

W EEK N O:		**D A T E:**	

P R O G R A M M E:	**Report 191 Electrical Engineering**		
S U B J E C T:	**Electrotechnics**	**LEVEL:**	**N4**

CLASS GROUPS:	

TOPIC / MODULE:

TOPIC 5: Circuit Diagrams

Module 14: Circuit diagrams of electrical sub-circuits.

SUBJECT OUTCOME(S) / OBJECTIVES:

ON COMPLETION OF THIS MODULE THE STUDENT MUST BE ABLE TO: -

- *Identify common drawing symbols and abbreviations used in electrical drawings of electrical installations and various electrical sub-circuits.*
- *Understand basic circuit diagrams and the interpretation thereof.*
- *Produce basic circuit diagrams and draw up a parts list including component ratings.*

LEARNING OUTCOMES / OBJECTIVES:

ON COMPLETION OF THIS MODULE THE STUDENT MUST BE ABLE TO: -

- *Explain the requirements of a typical electrical circuit.*
- *Draw different circuit diagrams that conform to standard practice (international standards).*
- *Compile a parts list from the circuit diagram that includes component ratings.*

SEQUENCE OF LESSON ACTIVITIES:

Activity	**By Whom (✓)**		**Time Allocated (minutes)**	**Resources Required**
	Lecturer	**Learner**		
Unit 14.1 Students to draw table 14.1 in their notebooks.	√	√		

Electrical wiring diagrams have three sub-categories. Explain and differentiate in detail (P158) • Circuit diagrams • Wiring diagrams • Block diagrams				
Requirements of a typical electrical circuit diagram. Electrical circuit diagrams should be drawn in such a way that it allows a reader to identify its purpose. When drawing you should: • Use correct symbols. • Use a suitable symbol orientation. • Pay attention to the arrangement of symbols. • Pay attention to the routing of interconnections. • Input to output is always drawn from left to right or from top to bottom. • Relays and switches are normally shown in their non-operating mode. • A line representing a conductor should not change direction at a point where it crosses other lines. • Make sure your drawing is neat and tidy. ○ Draw figure 14.6 (One luminaire controlled from one switch) ○ Draw figure 14.7 (Two luminaires controlled from one switch)	√	√	**90 MIN**	**w/shop, tools, simulated panels. Work-stations, equipment.**

○ Draw figure 14.8 (Two luminaires controlled from own switch) ○ Draw figure 14.9 (One luminaire controlled from two switches) The above drawings (P160) will become the base for teaching the complicated aspects of reading, understanding and interpreting electrical wiring diagrams. Students will then need to generate a parts list of components to construct the wiring diagram as per figure 14.9.				
Subject outcome 14.2 **Preparing a parts list.** It is important for an electrician to prepare a parts list of materials that will be required for a specific installation. These materials fall into two main categories, namely numbered parts and measured parts. Numbered Parts: These are materials that can be counted. Measured Parts: These are materials that are charged per length. The electrician writes the list of materials (both numbered and measured) on a requisition, order or quotation. Task1: ▪ On completion of the drawing students must generate a parts list. ▪ Students must use this list to choose the parts required to construct the	√	√	**30 MIN**	

circuit. ▪ Students must construct the circuit using the parts from the list generated at their workstation.				
Subject outcome 14.3 **Evaluating whether the knowledge can be applied to other wiring diagrams.**	√	√	60 MIN	
On completion of task 1, students will then be tested to determine if they can apply the knowledge gained from the above lesson to perform Task 2 (a complicated task) Task 2: Draw read and interpret a direct online wiring diagram. Students will draw the diagram, generate a parts list and construct the circuit. When this is done students will be evaluated to determine their competence.		√		

COMMENTS:

THE LESSON WILL BE INTERACTIVE. IT WILL UTILISE POWERPOINT, DEMONSTRATIONS, SIMULATED PANELS AT WORKSTATIONS AND CHALK AND TALK.

Challenges:

- How do students master symbolic representations?
- Schematics are meaning-dense. They contain more than one complex electrical concept (e.g., single-cell; conductor; resistor; switch).
- Can students conceptually connect the abstract diagram to real world scenarios?
- How do students develop spatial reasoning skills?
- What are the misconceptions of how electricity works and how can this be addressed?
- Will the student learn better collaboratively or individually?

Appendix I Amended Lesson Plan

higher education
& training
Department
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

2023

[redacted] LESSON PLAN

WEEK NO:	16	DATE:	17 November 2023
PROGRAMME:	NCV Electrical Engineering	Time: 4 hours	
SUBJECT:	Electrical Principles and Practice	LEVEL:	2
TOPIC 5: Circuit Diagrams	Module 14: Circuit diagrams of electrical sub-circuits.		

SUBJECT OUTCOME(S) / OBJECTIVES:

ON COMPLETION OF THIS MODULE THE STUDENT MUST BE ABLE TO: -

- *Identify common drawing symbols and abbreviations used in electrical drawings of electrical installations and various electrical sub-circuits.*
- *Understand basic circuit diagrams and the interpretation thereof.*
- *Produce basic circuit diagrams and draw up a parts list including component ratings.*

LEARNING OUTCOMES / OBJECTIVES:

ON COMPLETION OF THIS MODULE THE STUDENT MUST BE ABLE TO: -

- *Explain the requirements of a typical electrical circuit.*
- *Draw different circuit diagrams that conform to standard practice (international standards).*
- *Compile a parts list from the circuit diagram that includes component ratings.*

Prior Knowledge required before completing this module. (Students would have been told in the previous lesson to go back and read the following modules to prepare for this lesson.) The lecturer should also revisit these following modules prior to presenting the lesson.

Recap.

1. In module 4 we studied Electrical Supply Systems. We examined single phase (230V) and three phase (400V) supply systems.
2. In module 5 we studied electro-magnetic circuits. This will be important for the relays, contactors and switches especially regarding energized and non-energized states.
3. In module 6 we studied continuity and current flow. Understanding those concepts gives us a better understanding of open and closed circuits.
4. In module 11 we studied the importance of earthing electrical appliances, equipment and installations. Those concepts must be applied to all the circuits of this module.
5. In module 12 we studied measuring and testing instruments and how they are used in practice. You will use a multimeter for continuity testing in this module.

SEQUENCE OF LESSON ACTIVITIES:

Activity	By Whom (✓)		Time Allocated (minutes)	Resources Required
	Lecturer	Learner		
Why do we need to draw circuit diagrams? Explain that circuit diagrams are an international communicable tool that can be read anywhere in the world irrespective of language barriers.	(✓)			
Unit 14.1 Circuit Symbol Table Students would have been required to draw this table as homework prior to this lesson. This is an international symbol chart that standardises circuit diagrams globally.	(✓)	(✓)		
For the lesson we will not utilise all the symbols but just concentrate only on the relevant symbols relating to the	(✓)			

circuits to be drawn. Students to extract symbols from the symbol chart and insert into table (annexure A). Electrical diagrams have three sub-categories. Explain and differentiate in detail (P158 illustrates all types) • Circuit diagrams • Wiring diagrams • Block diagram	(✓)			
Requirements of a typical electrical circuit diagram. Electrical circuit diagrams should be drawn in such a way that it allows a reader to identify its purpose. When drawing you should: • Use correct symbols. • Use a suitable symbol orientation. • Pay attention to the arrangement of symbols. • Pay attention to the routing of interconnections. • Input to output is always drawn from left to right or from top to bottom. This will be dealt with in detail in ESC where you will learn about ladder diagrams. • Relays and switches are normally shown in their non-	(✓) (✓) (✓)			w/shop, tools, simulated panels. Work-stations, equipment.

operating mode. Explain activated/deactivated/ energised/non-energised • A line representing a conductor should not change direction at a point where it crosses other lines. This should be explained in detail especially regarding where lines cross (the dot and no dot). Use illustrations. • Make sure your drawing is neat and tidy. ○ Draw figure 14.6 (One luminaire controlled from one switch) ○ Draw figure 14.9 (One luminaire controlled from two switches) The above drawings (P160) will become the base for teaching the complicated aspects of reading, understanding and interpreting electrical wiring diagrams. Although the fuse will be shown in this diagram it will not be utilized for the construction. However, the purpose of the fuse is to disconnect the supply during short circuit and overload. It has the same purpose of a circuit breaker, but ruptures and does not trip. Colour Coding	(✓) (✓)	(✓) (✓)		

Live, Neutral, Earth and the strappers Explain in greater detail. Explain earth and its omission on the plug and play unit. Students will then need to generate a parts list of components to construct the wiring diagram as per figure 14.9.		(✓)		
Subject outcome 14.2 **Preparing a parts list.** It is important for an electrician to prepare a parts list of materials that		(✓)		

will be required for a specific installation. These materials fall into two main categories, namely numbered parts and measured parts. Numbered Parts: These are materials that can be counted. Measured Parts: These are materials that are charged per length. The electrician writes the list of materials (both numbered and measured) on a requisition, order or quotation. Task1: 1.On completion of the drawing students must generate a parts list. 2.Students must use this list to choose the parts required to construct the circuit. 3.Students must construct the circuit using the parts from the list generated at their workstation.				
Subject outcome 14.3 **Evaluating whether the knowledge can be applied to other wiring diagrams.**				
On completion of task 1, students will then be tested to determine if they can apply the knowledge gained from the above lesson to perform Task 2 (a complicated task)				

Do a block diagram of the DOL and ask the students to insert the correct symbols from the symbol chart to complete the circuit diagram. Task 2: Draw read and interpret a direct on line wiring diagram. Students will draw the diagram, generate a parts list and construct the circuit. When this is done students will be evaluated to determine their competence.				

Review: Have the students grasped the concepts. If not what remedial exercises can be used to address any challenges?
COMMENTS:

THE LESSON WILL BE INTERACTIVE. IT WILL UTILIZE POWERPOINT, DEMONSTRATIONS, SIMULATED PANELS AT WORKSTATIONS AND CHALK AND TALK.

Challenges:

- Time is a major challenge.
- How do students master symbolic representations?
- Schematics are meaning-dense. They contain more than one complex electrical concept (e.g., single-cell; conductor; resistor; switch).
- Can students conceptually connect the abstract diagram to real world scenarios?
- How do students develop spatial reasoning skills?
- What are the misconceptions of how electricity works and how can this be addressed?
- Will the student learn better collaboratively or individually?

Appendix J

Observation Schedule from a summative assessment

RECORD OF PERFORMANCE IN INTEGRATED ASSESSMENT TASK		
STUDENT'S MARKING SHEET:		
Student's surname and first name(s)		
Student's ID number		
Lecturers' surnames and initials	[redacted]	
Sub-task 1: Schematic diagram	**Total Possible Mark**	**Student's Mark**
POWER CIRCUIT		
L1/L2/L3 indicated correctly.	1	
Three-phase circuit breaker.	1	
Contactor.	1	
Overload relay.	1	
Three-phase motor.	1	
Earth connection.	2	
CONTROL CIRCUIT		
Control circuit breaker.	1	
E/STOP.	2	
Overload relay.	1	
Stop push button.	1	
Start push button.	1	
Holding contacts on contactor.	2	
Contactor coil.	1	
Indicator lamp.	1	
Neutral connection if 220 V contactor is used, 2nd phase connection if 400 V contactor is used.	2	
Correct labelling was done.	2	
Correct symbols were used throughout drawing.	2	
Drawing was neat and logically laid out to assist construction and wiring.	2	
SUB-TOTAL	**25**	

Sub-task 2: Installation and panel wiring	Total Possible Mark	Student's Mark
Correct colour of conductor: • All colours of conductors were chosen correctly = 5 marks. • Most colours chosen correctly = 3 marks. • Some colours chosen correctly = 1 mark. • Few or no colours chosen correctly = 0 marks.	5	
Wiring of components: • All components were wired correctly = 5 marks. • Most components were wired correctly = 3 marks. • Some components were wired correctly = 1 mark. • No components were wired correctly = 0 marks.	5	
Conductors neat and secured: • All conductors neat and secured = 5 marks. • Most conductors neat and secured = 3 marks. • Some conductors neat and secured = 1 mark. • No conductors neat and secured = 0 marks.	5	
Earthing done in accordance with the SANS 10142 regulations • All metal parts were earthed = 5 marks. • Most metal parts were earthed = 3 marks. • Some metal parts were earthed = 1 mark. • No metal parts were earthed = 0 marks.	5	
SUB-TOTAL	**20**	

Sub-task 3: Circuit testing and fault-finding		
Control circuit, power circuits and motor connections were collaboratively undertaken.		
Task completed within time frames (drawing, wiring and basic functionality checked). **NB:** 5-mark penalty per 10 minutes extra used.	15	
The following marks are either achieved (2) or not achieved (0). If the installation is fully functional, the lecturer must introduce a fault and candidates must perform fault-finding.	2	
Check to see if incoming supply was present before switching on.	2	
Test instruments (i.e. multi-meter, tong tester) were used correctly.	2	
Good housekeeping was exercised (i.e. no clutter in work area).	2	
Student worked safely during performance of task.	2	
Emergency stop function was demonstrated correctly.	2	
Overload functions were demonstrated correctly.	2	
Stop function was demonstrated correctly.	2	
Start button function was demonstrated correctly.	2	
Indication light function - turned on when motor was running.	2	
SUB-TOTAL	**35**	
GRAND TOTAL	**80**	

6. RECORD OF PERFORMANCE IN INTEGRATED ASSESSMENT TASK

College:	
Campus:	
Student's Surname and First Name/s:	
Student's ID Number:	
Lecturer's Surname and Initials:	[redacted]
Date of conclusion of assessment:	**17 November 2023**

ASSESSMENT GRID		
TASKS	**MARK ALLOCATION**	**STUDENT'S MARK**
Sub-task 1: Wiring diagram	25	
Sub-task 2: Panel wiring	30	
Sub-task 3: Circuit testing	35	
Total	**80**	

COMPETENCE LEVEL INDICATORS

5-POINT ACHIEVEMENT RATING SCALE				
Outstanding	**Highly competent**	**Competent**	**Not yet competent**	**Not achieved**
80-100%	**70-79%**	**50-69%**	**40-49%**	**0-39%**
5	**4**	**3**	**2**	**1**

Student's Competence Level:	
Student's Signature:	
Lecturer's Signature:	
Date:	17 November 2023

Appendix K
Student Worksheets
Name:

ID Number:

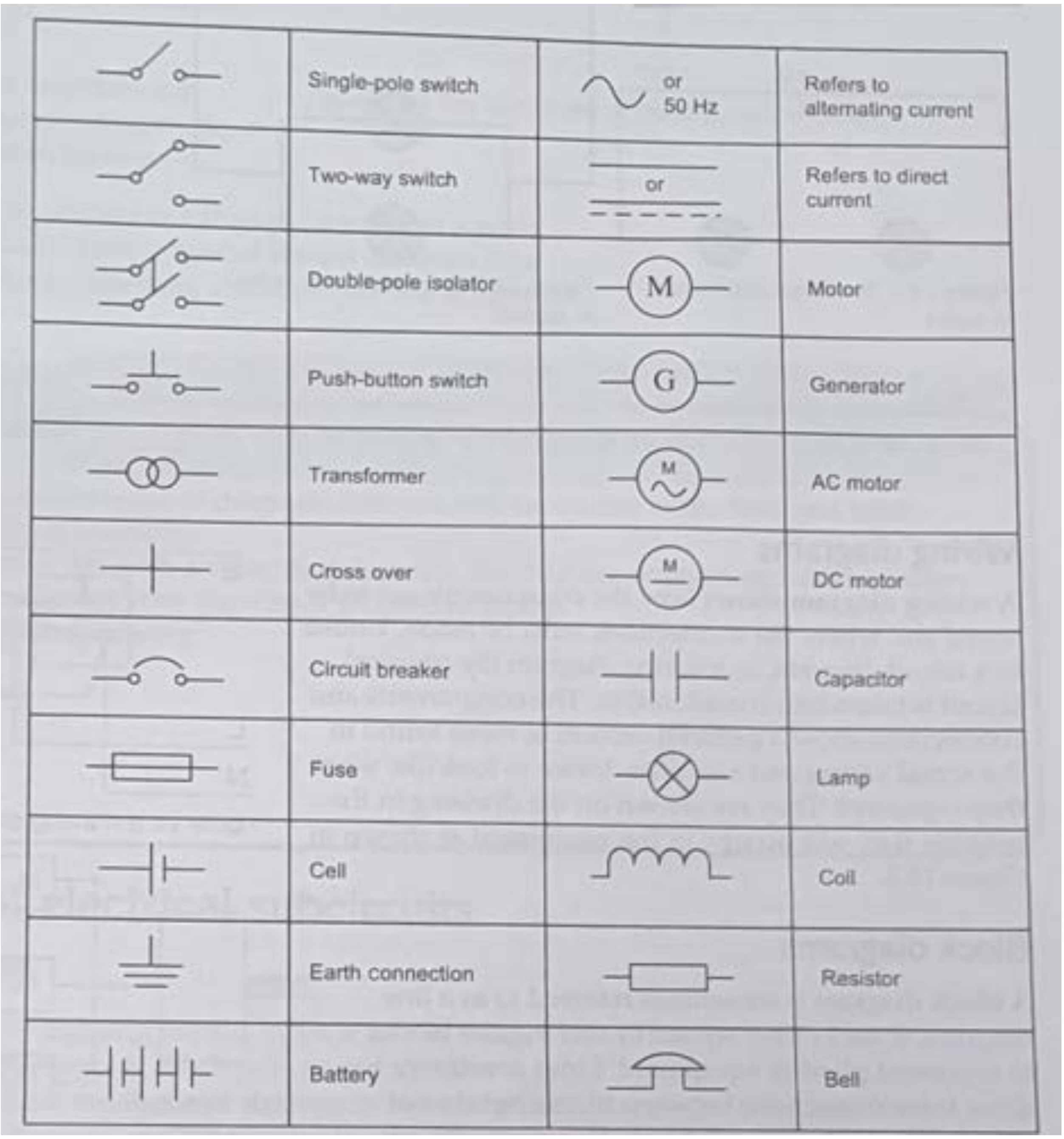
Appendix: K Student-generated data

Title: Implementing Lesson Study to influence the teaching and learning of electrical wiring diagrams in a South African TVET college.

Researcher: **<u>Mr M Sanjeevy</u>**

Research Objective:

This study seeks to understand how students learn electrical wiring diagrams utilising the phenomenon Lesson Study (LS). Lesson Study is a professional development activity that is characterised as classroom-situated, context-based, learner-focused, improvement-oriented, and teacher-owned. Although this study will examine how lecturers can change practice, the focus will be on lecturers' learning about pupils' learning. Findings in this case study will investigate how lesson study establishes professional learning through explicit and visible teachers' talk; through joint lesson planning, observation and joint evaluation of lessons and student learning. The study will evaluate whether LS promotes a shift in how teachers teach to how pupils learn. The objective is to conduct a reflexive self-study of a lecturer implementing lesson study to teach electrical wiring diagrams and to assess a team-oriented instructional design and shared responsibility for the instructional work and outcome.



	Single-pole switch	or 50 Hz	Refers to alternating current
	Two-way switch	or	Refers to direct current
	Double-pole isolator	M	Motor
	Push-button switch	G	Generator
	Transformer	M	AC motor
	Cross over	M	DC motor
	Circuit breaker		Capacitor
	Fuse		Lamp
	Cell		Coil
	Earth connection		Resistor
	Battery		Bell

Requirements of a typical electrical circuit diagram.

Electrical circuit diagrams should be drawn in such a way that they allow a reader to identify their purpose.

When drawing, you should:

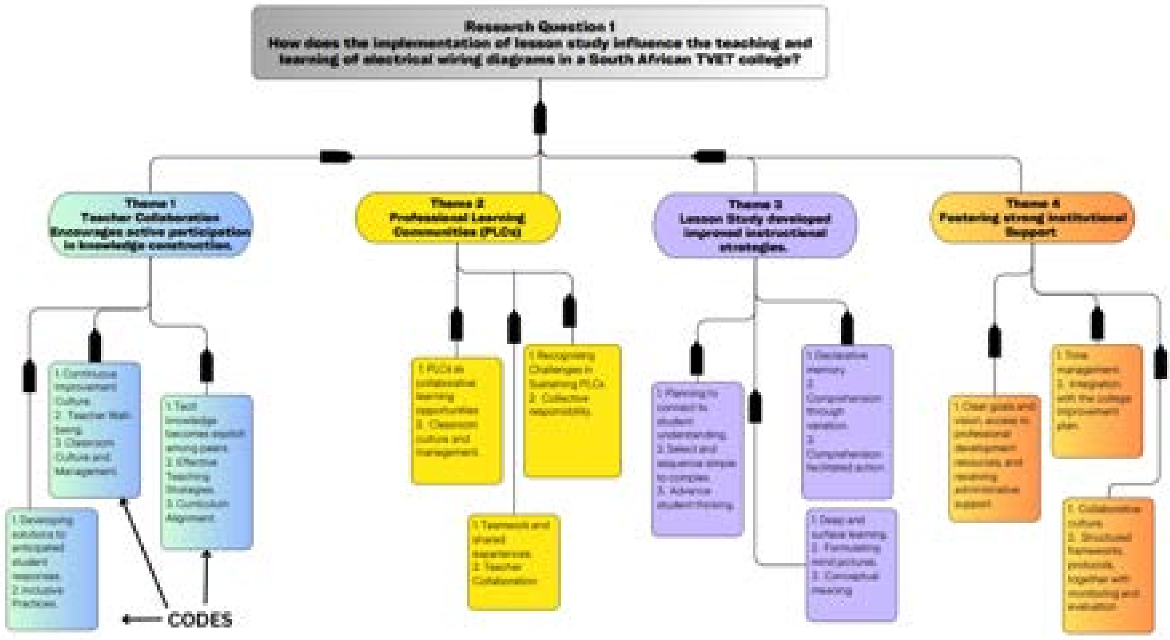
- Use correct symbols.

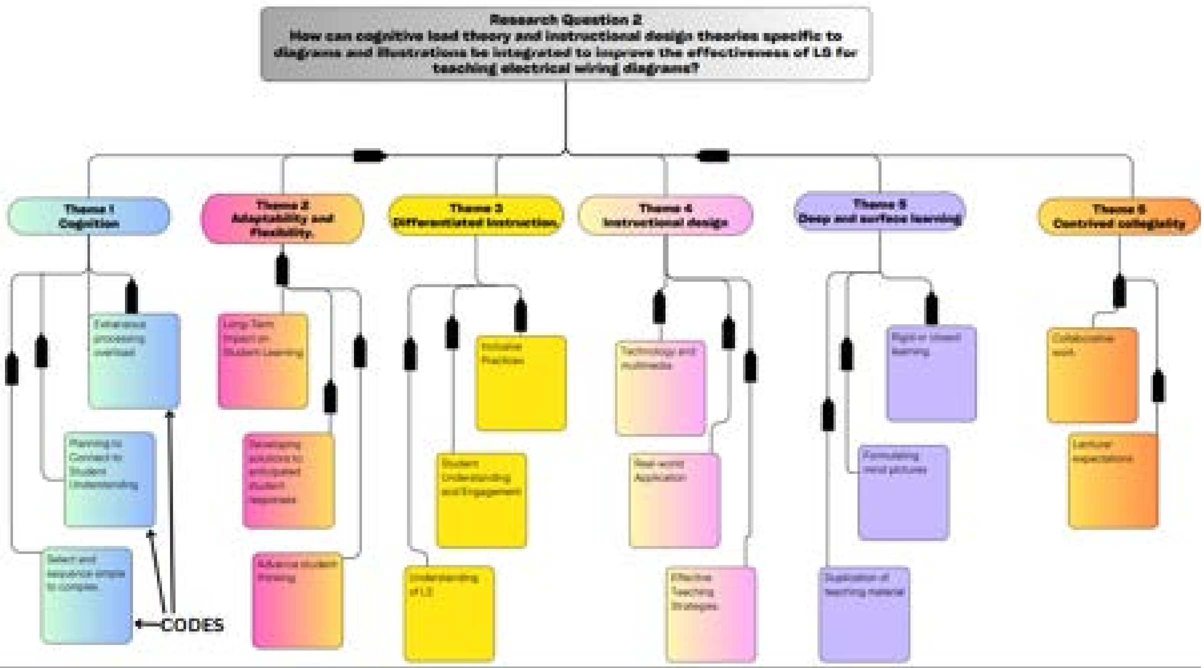
- Use a suitable symbol orientation.
- Pay attention to the arrangement of symbols.
- Pay attention to the routing of interconnections.
- Input to output is always drawn from left to right or from top to bottom.
- Relays and switches usually are shown in their non-operating mode.
- A line representing a conductor should not change direction at a point where it crosses other lines.
- Make sure your drawing is neat.

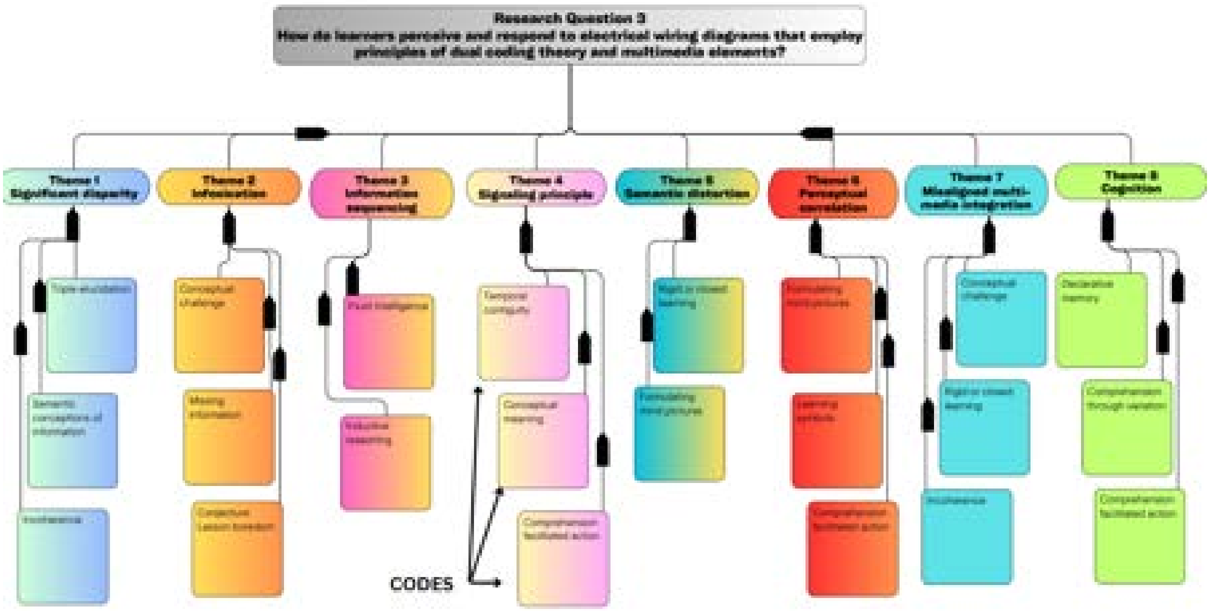
Draw the two-way switch circuit diagram. Below the circuit diagram, generate a parts list.

Draw the DOL starter. The drawing must include the main circuit and the control circuit(230v).

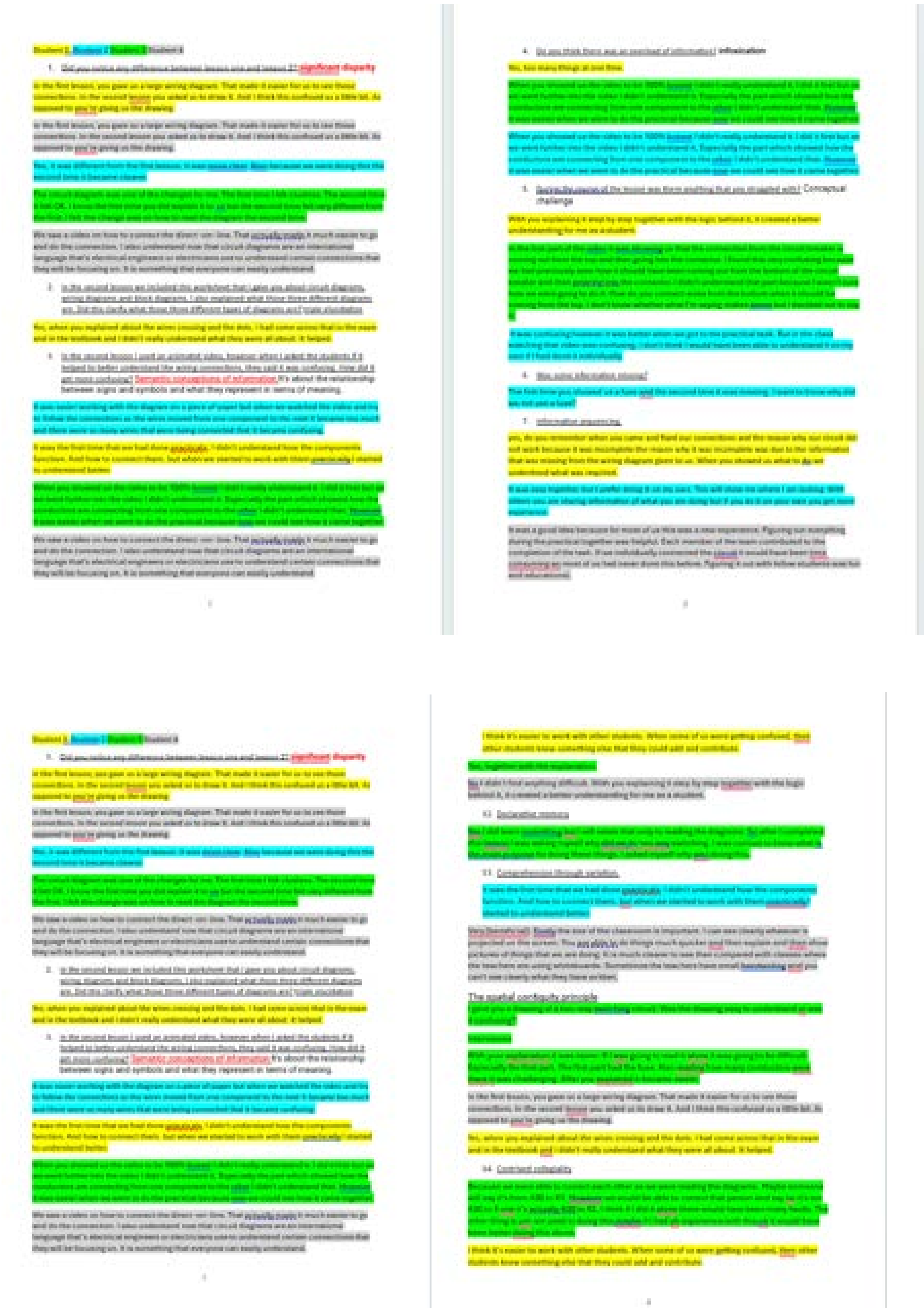
Appendix L: Codes to themes for Research Questions 1,2, and 3

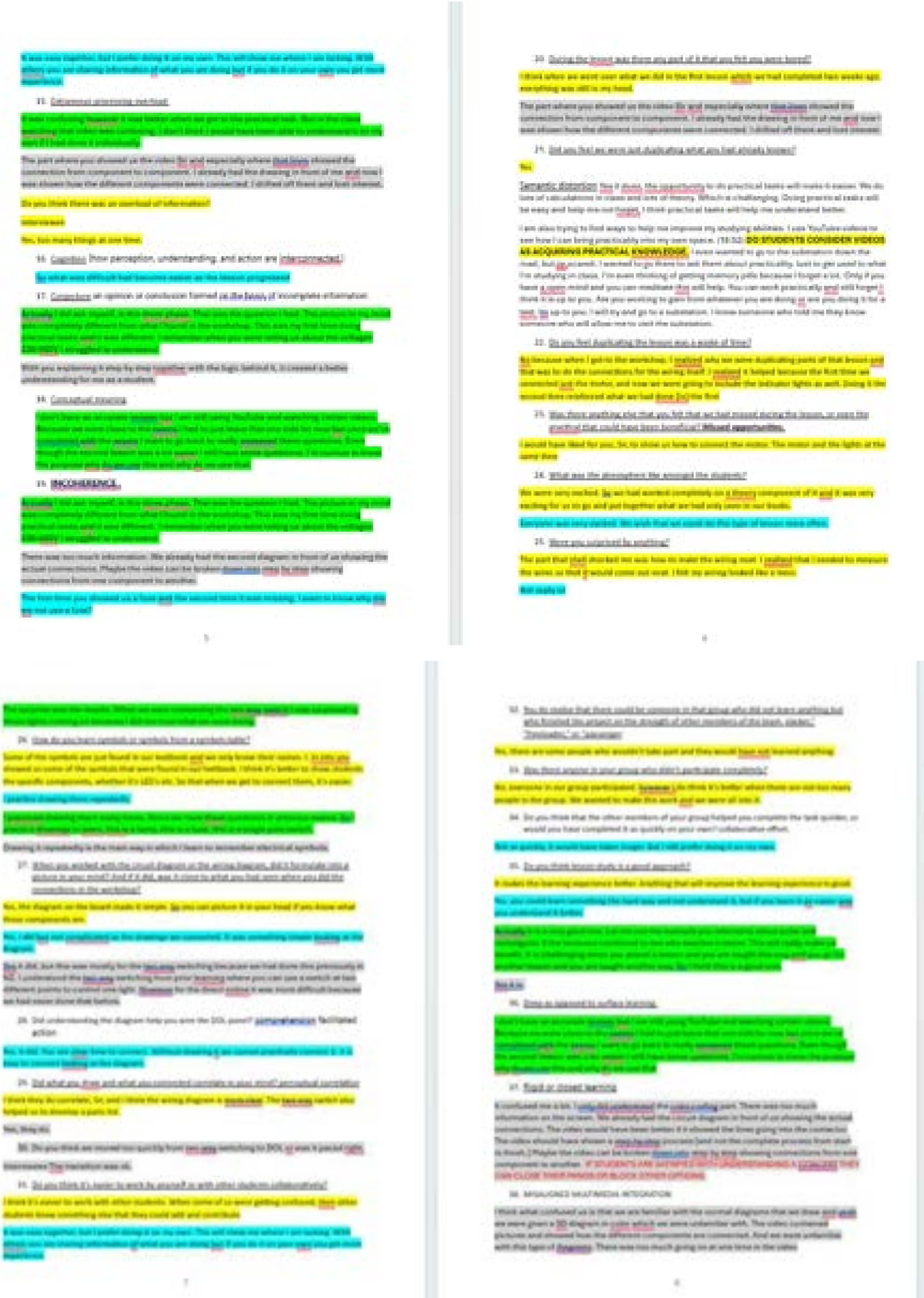





Research Question 3
How do learners perceive and respond to electrical wiring diagrams that employ principles of dual coding theory and multimedia elements?
Theme 1
Significant disparity
Triple elucidation
Semantic conceptions of information
Incoherence
Theme 2
Infoxication
Conceptual challenge
Missing information
Conjecture
Lesson boredom
Theme 3
Information sequencing
Dual intelligence
Inductive reasoning
Theme 4
Signaling principle
Temporal contiguity
Conceptual meaning
Comprehension facilitated action
CODES
Theme 5
Semantic distortion
Rigid or closed learning
Formulating mind pictures
Theme 6
Perceptual correlation
Formulating mind pictures
Learning symbols
Comprehension facilitated action
Theme 7
Misaligned multi-media integration
Conceptual challenge
Rigid or closed learning
Incoherence
Theme 8
Cognition
Declarative memory
Comprehension through variation
Comprehension facilitated action

Appendix M: Sample synthesis of the generated data (Codes to Patterns to Themes) for Research Question 3





It was easier working with the diagram on a piece of paper but when we watched the video and try to follow the connections as the wires moved from one component to the next it became too much and there were so many wires that were being connected that it became confusing.

In the first part of the video it was showing us that the connection from the circuit breaker is coming out from the top and then going into the contactor. I found this very confusing because we had previously seen how it should have been coming out from the bottom of the circuit breaker and then entering into the contactor. I didn't understand that part because I wasn't sure how we were going to do it. How do you connect wires from the bottom when it should be coming from the top. I don't know whether what I'm saying makes sense but I decided not to say it.

	Emerging Codes		
1	Significant disparity	20	Incoherence
2	Triple elucidation	21	Lesson boredom
3	Semantic conceptions of information	22	Duplication of teaching material.
4	Infoxication	23	Semantic distortion
5	Conceptual challenge	24	Duplicating the lesson was a waste of time.
6	Missing information	25	Missed opportunities.
7	Information sequencing.	26	Classroom atmosphere
8	Fluid Intelligence:	27	Surprises
9	Inductive reasoning	28	Learning symbols
10	Temporal contiguity	29	Formulating mind pictures
11	Signaling principle	30	Comprehension facilitated action
12	Declarative memory	31	Perceptual correlation
13	Comprehension through variation.	32	Collaborative work
14	Spatial contiguity	33	slacker, freeloader, or passenger in the team
15	Contrived collegiality	34	Collaborative effort.
16	Extraneous processing overload	35	Is Lesson Study effective
17	Cognition	36	Deep and surface learning
18	Conjecture	37	Rigid or closed learning
19	Conceptual meaning	38	Misaligned multi-media integration

Condensing the codes and patterns into themes

Significant disparity	Infoxication	Information sequencing	Cognition	Signaling principle	Contrived collegiality	Semantic distortion	Perceptual correlation	Deep and surface learning	Misaligned multi-media integration
Triple elucidation	Conceptual challenge	Fluid Intelligence	Declarative memory	Temporal contiguity	Collaborative work	Rigid or closed learning	Formulating mind pictures	Rigid or closed learning	Conceptual challenge
Semantic conceptions of information	Missing information	Inductive reasoning	Comprehension through variation	Conceptual meaning	What was the atmosphere like amongst the students	Formulating mind pictures	Learning symbols	Formulating mind pictures	Formulating mind pictures
	Conjecture		Extraneous processing overload	Comprehension facilitated action	Collaborative effort		Comprehension facilitated action	Duplication of teaching material	Rigid or closed learning
	Lesson boredom		Comprehension facilitated action						Missing information
	Incoherence								Missed opportunities
	Extraneous processing overload								Incoherence

Final themes for RQ3

	Themes		
1	Significant disparity	5	Semantic distortion
2	Infoxication	6	Perceptual correlation
3	Information sequencing	7	Misaligned multimedia integration
4	Signalling principle	8	Cognition

Appendix N Turnitin certification

Turnitin Originality Report

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