The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously submitted it, in its entirety or in part, at any university for a degree.

Signature:

Date : 11 November 2023

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ABSTRACT

This study sought to investigate the influence of an intervention on the Life Sciences teachers' perceptions of the nature of science, indigenous knowledge, and the implications for their pedagogy as well as self-directed learning. Vygotsky's social constructivism served as the theory underpinning this study and Warford's Zone of Proximal for Teacher Development (ZPTD) was used to carry out the intervention. The intervention comprised of two, two-day Short Learning Programmes (SLPs) which took place at the Landmark Protea Hotel in Polokwane, at the African Centre for DNA Barcoding (ACDB) and at the University of Johannesburg (UJ). This study adopted a mixed-methods approach, and a concurrent transformative research design was used where 38 Life Sciences teachers were conveniently sampled. Out of the 38 Life Sciences teachers, only 12 served as the experimental group, while 26 served as the control group for the Self-Direct Learning Instrument (SDLI). The data was collected pre and post intervention using three open-ended questionnaires, one closed-ended classroom observation and semi-structured interviews. The collected data was coded, and emerging themes were deliberated upon. The third generation Cultural Historical Activity Theory (CHAT) was used on a personal, institutional and on an interpersonal plane to interpret the findings. The recommendations from this study included the need to engage in change laboratories, a methodology emerging from Activity Theory, which advocates for the involvement of all stakeholders to address systemic pressures and the need for a bigger pool of participants during short learning programmes to benefit more participants. Furthermore, the study recommended that during teacher professional development interventions, more focus should be placed on the teachers' self-directed learning and building Teacher Professional Development (TPD) programmes around the needs of teachers. Lastly, the study recommended the increased duration of short learning programmes and establishing conducive communities of practice to support TPD.

The nine themes that emerged from both the holistic analysis and the six participating Life Sciences teachers from the three settings were:

The intervention helped the participating teachers by improving their perceptions of the nature of indigenous knowledge.

The intervention helped the participating teachers by improving their perceptions of the nature of science.

The intervention helped the participating teachers by shifting their pedagogical orientation mainly from didactic direct to either guided inquiry or open inquiry.

There is evidence of a lack of significant or tangible change in the participants' self-directed learning, post-intervention.

There was no submission of portfolios by the participating teachers.

The intervention helped the participating teachers from all the settings by improving their perceptions of the nature of indigenous knowledge. However, there were nuances with regards to the teachers' integrating nature of indigenous knowledge in their classrooms.

The intervention helped the participating teachers from all the settings by improving their perceptions of the nature of science. However, there were nuances with regards to the teachers' integrating the nature of science in their classrooms.

There was evidence of poor preparation, the lack of time management and poor reflective abilities.

There is no evidence of lesson preparation amongst the participants who were observed in their classrooms post-intervention.

Keywords: Indigenous Knowledge; Intervention; Life Sciences teachers; Nature of Indigenous Knowledge; Nature of Science; Perceptions; Short-learning programme; Views

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ACDB	African Centre for DNA Barcoding
AD	Active Direct
AS	Activity System
C2005	Curriculum 2005
CAPS	Curriculum and Assessment Policy Statement
CHAT	Third-Generation Cultural-Historical Activity Theory
CL	Cooperative Learning
CNEP	Christian National Education Policy
DD	Didactic Direct
DNA	Deoxyribonucleic Acid
GI	Guided Inquiry
IK	Indigenous Knowledge
IV	Informed Views
MKO	More Knowledgeable Other
MM	Mixed Methods
NC	No Classification
NCS	National Curriculum Statement
NOIK	Nature of Indigenous Knowledge
NOS	Nature of Science
NWU-EMELTEN-REC	North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics
OBE	Outcome-Based Education
OI	Open Inquiry
PBL	Problem-Based Learning
PCK	Pedagogical Content Knowledge
PCR	Polymerase Chain Reaction
PIV	Partially-Informed Views
POSTT LFSC	Pedagogy of Science Teaching Test for Life Sciences
PPC	Person-Process-Context

RTOP	Reformed Teaching Observation Protocol
SA	South Africa
SACE	South African Council of Educators
SDL	Self-Directed Learning
SDLI	Self-Directed Learning Instrument
SGBs	Schools Governing Bodies
SLP	Short-Learning Programme
SPSS	Statistical Package for the Social Sciences
TRREE	Training and Resources in Research Ethics Evaluation
UJ	University of Johannesburg
UV	Uninformed Views
VNOIK	Views of the Nature of Indigenous Knowledge
VNOS-D+	Views of the Nature of Science
ZPD	Zone of Proximal Development
ZPTD	Zone of Proximal Teacher Development

CHAPTER 1: OVERVIEW OF THE STUDY

1.1 Introduction to the study and problem statement

Life Sciences as a school subject is referred to as "the scientific study of living things from molecular level to their interactions with one another and their environments" (South Africa [SA], 2011, p. 8). As a result, Science teachers must simplify the acquisition of 21st-century abilities for learners and scaffold the information and skills on how learners should use the knowledge in their daily life. However, research have demonstrated that many Science teachers' teaching approaches were influenced by their conceptions of the Nature of Science (NOS) (Abd-El-Khalick et al., 1998). In addition, the Life Sciences teachers often did not hold a nuanced understanding of the NOS and they may also have held certain perceptions about the Nature of Indigenous Knowledge (NOIK) which may have influenced their classroom pedagogy (Cronje, 2015; Mothwa, 2011; Ramnarain & Schuster, 2014). Hence, the Science teachers' perceptions of the NOS and the NOIK influenced the pedagogical choices that they made (Abd-El-Khalick & Lederman, 1998; Ramnarain & Schuster, 2014). Furthermore, the pedagogical choices include a teachers' ability to use the suitable teaching strategies, and how they structured and facilitated the learning opportunities for the learners. Although there is no specific way of defining NOIK, Ankiewicz (2015), and Cronje et al. (2015) suggested that its philosophical framework is comprised of components such as ontology (description of IK), epistemology (means of knowing), methodology (methods of wisdom in action), and volition (the will to—linked to values, beliefs, and attitudes) of Indigenous Knowledge (IK).

The study's research problem was that in South Africa, the current Life Sciences policy document which is the Curriculum and Assessment Policy Statement (CAPS) is explicit on the NOS. It is also clear about the IK), particularly in Specific Aim (aims that outline the key steps to fulfil intended objectives) three, but it gives little direction to the teachers on the ways to infuse the IK and the NOS in their lessons while teaching the Life Sciences (Cronje, 2015; Monte & Libby, 2018; Motambatamba, 2018; SA, 2011). Cronje et al. (2015) outline that despite the reform initiatives that recommended the inclusion of the IK in the Science curricula locally and internationally, the Science teachers found it difficult to integrate the IK in their lessons. Thus, this research intended to determine whether the Life Sciences teachers could be positively influenced by an intervention concerning their perceptions of the NOS and the NOIK as well as their pedagogy and their Self-Directed Learning (SDL). This study focused on the possible influences such an intervention may have on the Life Sciences teachers' (based in urban, semi-urban and rural areas) perceptions of the NOS and the NOIK as well as the implications on their pedagogy and on the SDL. The intervention was made up of two Short Learning Programmes (SLPs), namely a two-day SLP on infusing IK in the Life Sciences curriculum content at the Landmark Protea Hotel in Polokwane. Furthermore, there was another two-day SLP at the African Centre for Deoxyribonucleic Acid (DNA) and Barcoding (ACDB) at the University of Johannesburg (UJ) (further elaborated on under 3.5 in Chapter three of this study).

1.2 The context of the study

This study sought to investigate the influence of an intervention on Life Sciences teachers' (based in Dimamo and Pietersburg circuits in Capricorn South and Capricorn North Districts from Limpopo Province) perceptions of the NOS, NOIK and implications for their pedagogy and SDL. The study used the Views of Nature of Science (VNOS-D+) and Views of Nature of Indigenous Knowledge (VNOIK) questionnaires to determine the teachers' perceptions of NOS and NOIK (Cronje et al., 2015; Lederman et al., 1998). Although the questionnaires are usually used to determine views, in this study the two questionnaires were used to determine the teachers' perceptions, an aspect that was explored in other studies (see Deng et al., 2011; Yalçinoğlu & Anagün, 2012). Hence, in the context of this study, the words *'views'* and *'perceptions'* were interchangeably used and treated as synonyms, although there is a slight difference.

The study worked with participants based in public high schools situated in urban, semi-urban and rural settings. According to the Centre of Expertise for Urban Programming [CEUP], 2016; Weeks, 2010; an urban setting is defined as one that is typified by a high population density, a concentration of administrative bodies and infrastructure, and a variety of livelihood and revenue generation options. In addition, the authors classified semi-urban settings as places with rural characteristics that are found on the periphery of large urban areas or cities (CEUP, 2013). Conversely, administrative institutions, government services, and other infrastructure are scarce in rural areas (CEUP, 2013; Week, 2010).

In the context of this study urban setting is characterised by a school with all the necessary teaching and learning infrastructure with learners that have access to materials necessary for their learning needs. Furthermore, semi-urban setting is characterised by school with most of the necessary teaching and learning infrastructure with most of the learners having access to necessary materials for their learning needs. While rural setting is characterised by school with few to no teaching and learning infrastructure except for basics such as chairs, boards etc, with most of the learners coming from impoverished background.

In addition, this study used the adapted version of Pedagogy of Science Teaching Test for Life Sciences (POSTT LFSC) multiple-choice questionnaire (Cobern et al., 2014). The questionnaire was used to determine the pedagogical orientation of the Life Sciences teachers based in the rural, semi-urban and urban settings from the two districts (Ramnarain & Schuster, 2014). The study also used the Self-Directed Learning Instrument (SDLI) (Cheng et al., 2010) and the Reformed Teaching Observation Protocol (RTOP) instrument (Piburn et al., 2000) to determine if the teachers were aware of their own SDL and classroom observations respectively. Lastly, the study used semi-structured interviews on teachers who were observed to determine if they were able to reflect on their own pedagogical practices.

1.3 Theoretical and conceptual frameworks

This section addresses an overview of the literature which was structured according to the theoretical and the conceptual frameworks of the study.

1.3.1 The theoretical framework of the study: Social constructivism, supporting learning across the zone of proximal teacher development

This study's theoretical foundation is social constructivism, as proposed by Russian social constructivist Vygotsky (1978). Social constructivism emphasises cultural and contextual understanding, and it views knowledge as a man-made activity acquired (built) via cultural and social interactions (Kim, 2014). Warford's Zone of Proximal

Teacher Development (ZPTD) (Warford, 2011) as shown in Table 1.1 was influenced by Vygotsky's (1978) Zone of Proximal Development. The ZPTD was used to scaffold the teachers' learning through the intervention (2x SLPs).

Table 1.1: Warford's Zone of Proximal Teacher Development that underpins the research study (Warford, 2011, p. 254. Verbatim table)

ZPTD	"Sample Interventionist DA"	"Sample Interactionist DA"
Self-assistance [Stage ii in ZPD (Gallimore & Tharp, 1990)]	"Preparing learning autobiographies. Responding to prompts about prior experiences"	"Discussions, sharing autobiographies, follow-up questions"
Expert other assistance [Stage I in ZPD (Gallimore & Tharp, 1990)]	"Analysis of teaching practices (demos, videos, field observation). Role-taking/playing. Forced choice quizzes (written). WebQuests. Cubing exercises"	"Leading questions and follow-up discussion. Processing role plays. Oral quizzes"
"Internalisation (automatisation)"	"Journaling. Micro-teaching Candidate statement of teaching philosophy"	"Discussion, dialogic partners"
"Recursion (De-automatisation)"	"Journaling clinical reflective reports: collecting information and making warranted claims for change On-line forum role taking/playing"	"Discussion, sharing autobiographies, follow-up questions, post-observation conferencing. Processing role-plays"

In this study, 3rd generation Cultural-Historical Activity Theory (CHAT) is used as a research lens. CHAT as outlined by Engeström (1987), is embedded in the Vygotskyan theory of social constructivism, so the research lens is embedded in the theoretical framework of the study. Engeström (1999) suggests that the rationale for using the CHAT for research is in its historically rooted strength and that it is contemporarily used.

1.3.2 The conceptual framework that underpinned this study

Jansen (2008) defines a conceptual framework as the capacity within which a researcher can make sense of the data and decide on a conceptual framework in advance and it helps in providing a clear direction on how to use the data that is to be collected. Therefore, the conceptual framework for this study included various constructs which are namely, the NOS and the NOIK, conceptual change; Pedagogical Content Knowledge (PCK) using the PCK for the Science teaching model, incorporating IK in the CAPS Life Sciences themes, integrating the NOIK and the NOS, the three perspectives of the NOS and the NOIK, and lastly the SDL. All these constructs are unpacked in this thesis based on the theoretical framework, which is social constructivism.

1.3.2.1 Pedagogical Content Knowledge (PCK)

Initially, PCK was presented by an educational psychologist from America called Lee Shulman in 1986 and in 1987. The psychologist highlighted PCK as one of the categories of a teacher's knowledge base. Shulman (1987, p. 8) described PCK as the "blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented and adapted to the diverse interests and abilities of learners and presented for instruction". Many models have been developed to conceptualise PCK as the knowledge that the teachers need to effectively teach in schools, however, this study used a model called the PCK for Science teaching that was established by Magnusson et al. (1999).

1.3.2.2 Nature of Science and indigenous knowledge

Post 1994, the curriculum policies required the Life Sciences learners to attain the scientific knowledge and IK which would benefit them in resolving the real-world challenges in and out of the Life Sciences classroom (Ogunniyi, 2004) and the ability to show comprehension of the association between the Life Sciences and the environment (Ogunniyi, 2004). Assuming that the mainstream of the South African learners is African (81.4%), Indian (2.7%), Coloured (8.2%), Khoi and San (0.4%), as well as Caucasian (7.3%) (Statistics South Africa, 2022), school Science therefore needs to be taught in the two epistemologies where the nature of Western Science and the nature of IK of all the diverse groups are merged to create an equal education system for all. There is also a need to create connections between the two knowledge systems and in this way, the learners can negotiate new personal meanings (Koopman, 2018). According to Naidoo and Vithal (2014), the acknowledgement of the fundamental roles that are played by IK in the South African national curriculum for schools also supports the IK integration in the Life Sciences.

1.3.2.3 The three perspectives representing the relationship between the NOS and the NOIK

According to Zinyeka et al. (2016), there are three perspectives that represent the relationship between the two knowledge systems, and they are Science and IK. The first perspective is the inclusive perspective. This perspective considers IK as part of Science because of the shared tenets between the two systems (Zinyeka et al., 2016). The second perspective which is called the mutually exclusive perspective regards the two knowledge systems (Science and IK) as being independent from one another (Zinyeka, et al., 2016). The third perspective is called the overlapping perspective, where IK and Science are shown to share certain tenets, although they also have unique tenets (Zinyeka et al., 2016). The three perspectives are comprehensively deliberated upon in Chapter two of this study.

1.3.2.4 Self-directed learning

Knowles (1975, p. 19) defines SDL as “a process by which individuals take the initiative, with or without the assistance of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes”. The Science teachers should be lifelong learners. SDL can play a key role in enabling the Science teachers to identify their learning needs and taking initiatives to address them (Towle & Cottrel, 1996). As such, during the intervention (2x SLPs), the teachers were required to set learning goals for their own professional development as self-directed learners.

1.4 Aims of the research and the research questions

1.4.1 The aim of the study

The main aim of the research was:

To investigate the influence of an intervention on the public schools Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and the implications for their pedagogy and self-directed learning.

1.4.1.1 Secondary aims

a) To investigate the influence of an intervention on the Life Sciences teachers' perceptions of the NOS and the implications for their pedagogy pre- and post-intervention.
b) To investigate the influence of an intervention on the Life Sciences teachers' perceptions of the NOIK and the implications for their pedagogy pre- and post-intervention.
c) To determine the transfer of new knowledge and skills that occurs in the classroom post-intervention.
d) To determine how the Life Sciences teachers' perceptions of their own SDL abilities change during their participation in this research.

1.4.2 Primary research question

What is the influence of an intervention on the public schools Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and the implications for their pedagogy and self-directed learning?

1.4.2.1 Secondary research questions:

a) How do the Life Sciences teachers teaching in the urban, in semi-urban and in the rural based schools perceive the NOS, and how do these perceptions influence their pedagogy before and after the intervention?
b) How do the Life Sciences teachers teaching in the urban, in semi-urban and in the rural based schools perceive the NOIK, and how do these perceptions influence their pedagogy before and after the intervention?
c) What transfer of new knowledge and skills occur in the classroom after the intervention?
d) How did the Life Sciences teachers' perceptions of their own SDL change, during their participation in this research?

1.5 Research Methodology

This study adopted a Mixed Methods (MM) approach (Creswell & Garret, 2008), with the emphasis on seeking to determine the influence of an intervention on the Life Sciences teachers' perceptions of the NOS, the NOIK, and the implications for their pedagogy and SDL. The typology of the study is a partially mixed concurrent with dominant status or QUAL + quan, where most of the instruments that were used were qualitative (Creswell & Garrett, 2008). The involved quantitative component was only the use of a self-rating instrument to measure the individual teachers' perceptions of their own SDL abilities (Cheng et al., 2010).

1.5.1 Research paradigm

Morgan (2007) defines a paradigm as the organisations of views that have influence on how the researchers choose both the questions they study and the methods they use to study them. In the MM, Creswell and Plano Clark (2011) mention paradigms that include but are not limited to post positivism, constructivism, and interpretivism. The paradigm that befitted this study was pragmatism which was initially coined by Peirce (1839-1914), and it was further developed by Dewey (1859-1952) as well as by James (1842-1910).

1.5.2 Research Design

The research design that was underpinned in this study is a concurrent transformative design. The design enabled the researcher to interpret the gathered data concurrently, by making use of various and diverse data collection instruments (Creswell & Garrett, 2008). Furthermore, the design helped to provide the affordances in doing a study that offers improved comprehension of the research problem (Creswell & Garrett, 2008).

1.5.3 Sampling

The study was conducted in high schools from two circuits in the Limpopo Province's Capricorn North and South Districts. The rural, semi-urban, and urban settings of the two circuits are well-known. The two circuits were chosen for their convenience, owing to their accessibility and geographical proximity to the schools where the participants were located (Etikan et al., 2015). There were 42 Life Sciences teachers in these two circuits, however only 38 participated in the study. Of the total, 26 served as a control group, while the remaining12 Life Sciences teachers were sampled to form the experimental group.

1.5.4 Intervention

The intervention played out as follows:

The experimental group of the Life Sciences teachers that were involved in the study participated in an intervention consisting of two parts. In part one, the teachers attended a two-day SLP at the Landmark Protea Hotel in Polokwane. During this SLP, the teachers were engaged in various activities such as in Problem-Based Learning (PBL), and in cooperative teaching and learning approaches. They were engaged in laboratory work using the Kirby Bauer technique and in planning an investigation on the role of ethylene in seed germination. This SLP was expected to assist the teachers and their learners in developing a true sense of the NOS.

In part two of the intervention to expose the teachers to an authentic laboratory experience, they attended a two-day SLP at the African Centre for DNA Barcoding (ACDB), at the University of Johannesburg. During the workshop, the teachers were engaged in several activities such as in the Polymerase Chain Reaction (PCR) at the ACDB. Real scientists working in the centre through mentoring and facilitation scaffolded the teachers. In this regard, the teachers were exposed to working with real scientists in an authentic laboratory. This assisted the participating teachers to realise that they might not have a true sense of the tenets of the NOS, and they can consequently identify their own developmental needs in this regard.

1.5.5 Data Collection

In this MM study, both qualitative and quantitative data was collected.

The quantitative data was collected as follows:

- All 38 teachers completed the Self-Directed Learning Instrument (SDLI) (Cheng, et al., 2010) pre- and post-intervention.

The qualitative data was collected as follows:

- The experimental group (12) completed three open-ended questionnaires, namely the Views on the Nature of Science (VNOS-D+), the Views on the Nature of Indigenous Knowledge (VNOIK) and a Pedagogy of Science Teaching Test (POSTT LFSC) (Cobern et al., 2014) pre- and post-intervention. The rational for using these instruments to collect qualitative is deliberated in chapter three of this study.

- A total of six teachers from the experimental group's classroom practice were observed using the Reformed Teaching Observation Protocol (RTOP) instrument (Piburn et al., 2000) two months after the second SLP. The observations were followed up by individual semi-structured interviews with open-ended questions with the same six teachers immediately after the observations took place.

1.5.6 Data Analysis

The qualitative and quantitative data was analysed as follows:

- Qualitative data: Data was drawn from the VNOS-D+ and the VNOIK, and it was analysed using the In vivo coding of using Cronje's (2015) method and it classified the participants' responses either as "(a) No Classification (NC), or as (b) Uninformed Views (UV), or (c) Partially-Informed Views (PIV), and (d) as Informed Views (IV)".Similarly, the data that was drawn from the POSTT LFSC was also analysed using In vivo coding and it classified the participants' responses either as (a) Didactic Direct (DD), (b) Active Direct (AD), or as (c) Guided Inquiry (GI), or (d) Open Inquiry (OI) (Cobern et al., 2010). The data drawn from both the classroom observations and the interviews was transcribed and coded to identify the emerging themes.
- The data that was drawn from the SDLI was analysed using the 26th version of the Statistical Package for the Social Sciences (SPSS). An independent t-test was used to compare the SDL count between the experimental and the control groups' pre-intervention. Thereafter, the dependent t-tests were used to determine the difference between the pre, and the post-SDL counts in both the experimental and in the control groups.

1.6 Using CHAT as a research lens to interpret data

The Cultural-Historical Activity Theory (CHAT) can offer a rigorous meta-theoretical framework as a research lens for providing a view of the Life Sciences teachers' lived experiences (Mentz & De Beer, 2019). The CHAT was used as a research lens on a personal, institutional, and interpersonal level using the unit of analysis called an activity system which could for example be a classroom (Mentz & De Beer, 2019; Rogoff, 1995). An activity system in the CHAT constitutes the subject, the object, the tools, the community, the division of labour and the rules.

1.7 Validity and reliability (trustworthiness and credibility)

According to McMillan and Schumacher (2010), validity entails the correct interpretation and the use of information that is collected through measurement, and it is required to assess the degree of validity that is present based on the available data and to address the validity of the study. The researcher deliberated on the aspects of the data and theory triangulation, the validation of data collection instruments, member checking and the prolonged engagement at the study site.

Frambach et al. (2013) define reliability as the degree to which the findings are consistent if the study is duplicated, or the degree to which the findings are consistent in relation to the environment in which they were created. In the context of this study, the researcher considered aspects such as data saturation, iterative data collection and iterative data analysis, which were all comprehensively discussed in Chapter 3 of this study.

1.8 Ethical considerations

According to McMillan and Schumacher (2010), the research ethics are concerned with what is ethically right and wrong while working with people or while obtaining archive material. Concerning this section, the researcher deliberated on aspects such as ensuring good ethics, which include but are not limited to voluntary informed consent, and building understanding among the participants which are discussed comprehensively in Chapter 3 of this study.

1.9 Overview of the chapters

The primary research question that was addressed in this study is: What is the influence of an intervention on the Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and the implications for their pedagogy and self-directed learning? The findings and results to this research question are presented in a coherent presentation in the following chapters.

- Chapter 1 provides an overview of the delineations of the study in terms of the conceptual and the theoretical frameworks, the research methodology, as well as the contributions of the study.
- In Chapter 2, I present a comprehensive literature review emanating from the theoretical framework as well as the conceptual framework that underpins this research.
- Chapter 3 highlights some aspects of the research methodology that were utilised to answer the research questions and other various aspects of methodology.
- Chapter 4 presents an analysis of both the qualitative and the quantitative data. The emerging themes are critically discussed through the theoretical and the conceptual frameworks.
- Chapter 5 presents the major findings, the limitations, the recommendations, the contribution of this study, and conclusion.

1.10 Summary of Chapter One

This chapter presented an introduction of the study and the problem statement. A preview of the theoretical and the conceptual frameworks to be deliberated on in Chapter 2, the aims of the research as well as the research questions are included in this chapter. Furthermore, I provided a preview of the research methodology and its aspects which are fully deliberated on in Chapter 3 of this study. The chapter also included the validity and reliability of the study, the ethical considerations and the overview of the chapters that follow.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The purpose of this study was to investigate the influence of an intervention on Life Sciences teachers teaching in urban, semi-urban, and rural settings, as well as their perceptions of the Nature of Science (NOS), the Nature of Indigenous Knowledge (NOIK), and the impact on their pedagogy and Self-Directed Learning (SDL). The argument is based on previous discussions concerning Life Sciences teachers' naive beliefs about NOS and their difficulties in incorporating IK into their courses (Govender & Zulu, 2017; Gwebu, 2015). Secondly, the common importance of including IK in the Life Sciences curriculum material is codified and envisaged in Specific aim number three in the Life Sciences Curriculum and Assessment Policy Statement (CAPS) document (South Africa [SA], 2011). Specific Aim 3 states that "…to understanding the applications of Life Sciences in everyday life, as well as understanding the history of scientific discoveries and the relationship between indigenous knowledge and Science" (SA, 2011, p. 13).

This chapter seeks to present a comprehensive literature analysis emanating from the theoretical framework as well as from the conceptual frameworks that underpin this research. One of the most significant parts of the research process is the theoretical framework (Grant & Osanloo, 2014), because it is a higher degree of conceptual organisation at which a full-fledged theory would be called to explain a specific occurrence (Jansen, 2008). This "higher level of conceptual organisation" is something which the conceptual frameworks fall short of because it is comprised of "one or more concepts linked together" (Reddy, 2018, p. 25). The theoretical framework of this study is comprised of social constructivism (Adams, 2006; Ernest, 1995), and Vygotsky's (1978) idea of the Zone of Proximal Development (ZPD), which inspired Warford's (2011) idea of the Zone of Proximal Teacher Development (ZPTD). The Cultural-Historical Activity Theory (CHAT), which was initially proposed by Vygotsky (1978), and advanced by Engeström (1987) as well as Leontiev (1978) functions as a research lens for this study.

Kivunja (2018) sees a conceptual framework as a logical direction and as the connection of everything that constitutes one’s complete research project's underlying thought, structures, strategies, methods, and execution. Miles and Huberman (1994) define a conceptual framework as a written product that describes the important topics to be studied, such as the key aspects or the ideas to be examined and the assumed links between them. In the case of this study, the event refers to the Life Sciences teachers’ experiences of a professional development intervention about their perceptions of the NOS, the NOIK and the implications they might have for their pedagogy and for self-directed learning. The following and other concepts are of significance to this study, conceptual change, self-directed learning, pedagogical content knowledge, the NOS, the NOIK and other aspects such as engaging pedagogies and the three epistemological perspectives.

2.2 Theoretical framework

Amineh and Asl (2015) contend that the teachers should adopt constructivism as their pedagogical philosophy to consider what the learners already know, and they should let them apply what they have learned. The same authors describe constructivism as “the way that the learners can make sense of the material and also how the materials can be taught effectively" (p. 9). Constructivism maintains that the optimal way to acquire knowledge is through a process of reflection and mental construction (Mascolo & Fischer, 2005). One of the pioneers of the constructivism theory was Jean Piaget. He believed that the constructivist theory suggests that the individuals generate knowledge by interacting with their experiences and ideas, and that the individual is at the core of the process of acquiring as well as creating new knowledge (Brau, 2020). Vygotsky goes further than Piaget and strongly believes that learning is a social activity between different individuals. Lev Vygotsky can therefore be regarded as the father of social constructivism.

Sommers-Flanagan (2015) alludes to the fact that both constructivism and social constructionism view knowledge as being fundamentally subjective, but the former focuses on the individuals' biological and cognitive processes, whereas the latter places knowledge in the context of social interaction (Sommers-Flanagan, 2015). Although both Lev Vygotsky and Jean Piaget were constructivists, their perspectives on how learning happens differed (Reddy, 2018). Vygotsky saw learning as a social endeavour in which social interaction is seen as important to learning and the involved participants internalise what they learn socially for learning to occur. Piaget, on the other hand, saw learning as a personal endeavour that begins with an individual and is defined by how one's brain develops physically, which eventually leads to social development (Rogoff, 1990).

It is important to first unpack the basics of constructivism from Piaget's perspective after which the social constructivism from a Vygotskian view, which is the different generations of the CHAT and the ZPTD will be described.

2.2.1 Constructivism from Piaget's Perspective

According to Sjøberg (2010), constructivism is used in a variety of contexts, and it has many distinct meanings. However, Piaget (1971) viewed constructivism as the idea of knowledge acquisition which posits that reality is determined by an individual's conceptions or perceptions. Constructivism is different to behaviourism, because the behaviourists suggest that knowledge is self-sufficient, and it occurs outside of the people. Jean Piaget who is frequently referred to as the father of cognitive constructivism was frequently concerned with the nature of knowledge, the genesis of knowledge and how knowledge develops. Thus, the emphasis was on cognitive functionality. This is highlighted by Piaget (1971) arguing that understanding and creating, in other words, forming frameworks by structuring reality, are crucial processes of the mind.

Piaget's constructivism theory gives a panoramic view of what children's interests are and if they may be realised at various stages of development from infancy to maturity (Ackermann, 2001). According to Piaget (1978), for learning to occur, there must be an intense construction of meaning in which the children are confronted with a circumstance that calls their thinking capacities into question. In this approach, an imbalance is created, and then a solution to correct that imbalance must be discovered by absorbing what the kid already knows and what the child is unfamiliar with (Amineh & Asl, 2015). The growth of the children becomes a deciding element in their learning; in other words, the biological development of the children's brains and other body components determines the methods in which learning will occur (Reddy, 2018). Piaget was more concerned with people's cognitive growth in line with each of their biological developmental phases than with external influences (Ginsburg, 1985).

As highlighted above that in contrast to the theory of behaviourism, constructivism emphasises on one’s cognitive development. The behaviourists argue that there is no relationship between mental activity as well as learning and they see learning as a behaviour that can be both observed and measured. They also argue that for learning to take place, the environment plays an important role (Faryadi, 2007; McDonald et al., 2005). In other words, the behaviourists believe that a person's mind plays no role in helping a person to attain any form of knowledge (Leahey, 2000). The major triggers of the behaviour originate from the exterior environment rather than from the internal environment (Faryadi, 2007). Contrary to that, Piaget suggested that mental change is a creation of the mind, and it is attained using observation and experimentation. The author also argued that people attain knowledge using active participation in their learning (Remmel, 2008; Weegar & Pacis, 2012). Thus, the people develop their understanding through individual experiences (Remmel, 2008) and learning is something that an individual does, rather than something that is imposed on an individual (Sjøberg, 2010). This learning takes place because of three fundamental processes which are assimilation, accommodation, and equilibrium (Piaget, 1964).

Piaget believed that the children learn objectively in a continuous trajectory until they can construct a figurative portrayal of reality (O'Loughlin, 1992). Contrary to Piaget, Vygotsky believed that a child constructs knowledge through (Vygotsky, 1962) social communication, interpretation, and comprehension (Adams, 2007). As highlighted by Hoppers (2005) that IK moves from one person to the next orally, this suggests that IK is a construct that is learned socially. Furthermore, the Cooperative Learning (CL) approaches and the BPL depend more heavily on social interaction than on individualism. Consequently, Piaget's constructivism becomes irrelevant to this study, as it tends to disregard the role that is played by social interaction in the learning process as suggested by Vygotsky.

2.2.2 Social constructivism in Vygotsky's View

As highlighted earlier, Vygotsky's social constructivism thrives on working in small groups, as Vygotsky believed that development occurs primarily in social and cultural settings, then it is internalised individually through reflection (Vygotsky, 1978). An individual develops through the interactions with their peers and the other members of their circle, where there is stimulation and facilitation to allow for a conducive environment for development (Davis et al., 2017; Kalina & Powell, 2009). As such, an individual's development relies heavily on the interactive discussions where the individual that is learning is at the centre of the discussion (Davis et al., 2017; Prawat, 1992). In other words, according to Vygotsky, personal development is driven by social interaction, which is what the Life Sciences teachers who participated in this study undertook through the intervention (2x short learning programmes [SLPs]). They interacted with one another under the facilitation and the motivation of the SLPs facilitators.

To understand the deliberation that was made above, I used the theory of social constructivism's core constructs that was developed by Vygotsky (Davis et al., 2017; Vygotsky, 1978). The first construct is called the ZPD, and it inspired Warford's ZPTD, which played a significant role during the intervention. The second construct is called the activity theory which Engeström (1987) later called the CHAT, and it was also used as a lens during the interpretation of the collected data. Firstly, I will deliberate on the ZPD followed by the CHAT to promote coherence.

2.2.2.1 Zone of proximal development

To help make sense of what the ZPD entails, Vygotsky the ZPD is defined as "the distance between the actual developmental level and the level of potential development. The actual developmental level…that is the level of development of a child's mental functions that has been established because of certain already completed developmental cycles" (Vygotsky, 1978, p. 85). The potential developmental level… that "is determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). In other words, the ZPD is the difference between what a learner has previously mastered and what the learner can achieve with educational assistance (Podolskiy, 2012). According to Raymond (2014), Vygotsky developed the notion of the ZPD to represent the spectrum of learning that the learners may attain when engaged in meaningful activities with competent individuals. Furthermore, Raymond (2014) claims that Vygotsky (1978) argued that the ZPD is a better predictor of what a learner can acquire than the knowledge acquisition exams.

The idea of the ZPD heuristically contributed significantly as a general intuition regarding the learning and development of human beings and contrary to animals, human learning presupposes a specific social nature and a process by which the children/learners become more involved in the intellectual lives of the others around them (Podolskiy, 2014; Vygotsky, 1978). In other words, the learners can emulate those around them. Furthermore, Vygotsky (1978) highlighted that through the ZPD, the learner emulates and follows the teacher's example, and they gradually develop the ability to carry out certain duties without assistance. For the learner to carry out these tasks without assistance, Vygotsky (1978) suggested one aspect and implied the other that operates within the distance between the actual development level and the level of potential development. These aspects are the More Knowledgeable Other (MKO) and the scaffolding deliberated below.

According to Abtahi et al. (2017), Vygotsky and his followers developed the concept to explain that a child learns in the ZPD and only in the presence of those who are more knowledgeable (MKO) than the child. McLeod (2018) defined the MKO as someone (teacher and peer) who has an enhanced comprehension or a much higher level of ability than that of a learner, concerning a specific task, process, or concept. The author further highlights that central to the MKOs is the higher level of knowledge of the topic that is being learned. Acknowledging the role that is played by the MKOs, Rogoff (1990) highlighted that the learners' cognitive growth is only thought to occur in the context of social support and the connection with others, as well as the presence of the socio historically evolved instruments that mediate intellectual activity.

The term scaffolding was first proposed by Wood, Bruner, and Ross in 1976 and it was used to describe the flexible role of the tutors, the teachers, and the parents in the children's/learners' learning processes (Malik, 2017). Puntambekar and Hubscher (2005) argue that when scaffolding was initially introduced, it was not directly associated with the ZPD. Growth (2017) defines scaffolding as establishing the safe environments in which the children may expand their present abilities and knowledge. According to Denhere et al. (2012), the term scaffolding is used to describe the social and the interactive character of teaching and learning in the ZPD. Kumar (2016) posits that the process of scaffolding is central to the development of a child's communication skills. In other words, the teacher and the other peers who are more advanced play a supporting role and they provide a structure in the interest of the learner's development to get to the next level (Raymond, 2000; Usanov Fayzulla Burkhanovich, 2020; Van Der Stuyf, 2002). Furthermore, a significant facet of scaffolding is its temporary nature, which as the learner's abilities progress due to scaffolding, the role that is played by the MKO decreases due to eventual withdrawal (Hammad Al-Rashidi et al., 2023; Van Der Stuyf, 2002). Figure 2.1 will be used to explain what each statement of each layer represents.

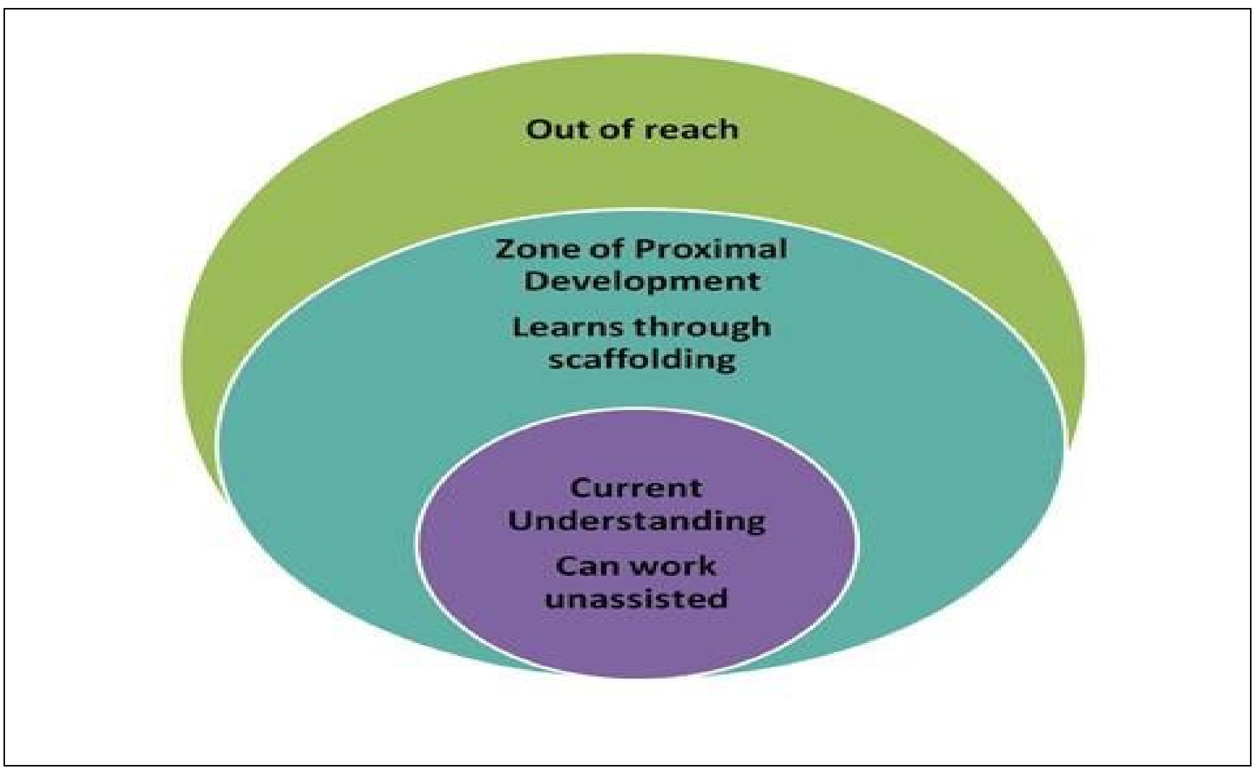

Figure 2.1: The diagrammatic representation of Vygotsky's ZPD (Erica Paquez Dias, 2018) [post]

Figure 2.1 reflects the three layers which are namely, ‘can work unassisted’, ‘learns through scaffolding-within the ZPD’ and ‘out of reach’ respectively. The first layer proposes that the learner can complete the activity without assistance, and they have grasped the skill set that is required to do so, as such they do not require the help of an expert (Cherry, 2019).

The second layer represents the level where the learner can achieve the goals that are set with the assistance of the teacher or of a more informed peer, which is within the learner’s ‘ZPD’. For the learner to move from the level of 'learns through scaffolding-within the ZPD' to the potential level, as highlighted earlier, the two aspects need to be present, and these aspects are the MKO and scaffolding. The MKOs represent the teacher or the more competent peer who is responsible for the initiation of scaffolding within the ZPD. In other words, at this level, the MKOs initiate scaffolding to guide the learner in reaching the potential level.

McLeod (2019) suggests that in scaffolding, the MKO or the teacher/more competent peer provides the activities to provide support to the learner as guided through the ZPD. Secondly, Denhere et al. (2013) posit that during scaffolding the teacher models the anticipated learning tasks, and then progressively moves accountability to the participating learner. Thirdly, Vygotsky (1978) suggested that the teacher uses the CL exercises where the less capable participating learners can develop with guidance from more skilled peers within the confines of the ZPD (Denhere et al., 2013). Hence, Rogoff (1990) postulates that scaffolding infers that the MKO's dynamic posture to the scaffolding of the learners' rising abilities and errors can serve as a signal to the teacher to elevate the scaffolding. In other words, the teacher/more competent peer plays a significant role in guiding the learner, by designing activities for the learner, cooperating with, and guiding the learner and by probing the activities' complexities depending on the learner's performance.

The third layer, which is 'out of reach' suggests that the level is outside of the learner's ZPD. In other words, the activities that are outside of the learner's ZPD are those whose degree of difficulty is beyond the learners' capability and perhaps a grade above the learners' current grade, even with the assistance of the MKO's (Cherry, 2019).

Fourthly, due to the nature of this study and the participants or the people assumed to be the 'learners', as explained at the beginning of this chapter, this study used the adapted version of the ZPD that is intended for teacher development called the ZPTD that was proposed by Warford (2011). Similarly, Warford (2011, p. 253) defines the ZPTD as "the distance between what a teaching candidate can do on their own without assistance and a proximal level they might attain through strategically mediated assistance from more capable others (i.e., methods teacher or supervisor)". In the context of this study, the ZPTD refers to the gap between what the Life Sciences teachers have already mastered and what they could potentially achieve with educational support (scaffolding) such as the guidance/facilitation and the activities provided during the intervention. In other words, the ZPTD is the gap between the Life Sciences teachers' initial perceptions of the NOS, the NOIK and the implication of their pedagogy as well as the SDL before the intervention, and their perceptions after they have received the educational support during the intervention by the facilitators. That is to say, the Life Sciences teachers, as the learners in this instance, their 'knowledge level' is assumed to be within '*learns through scaffolding'* (see Figure 2.1). Therefore, it can be deduced that Warford proposed that the ZPTD is like the ZPD only as the focus of development is on the teachers. More deliberations on Warford's proposed stages of the ZPTD and how they relate to this study are made below.

2.2.2.2 Warford's zone of proximal teacher development stages underpins the research study

In this section, I will attempt to discuss the four stages as proposed by Warford and show how each stage was contextualised to this study. Firstly, I will present Table 2.1 which provides a brief insight on how this study addressed each stage based on Warford's work and made deliberations thereafter.

Table 2.1: Warford's zone of proximal teacher development that underpins the research study [Author's own work based on Warford work (2011, p. 254)]

ZPTD Stages	Discussion of the stage	Activities in the interventions (2x SLPs)	Role of the MKOs or facilitators
1. Self-assistance	Determining the teachers' prior knowledge, the perceptions of the NOS, the NOIK, and the teaching experience.	Questionnaires and reflective discussions to determine the views and the perceptions of the teachers.	Mediate
2. Expert - other assistance	Scaffolding and mentoring by peers and facilitators. Teachers construct new knowledge in social settings together.	Leading questions and follow-up reflective discussions, laboratory work (two days) on various experiments where the teachers are assisted by the laboratory scientists at the DNA barcoding centrum, as well as a two-day short learning programme on campus (two days).	Scaffolding and monitoring
3. Internalisation (automatisation)	Teachers reflect on the new knowledge and skills as well as incorporate the elements of it in their teaching philosophies.	Reflections. Developing an evidence-based portfolio, with reflections, individual interviews and discussion.	Monitoring Facilitating reflective discussions
4. Recursion (De-automatisation)	Theory into practice. Teachers implement new knowledge and skills in practice/ transfer to the classroom.	Classroom observations, using the Reformed Teaching Observation Protocol (RTOP) instrument. Post-observation interviews.	Monitoring Facilitating reflective discussions

1. Self- assistance

Warford calls this stage the reflection stage, where the teacher reflects on the previous experiences and the traditions (Fani & Ghaemi, 2011), owing to the weight of previous learning experiences the teachers bring to their classrooms (Warford, 2011). In the context of this study, to fulfil this stage, the participating teachers were requested to complete two open-ended questionnaires that were intended to determine their perceptions of two knowledge systems (the NOS and the NOIK). The participating teachers were further requested to complete an itemised multiple-choice questionnaire whose answers helped to determine the teachers' pedagogical orientation (POSTT LFSC) and a close-ended Likert scale questionnaire (SDLI) that was intended to indicate the participating teachers' perceptions of their SDL abilities.

Lastly, Warford (2011) highlights that even at the self-assistance stage, mediation is still provided by the facilitators, but the emphasis at this level is on laying the groundwork by encouraging the introspection on one's own experiences and implicit beliefs on pedagogy. To ensure swift mediation, the participating teachers were invited to a venue in Polokwane where the first leg of the intervention took place. The venue was set up to create an environment that was suitable to execute the activities and that would help to jog the participating teachers' memories for proper reflection of their prior experiences. Hence, Warford (2011); as well as Fani and Ghaemi (2011) suggest that the stimuli used to encourage this reflection must anticipate the analytical foci, the formal concepts, and the concepts that the participating teachers will be exposed to in the curriculum.

2. Expert other assistance

Warford calls this stage a ZPTD stage that is aided by the teachers, which is an intervention-focused stage (or expert other assistance) (2011) where the scaffolding and the mentoring by the peers and the facilitators take place. At this stage, there are more rigorous interventions as the teachers are confronted with a surplus of the scientific language of academic discourse (Warford, 2011). As such, they should be addressed in the experiential concepts that materialise from their learning autobiographies and the investigation of the contemporary classroom realities (Fani &

Ghaemi, 2011; Warford, 2011). Hereafter, there were leading questions and follow-up reflective discussions. These activities took place during the first two days of the SLP in Polokwane, where the participants were exposed to a variety of Life Sciences related activities using cooperative teaching and learning methods such as the Jigsaw and De Bono's six thinking hats. The teachers were further involved in the PBL such as the laboratory work activity where they were engaged in the Kirby-Bauer technique for testing the antimicrobial substances that are present in the medicinal plant (De Beer, 2019) and in an experiment of fermentation. They were also involved in other PBL activities, which were focussed on the post-harvest physiology of cut flowers and in redressing the cultural challenges using puppetry.

In addition, Warford advised that the facilitator should carefully consider developing additional interventions to assist the applicant in closing the gap between the real and the ideal (2011). In response to Warford's advice, the participants were further engaged in a second two-day SLP at the ADCB at the UJ. The teachers were engaged in DNA analysis laboratory-work, where they had the opportunity to act as 'real scientists' working in a real laboratory. Warford (2011) further highlights that the candidates must see live and recorded examples of innovative teaching approaches in action in actual classrooms, as well as in field-based demonstrations. Therefore, during laboratory work, the participants were guided on laboratory protocol, by collecting plant materials, DNA extraction, and PCR set-ups and by doing experimentations amongst other things. All the activities done during laboratory work were intended to allow the participants to act like scientists and promote independence amongst them. According to Warford (2011), these types of activities are an additional benefit of eliminating the perception of separation between the classroom and the field.

After the intervention (SLPs), the participating teachers were requested to complete the two open-ended questionnaires, which were intended to determine their perceptions of the two knowledge systems (the NOS and the NOIK). The teachers were also requested to complete an itemised multiple-choice questionnaire (POSTT LFSC) that sought to determine their pedagogical orientation. Lastly, the teachers were requested to complete a self-rating Likert scale closed-ended questionnaire that sought to determine their perceptions regarding their SDL abilities post-intervention.

3. Internalisation (automatization)

According to Warford (2011), from the expert side, the ZPTD moves toward internalisation and the repetition of the teaching notions that the participating teachers have learned. In other words, the Life Sciences teachers were expected to reflect on the new knowledge as well as the skills and incorporate these elements in their teaching philosophies. Furthermore, the teachers were expected to use journaling, reflections, developing an evidence-based portfolio, with reflections, individual interviews, and discussions. In an attempt to assist the teachers to accomplish the aforementioned, the teachers were advised to develop action research to help to track their pedagogical growth. Therefore, as internalisation progresses, the candidates demonstrate their ability to apply the pedagogical information and the abilities that were advocated for by their program (Warford, 2011).

4. Recursion (De- automatization)

According to Warford (2011), the ZPTD recurrence stage is properly defined as the 'theory in practice' stage, as the candidates prepare to tackle the dichotomy of the theory and the practice with vigour. In the context of this study, the teachers were expected to put the theory into practice, where they implemented the new knowledge and skills in practice/ transfer to the classroom.

At this stage, it is assumed that the intervention was effective and the participating teachers' perceptions, scientific knowledge, pedagogical orientations, and the SDL had improved. Hence, the teachers were expected to practice their pedagogy using "innovative tools and techniques learned in the programme"/intervention, "this means letting go of more traditional variants that are much more known" (Warford, 2011, p. 256).

Even though it was intended that the teachers would put into practice what is learned during the intervention, Al-Musawi (2001), Anderson (2002), as well as

Borko and Mayfield (1995) argue that it is common knowledge globally that the teachers are frequently quick to abandon the way they perceive the real world of teaching. The teachers' aims to hold on to what they learned is not always successful as Warford (2011) cautions that as eager as the candidates are to discredit the old ways, they tend to struggle in their efforts to embrace a more liberating, discovery-based pedagogy. Therefore, to establish if the participating teachers were able to discard these old ways from their pedagogies, classroom observations were made on these teachers using the RTOP. After the classroom observations were done, the teachers who participated in the classroom observations were interviewed using the semi-structured interviews. These interviews were carried out to determine if the participating teachers were aware of their improved pedagogies or the lack thereof. Figure 2.2 provides a contextualised picture on how the ZPTD was carried out in this study. Thereafter it is followed by the deliberation on the different generations of the CHAT, which served as a lens to interpret the findings thereof.

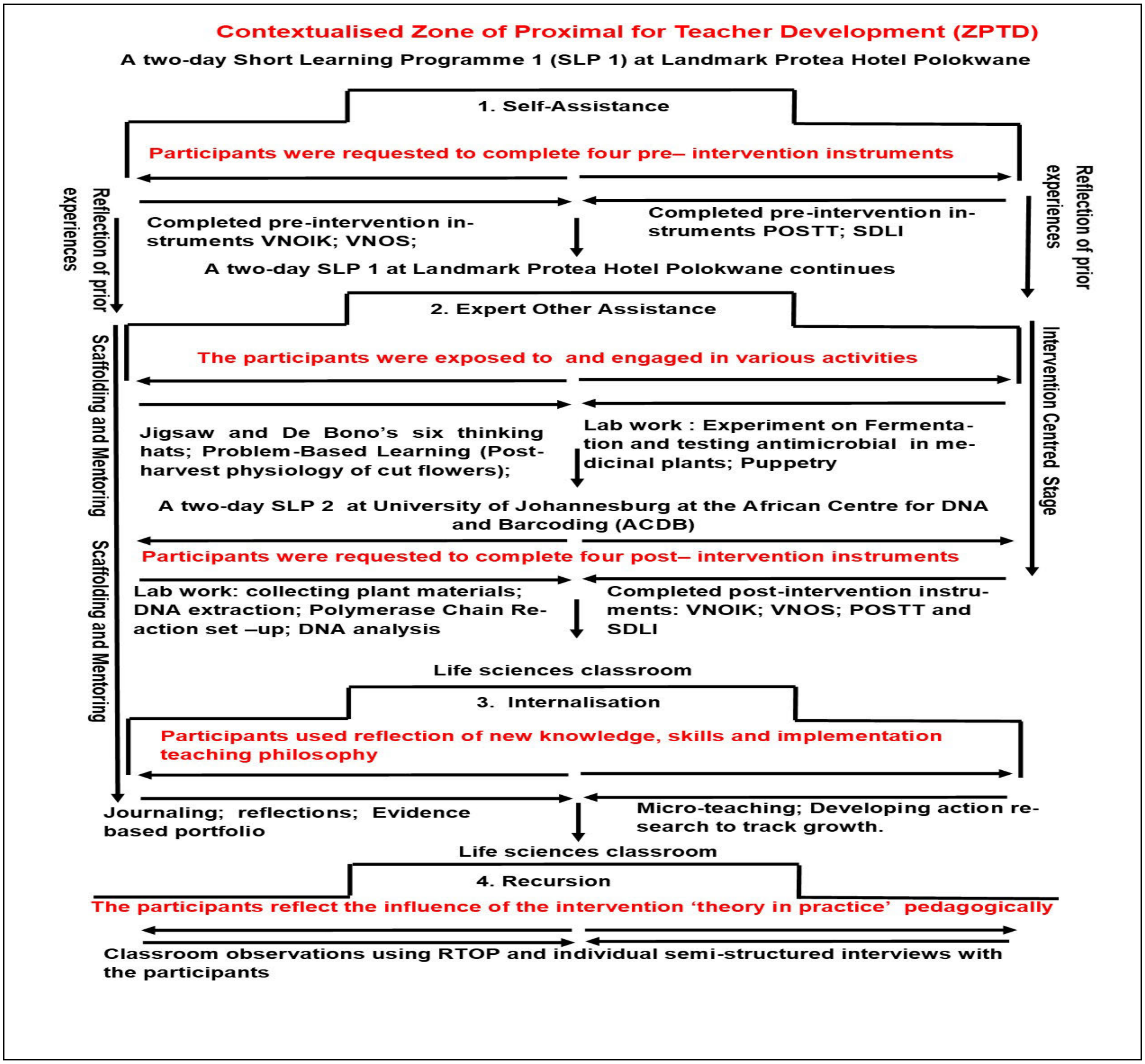

Figure 2.2: A contextualised view of how the ZPTD was carried out [Author's own construct, based on the insights of Warford (2011)]

Figure 2.2 reflects all the activities that were carried out during the intervention. A two-day SLP that took place at the Landmark Protea Hotel in Polokwane played a significant role of Stage 1 (Self-assistance) and Stage 2 (Expert-other assistance) of the ZPTD. The two-day SLP was then followed by another two-day SLP, which took place at the ACDB at the University of Johannesburg. This SLP played a significant role on Stage 2 of the ZPTD, which is a stage that is intervention intensive.

2.2.2.3 *Different generations of the Cultural Historical Activity Theory which is utilised as research lens*

Vygotsky's ZPD is said to be responsible for the establishment of the CHAT, which gave birth to the model of tool-mediation in which the 'tools' become central to human development (Vygotsky, 1978). According to Vygotsky (1978), the CHAT is an interdisciplinary theory for human growth and scholarship which can be used as a lens to draw out and provide an enhanced observation of human activity.

Through the CHAT, human activities may be characterised and analysed by considering motivational dynamics, societal structures, and laws, as well as activity modes (Nickerson, 2022). According to Engeström and Sannino (2021), the evolution of the activity theory may be seen as a series of four generations theorising research, with each generation developing its own primary unit of analysis. However, in this study, the emphasis of the deliberations will be from the first generation up to the third generation, because the focus of this study is on the third generation for reasons that will be deliberated on later. The three generations that were deliberated on will reflect the evolution of the CHAT, with three key aspects from its first generation to a plethora of key aspects in the third generation. Therefore, my deliberation starts with the first generation.

- **First Generation Cultural Historical Activity Theory**

Vygotsky (1978) is responsible for the budding of the first-generation activity theory and the "understanding of object-oriented action by cultural tools and signs emerged" (p. 40). Baguma et al. (2019), as well as Hashim and Jones (2007) define the activity theory as a theoretical framework that is used to analyse and understand human interaction by using their tools and artefacts. The activity theory is predominantly applicable in circumstances that have an important historical and cultural context and where the participants, their commitments and their tools are in a process of prompt and constant change (Cliff et al., 2022; Hashim & Jones, 2007). Figure 2.3 represents Vygotsky’s activity theory.

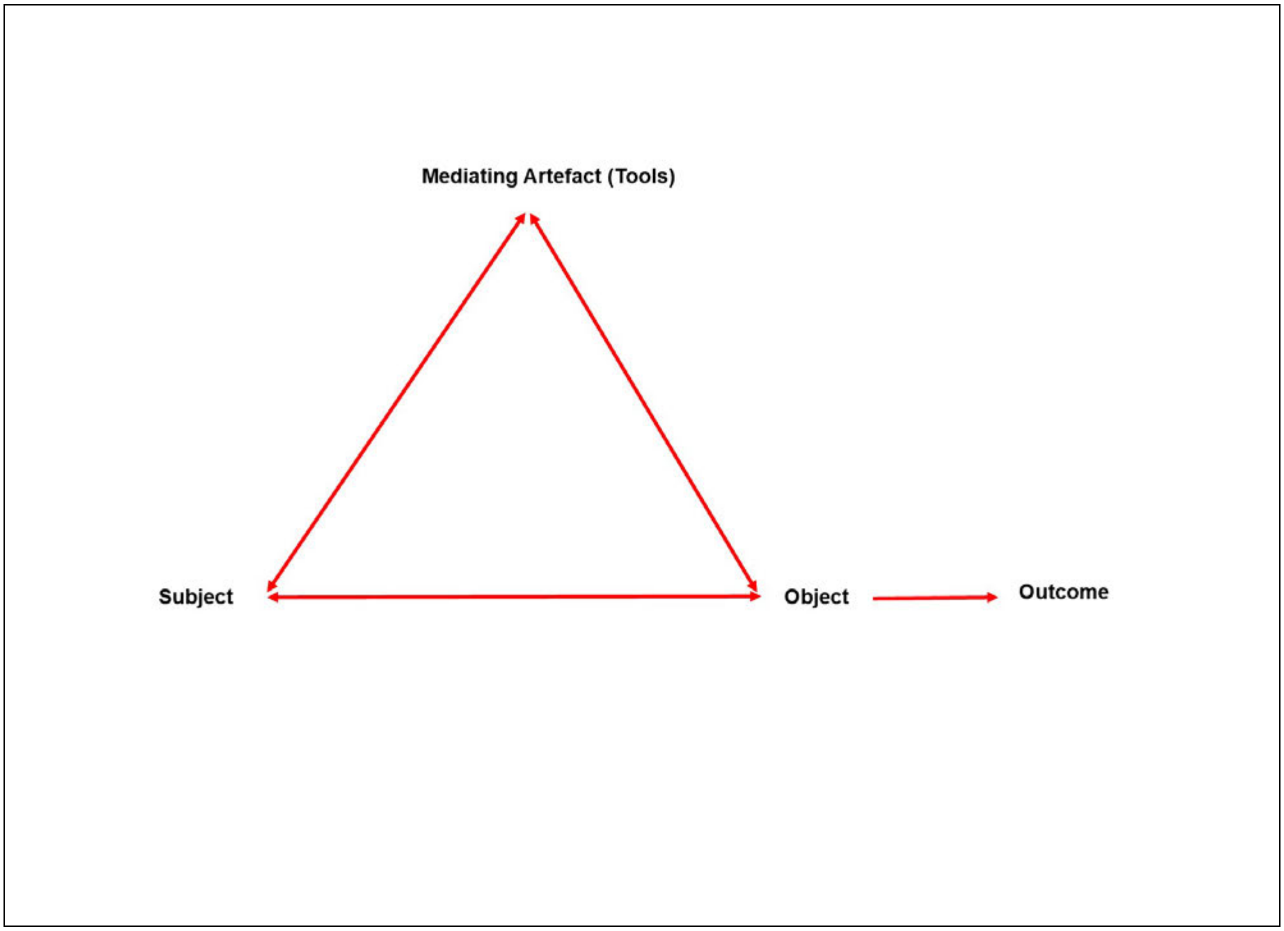

Figure 2.3: First-generation activity theory (based on Vygotsky, 1978 in Flavin; 2012, p. 2)

Vygotsky presented human intentionality and a varying factor between animal and human activity by suggesting that human activity is focused and is continuously done through an array of actions that are mediated by tools and artefacts (Klen-Alves, 2021). Vygotsky's (1978) activity theory (see Figure 2.3) is comprised of three elements namely, the **"subject"** which is referred to as 'the doer' who acts towards the **"object"** which is referred to as 'the deed' by using **"tools"** or facilitated objects. In other words, Vygotsky's activity theory reflected how an individual learns as he or she interacts with the world using mediating artefacts (tools). Furthermore, the person's reaction is mediated by the cultural environment, which is moulded by the individual's activity; hence, there is interdependence between society and the individual (Vygotsky, 1978; Hirsh, 2016). Henceforth, Vygotsky identified the cultural artefacts that are acquired via the social contact as the agents of learning and experience (Hirsh, 2016).

In this way, it is worth noting, that the human actions do not occur directly between the subject and the object, but they are mediated through the employment of (broadly defined) tools (Flavin, 2012). As opposed to Piaget, Vygotsky viewed learning and development on two planes, first as a social construct and second as individual internalisation on a personal plane. Furthermore, Vygotsky viewed the cultural development of the mind through the lens of how the artefacts including language, shape the mind from the broader culture and they are utilised by a person to solve problems that also emanate from the broader culture (Blunden, 2015).

However, Blunden (2015) points out that Vygotsky did not investigate how these variables, as well as the person's motivation, contribute to the social context problem. As a result, Vygotsky's first-generation activity system does not consider a person's motivation and social contribution (Reddy, 2018). According to Blunden (2015), the creation of Leontiev's version of second-generation activity theory (1978, 1981) was an attempt to explore the person's motive, which is fundamental to producing the circumstances, and preceded a later version with more aspects by Engeström (1987, 2000). To further elaborate, I will start by discussing Leontiev's version of the second generation and later discusses Engeström's version of the second-generation activity theory.

- **Leontiev's version of the second-generation Activity Theory**

The second-generation activity theory (Figure 2.4) expanded on what Vygotsky had begun, but the emphasis was on the idea of hierarchical levels in which humans' function, providing an answer to the question of an individual's contribution to society (Hardman, 2007; Reddy, 2018). Leontiev, Vygotsky's student, enlarged Vygotsky's version of activity theory (figure 2.4), and his hierarchical model of functioning generated an activity that relied on the object (Leontiev, 1981). According to Klen-Alves (2021), the activity is separated into three levels in Leontiev's model (see Figure 2.4). Klen-Alves (2021) further states that the first level, **"activity,"** is concerned with the aim or the motive of human action; the second, **"action,"** is concerned with the objective of the action; and the third, **"operation,"** is concerned with the conditions in which the goal is achieved.

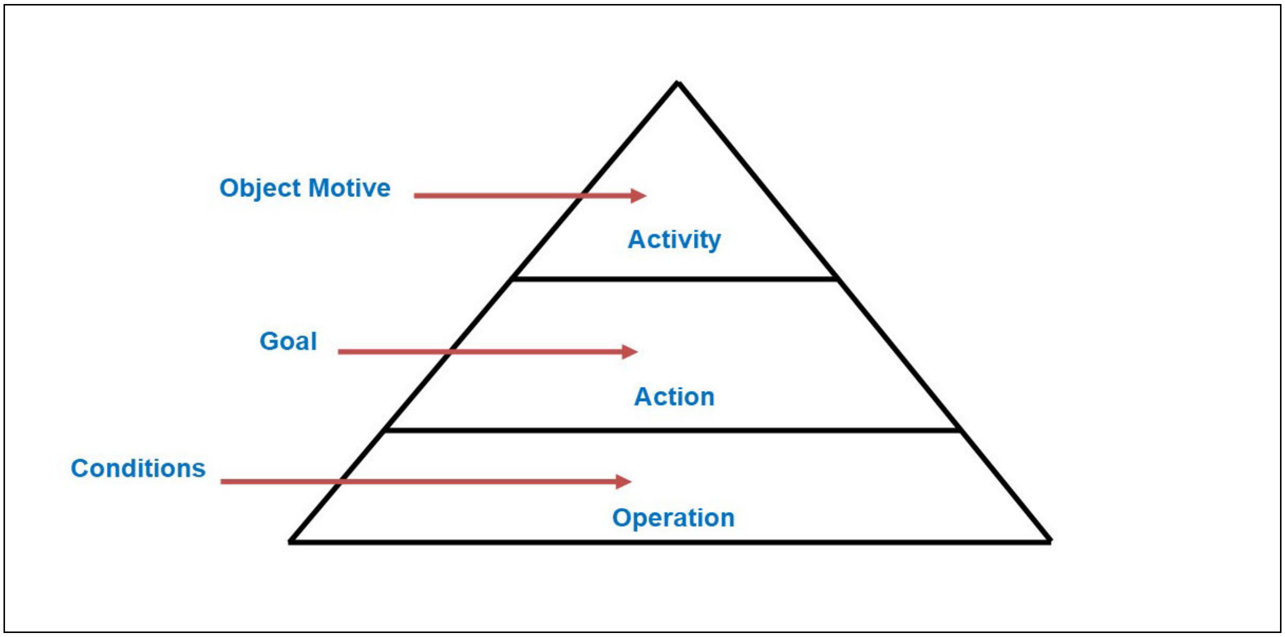

Figure 2.4: Leontiev’s second-generation activity theory (Leontiev, 1981; Hardman, 2007, p. 3)

Leontiev (1981) was able to explain how emotions, motivations, and creativity are social activities through his work on the second-generation activity theory (see figure 2.4), which was hard to prove using Vygotsky's theory (Hardman, 2007). Leontiev was able to illustrate all of this because the individual focused acts in his activity model are put inside the social framework of an activity (Hardman, 2007). This supplements Vygotsky's first model of individual action by demonstrating how the individual acts are goal-oriented, whereas the group activities are object-oriented (Hardman, 2007). According to Klen-Alves (2021), the principle is that the participation in many activities, whether it is biological or not, determines existence. That is, knowing the human ability to pursue numerous things at once and change the object of activities into operations, which reflects on the human’s potential to develop as they actively participate in various activities on a regular basis (Klen-Alves, 2021).

It is worth noting that, while the second-generation activity theory addressed and improved on Vygotsky's first-generation activity theory, Leontiev's theory emphasises the distinction between individual actions and collaborative activities, with a strong emphasis on collaborative activities (Engeström, 1987). Although Leontiev's theory may account for the hierarchical levels in which humans work, it falls short of adequately locating human activities in their context (Hardman, 2007). Furthermore, the theory does not illustrate how individual acts are turned to common objects through interactions among community members (Hardman, 2007). Thus, Engeström (1987) attempted to address Leontiev's shortcomings in his version of the second-generation activity theory by introducing another version of the second-generation activity theory that is elaborated below.

- **Engeström's version of the second-generation Activity Theory (CHAT)**

Engeström's version of the second generation (see Figure 2.5) reflects the interconnection among the subject, the community, and the object-oriented action to achieve an object (Klen-Alves, 2021).

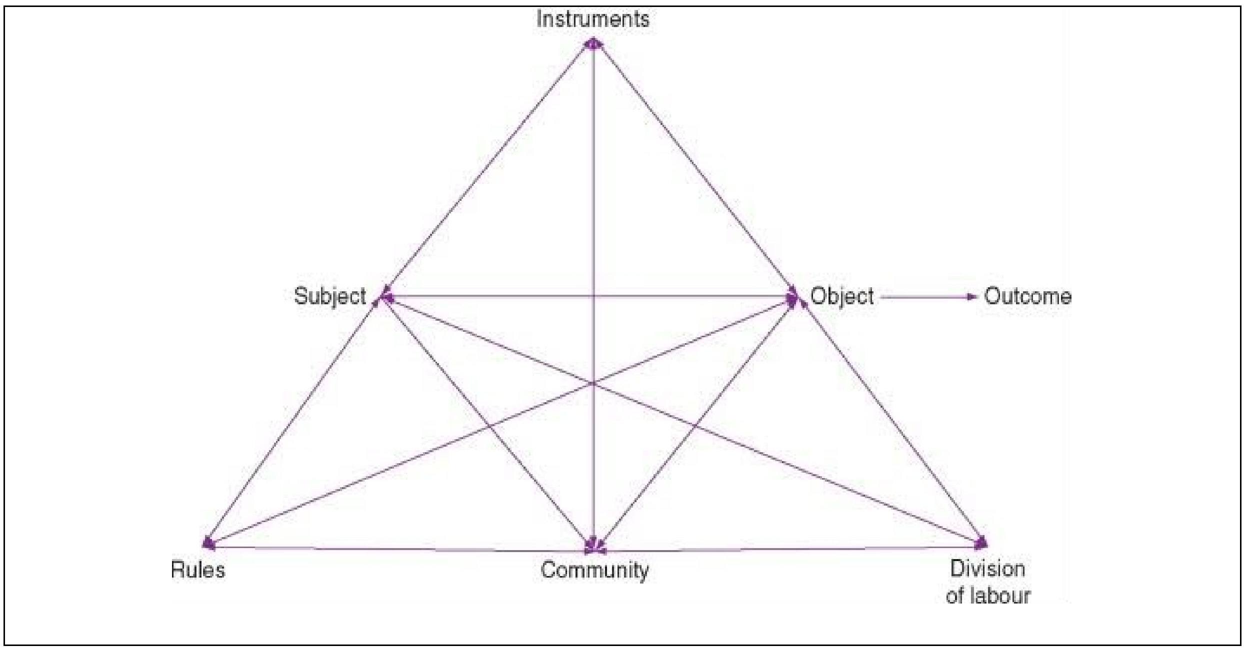

Figure 2.5: Engeström's second-generation activity theory (CHAT) (Engeström, 1989)

This version of second-generation activity system (figure 2.5) was coined as the Cultural-Historical Activity Theory (CHAT) by Engeström (1987). It is now viewed as an activity system which is defined as "any ongoing, object-directed, historically conditioned, dialectically structured, tool-mediated human interaction" (Russell, 1997, p. 510). Engeström's CHAT differs from the first two by its distinct two-way arrows in many directions thereby reflecting the six elements which are namely, tools; subject; object;

rules; community; and the division of labour (Engeström, 1987). Each element within the activity system plays a significant role.

Firstly, Engeström (1987) defines the "**tools"** as the physical items and the systems of symbols such as the language or the mathematics that the people use to accomplish the activity. Furthermore, Andriani et al. (2022) suggests that the **tools** are the media that are used to facilitate and support the processes of carrying out the activity, as well as to disclose the social and the material resources that are important in the activity.

Secondly, Engeström (1987) defines the **"subject"** as the person or an entity that is engaged in an activity who is the focus of a study on an activity system. Hence, Klen-Alves (2021) highlights that each CHAT element is related to the **subject**, that is affecting and is being affected by each element. Furthermore, it is the responsibility of the community members to carry out their tasks successfully for the subject to attain the desired results (Andriani et al., 2022).

Third, the **"object"** is the point of view utilised to focus on the action, and it symbolises the issue area. Engeström expanded the idea by completely contextualising and focusing it on the nature of communal activity (Hardman, 2007). Furthermore, he shifted the object's comprehension to make it more than merely a motivation (Kaptelinin, 2005). As a result, an activity system is initiated on its object as well as on stimulating the activity so that it may transform the object into an outcome (Issroff & Scanlon, 2002).

Fourthly, the **"rules"** in the system represent the laws, codes, conventions, customs, and the agreements that the people adhere to while engaging in the activity (Engeström, 1987). As for the **rules,** Issroff and Scanlon (2002) suggest that they were created to direct and manage the activities and without them, there might be a conflict of interest that may hinder the accomplishment of the outcome. According to Jonassen and Rohrer-Murphy (1999), these rules are intended to preclude such impediments and preserve order and these rules are formed by an organisation with the power to reach an agreement.

Fifthly, the **“community”** represents the people and the groups whose expertise, passions, stakes, and objectives affect action; and the **“division of labour”** in the activity system represents the way the tasks in the activity are distributed among the participants (Vahed et al., 2018). Consequently, Andriani et al. (2022) suggests that, in the community, the activity subjects work cooperatively to accomplish the given objectives. In other words, the community promotes and allows for cooperation using a variety of **divisions of labour** to reach the given objectives (Nussbaumer, 2012).

In addition, the word **“activity”** in the CH**A**T, is described as what the people do as a team. Its position is modified by the culture and history. In the context of this study, the participating teachers were engaged in activities that required them to work together as a team. The activities that included but were not limited to carrying the experiment of fermentation, the Kirby-Bauer technique, and puppetry were done throughout the intervention. Hence, Jaustse et al. (2016) emphasise the significance of the CL in facilitating IK because it respects its syntactical character.

Lastly, the word **“theory” in the** CHA**T** is viewed as a conceptual framework that helps in the comprehension and in the description of the human activity (Foot, 2014). In the context of this study, this is the aspect that is used as a lens to promote the comprehension and the description of the participants’ activities using their cultural background that was developed as they worked together using the CL.

The third-generation activity system is a combination of both the first-generation and the second-generation activity theory models that were developed by both Vygotsky and his student Leontiev (Reddy, 2018).

- **Third-generation Cultural Historical Activity System**

As highlighted at the beginning of this section, this study used a third-generation activity theory approach because the study juxtaposed more than one activity system. Hence, the third-generation CHAT is based on the effort of Engeström, and it shows that different activity systems with common outcomes can interrelate with one another (Engeström, 2000). In other words, Engeström (2009) makes it clear that a researcher ought to continuously take two interdependent activity systems as the minimal unit of analysis. I therefore juxtaposed two activity systems by focusing precisely on the 'objects' of the two activity systems. Klen-Alves (2021) reflected on over two decades of Engeström's work on how he consolidated the advances to the popularisation of the name CHAT as a theoretical perspective and technique of analysis. Furthermore, the third generation and the sociocultural understanding of the activity theory as individually-collectively created, historical and cultural constraints.

Furthermore, these constraints are seen when Life Sciences teachers move through their teaching and how they connect with their seniors and other stakeholders in the school, which have a significant influence on the aims that were meant for their teaching effort (Foot, 2014). According to Blackler (1992), the CHAT's emphasis on the contradictions, tensions, and breakdowns within an activity system makes it a helpful instrument for social, institutional, and organisational reform, which is unavoidable as part of a functioning activity system. According to Kuuti (1996), activities are unit-like knots that form part of a network of command chains in which they impact and are influenced by other activities and other changes in their context. External variables, according to Kuuti (1996), may affect certain features of the activities, resulting in a disequilibrium between the activities; nonetheless, the activity system uses the disequilibrium to reflect mismatches within the components of the activity system. As tensions manifest as "problems, ruptures, and clashes," or, in Veresov's (2004) terminology, "dramatical collisions" (p. 34), the activity system sees these difficulties as a source of progress, because activities are always working with tensions (Kuuti, 1996).

Internal tensions in an activity system operate as destabilising forces, causing it to expand, and they aid in identifying chances for innovation and novel ways of rebuilding and ratifying the activity (Engeström, 1987; Foot, 2014). The tensions serve as the activity system's power and richness, and they work as a magnifying glass that people in the system may use to reflect on the activity system's direction and grasp its changing characteristics (Beatty & Feldman, 2009; Foot, 2014). The tensions are not a reflection of failure, nor are they impediments to defeat; rather, they should be viewed and understood as illuminating hinges that might be a new doorway to understanding (Beatty & Feldman, 2009; Foot, 2001; Foot, 2014).

According to Mentz and De Beer (2019, p. 56), "the third-generation CHAT is a practical research tool that can assist me in interpreting data embedded in specific cultural and historical context”. Furthermore, the CHAT has become a well-known research lens that boasts about its flexibility that it can even be used on three levels namely on the; personal, the institutional and the interpersonal levels (Mentz & De Beer, 2017; Rogoff, 1995). In the context of this study, I used all the three levels of which more deliberations are made in Chapter 4 of this study. For this section I attempted to shed light on how each level was contextualised and made to relate to this study. Firstly, the deliberations were made on a personal level, followed by the institutional level and then the conclusion was made with the interpersonal level.

- ***The personal level***

According to Mentz and De Beer (2019), the personal level (see Figure 2.6) allows the activity system to place focus on the individual who serves as the subject in the activity system. The two activity systems reflect the comparison of the Life Sciences teachers during the intervention (A) and in the post-intervention classroom (B). Activity System A reflects the teachers during the intervention (comprising of two SLPs), while Activity System B represents the same teachers in their implementation after the intervention had occurred, to determine whether there is evidence of reformed teaching practices in the post-intervention classroom.

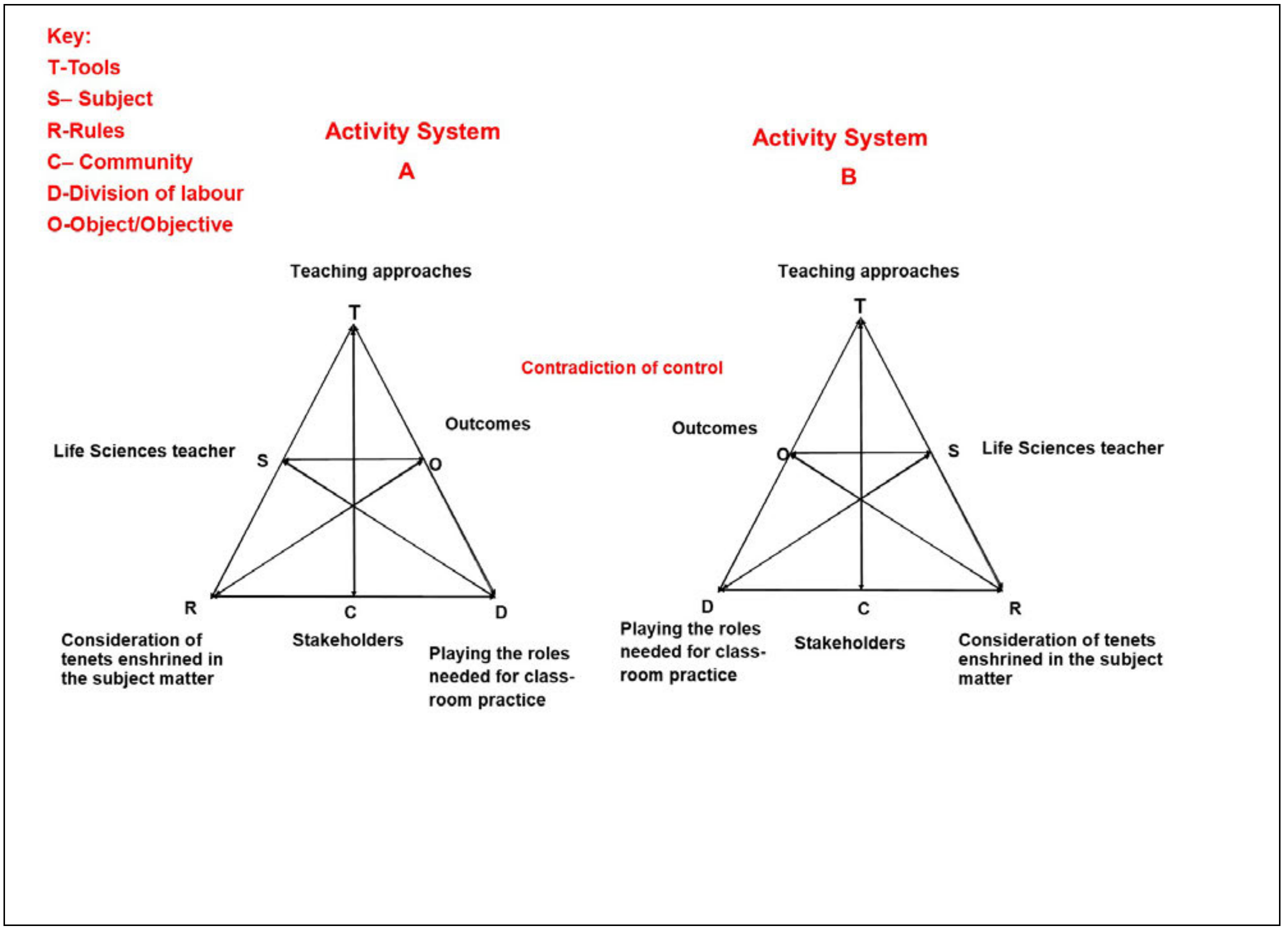

Figure 2.6: Third-generation CHAT reflecting the personal level

Source: Author's own drawing based on Engeström (1989). (In Chapter 4 the data will be analysed in terms of Activity system B. This merely serves as an illustration of how CHAT will be utilised on a personal level)

Figure 2.6 reflects the two activity Systems A and B. The elements of both Activity System A and B are presented as follows: the tools used are teaching approaches which may differ depending on the outcome of the intervention; the subject as highlighted is represented by the Life Sciences teacher. The rules are represented by the consideration of tenets enshrined in the subject matter. The community is represented by the stakeholders, these includes learners, parents, curriculum advisor and the school principal. The division of labour is represented by the teacher playing the roles needed for classroom practice and these roles will differ depending on the outcome of the intervention. Lastly, the object is represented by the outcomes that vary depending on the influence of the intervention.

In Chapter 4, I will use CHAT as research lens to interrogate my data. This figure serves merely as an example, and I was guided by literature, which shows that there is often a "wash-out effect", where teachers go back to pre-intervention transmission-mode pedagogical choices.

- ***The institutional level***

According to Mentz and De Beer (2019), the institutional level (see Figure 2.7) places focus on the phenomenon that serves as the subject in the system. In other words, the 'subject' is not represented by a person but by "an entity or a construct" (p. 59). The two activity systems (C & D) reflect a comparison of the two knowledge systems which are namely the NOS and the NOIK that had to be considered in preparation of the activities to be undertaken during the intervention. NOS and NOIK therefore represent the 'subject' in the respective activity systems.

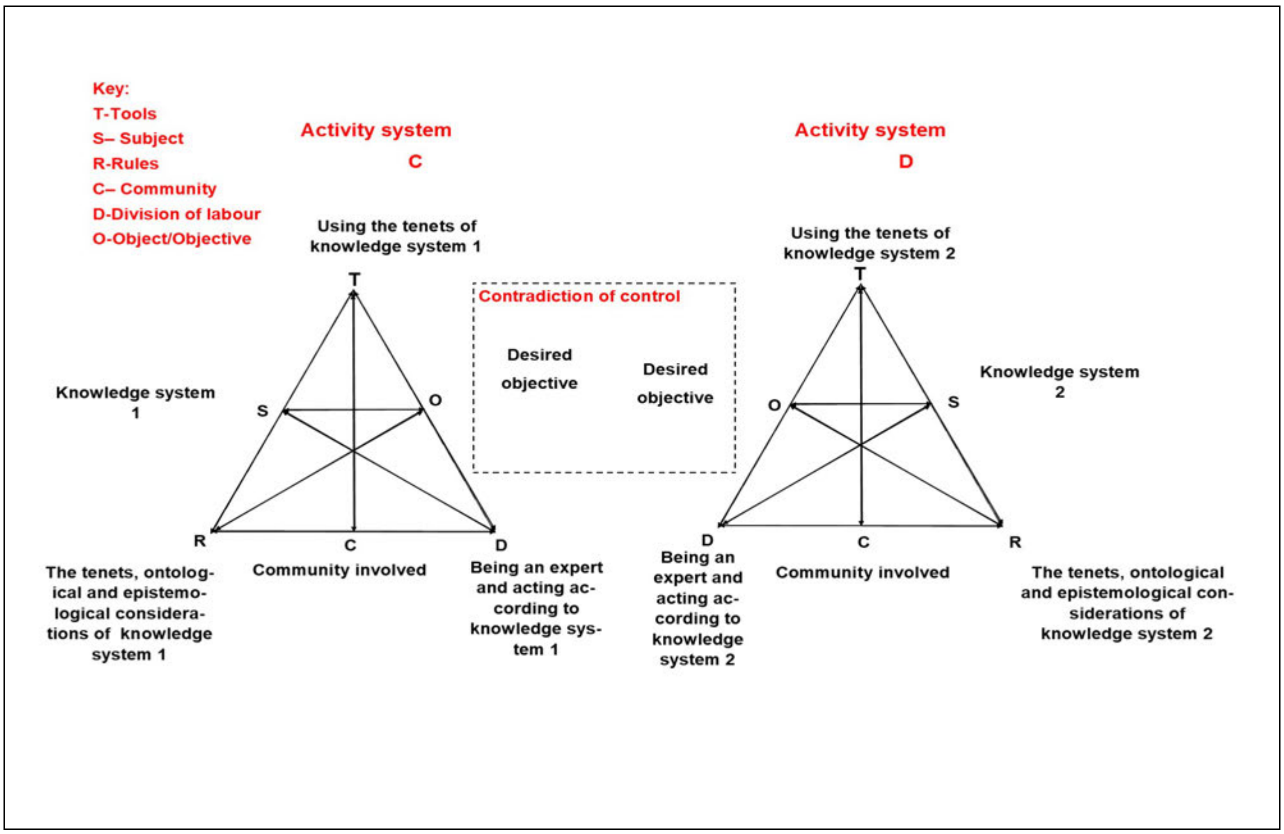

Figure 2.7: Third-generation CHAT reflecting the institutional level

Source: Author's own drawing based on Engeström (1989). (In Chapter 4 the data will be analysed in terms of Activity system D. This merely serves as an illustration of how CHAT will be utilised on an institutional level)

Figure 2.7 reflects the two-activity systems C and D. The elements of both Activity System C and D represent knowledge systems as entities that are comprised of different tools that are represented using their tenets. The subject in both activity systems is represented by knowledge system 1 and knowledge system 2, while the rules are represented by the tenets, ontological and epistemological considerations of both knowledge systems. The community in both Activity Systems are represented the community or stakeholders that are usually the custodians of these knowledge systems. The division of labour for both Activity Systems is represented by expertise and respect for the tenets enshrined in each knowledge system. Lastly, the object from each Activity System is represented by the outcomes that are likely to differ, because these are two knowledge systems, and these differences will play a significant in contradiction of control. Using CHAT on such an institutional level, provides clarity on how such epistemological border-crossing could take place in the classroom, and how a pedagogy could be used which aligns the tenets of respectively natural sciences and indigenous knowledge systems.

- ***The interpersonal level***

According to Mentz and De Beer (2019), the interpersonal level allows for more than one subject to be present. The three activity systems (E, F & G) reflect a comparison of the three Life Sciences teachers who teach in three different schools from different sociocultural and environmental settings. The Activity System E comprises of the ‘subject’ who is a Life Sciences teacher who teaches at a school that is based in a rural setting. Activity System F reflects the Life Sciences teacher who teaches in a school that is based in a semi-urban setting, while Activity System G represents the Life Sciences teacher who teaches at a school that is based in an urban setting. The socioeconomic and the sociocultural factors played a significant role in how the tensions may emerge from Figure 2.8. This is a unique contribution of this study, as CHAT has not been used on interpersonal level to investigate the role of context in obtaining the object of the activity (in this case, teacher professional development).

Key: T-Tools; S– Subject; R-Rules; C– Community; D-Division of labour.

O-Object/Objective

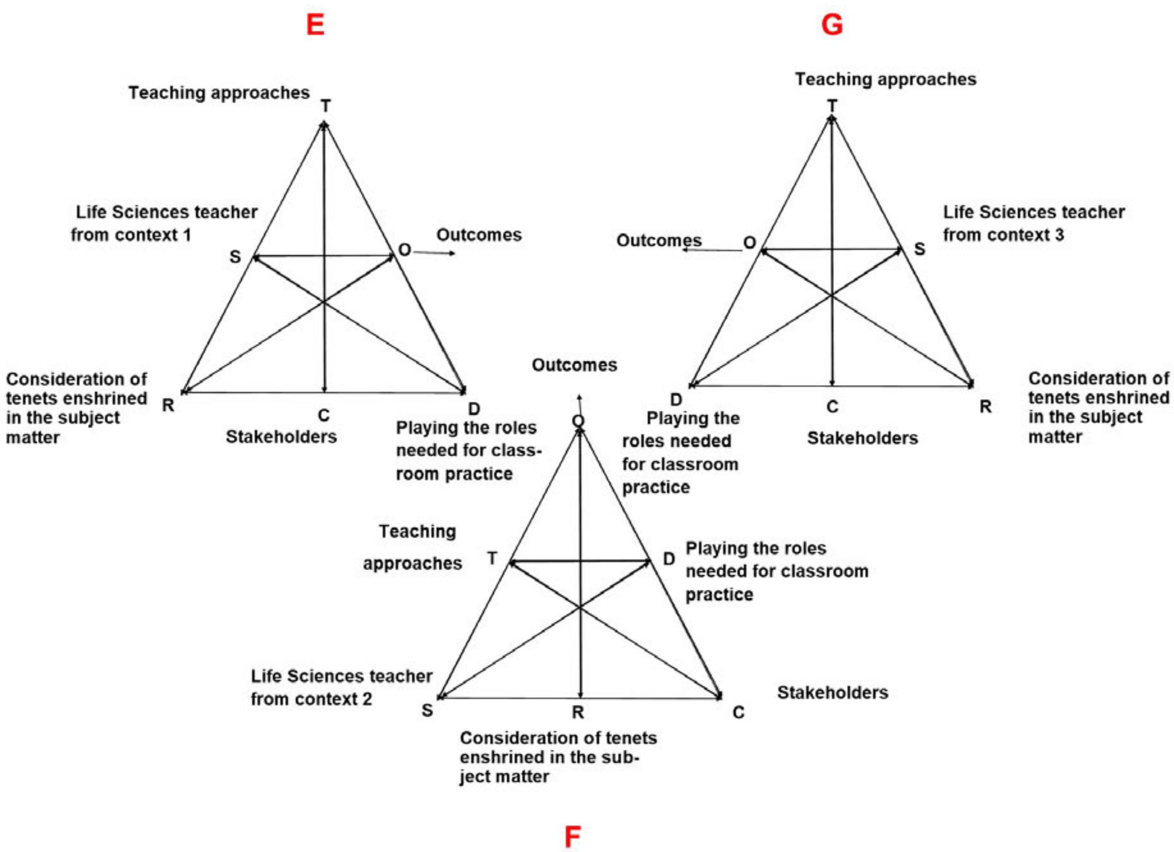

Figure 2.8: Third-generation CHAT reflecting the interpersonal level

Source: Author's own drawing based on Engeström (1989). (In Chapter 4, I will utilise CHAT on interpersonal level to analyse the data. This illustration merely serves as an example of how CHAT will be used in Chapter 4)

The elements from Activity Systems E, F and G are comprised of the subjects that are represented by the Life Sciences teachers from three different contexts or settings. The teachers from the three settings/contexts subscribe to the same rules, which is the consideration of tenets enshrined in the subject matter. The communities from the three Activity Systems are represented by stakeholders that include learners, parents, principals and curriculum advisors. Furthermore, due to different contexts/settings, culturally and racially the learners, and parents may differ from one context/setting to another. The divisions of labour from the three Activity Systems are represented by the teachers' ability to play their roles needed for classroom practice. The tools are represented by the teaching approaches and because these are different teachers from different settings who may be teaching culturally and racially different learners, their teaching approaches may differ. Lastly, the objects from the three Activity Systems are presented by the different outcomes that may vary depending on the context/setting which may allow for contradiction of control. Lastly, more deliberations regarding the juxtaposition of the three CHAT levels are made in Chapter 4 of this study.

The section below fully focuses on the conceptual framework underpinning this study where multiple concepts such as the NOS, the NOIK, the conceptual change, the PCK, as well as the SDL are deliberated on at length.

2.2.3 Conceptual Framework

2.2.4 Introduction

A conceptual framework, according to Kivunja (2018), is the overarching, logical direction, and association of everything that forms the underlying concepts, structures, plans, and processes, as well as the implementation of a whole research effort. This sort of framework is based on principles from many theories and findings from earlier research that serve as a guide for the investigation (Green, 2014). Numerous topics in this research investigate the influence of the intervention on the perceptions of the NOS and the NOIK among Life Sciences teachers, as well as the implications for their teaching and the SDL. To have informed perspectives and to be able to incorporate IK in their Life Sciences classroom, these teachers had to attend the two SLPs that comprised the intervention. The intervention was supposed to improve the teachers' perspectives, SDL, and pedagogical orientation based on all the considerations used in developing the activities that were done during the SLPs. As a result, increased teaching practise and Life Sciences learners' knowledge and performance content.

CHAT remains central as a lens that is used to interpret the findings of this study. As suggested earlier in this chapter, the concepts that were deliberated upon include SDL; conceptual change, PCK; conceptualising the NOS; and conceptualising the NOIK.

Furthermore, I looked at the three epistemological perspectives of the NOS and IK as well as the teacher professional programmes in IK and in the NOS. I will begin the deliberation of these concepts with the presentation of SDL.

2.2.5 Self-directed learning

According to Kapur (2019), SDL has existed since antiquity and aided the personal growth of Greek scholars. SDL refers to an education (learning) process that a person does freely, employing a variety of approaches and tactics that are necessary and important for carrying out education efficiently and successfully (Gibbon, 2002; Kapur, 2019). To define SDL, Kapur (2019) highlights independence and the capacity to design techniques and strategies to aid in the achievement of the defined goals. SDL, on the other hand, is defined by Mahlaba (2020) and Oddi (1987) as education for oneself, autonomous learning, and self-sufficient learning, which is learning started by oneself. The latter writers (Mahlaba, 2020) centred their views on self-sufficiency and independence as reflected by the individual who is embarking on SDL.

In addition, Knowles (1975, p. 19) defines SDL as a "process in which learners take initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes". The outstanding component in this definition is the initiative that is taken by an individual, with or without the help of others which has relevance to this study (Kõiv & Saks, 2023). In the context of this study, the Life Sciences teachers needed to attend the SLPs to improve their SDL, which means they needed the assistance of the SLPs, and they also assisted each other as peers. In terms of the ZPD, it referred to the MKOs.

During the SLPs, participating teachers were encouraged to set goals for their professional growth. They had to do a self-assessment when creating their objectives, which helped them think about their weaknesses within the information and skills they already had before the SLPs. The teachers also needed to create measurements that would help them break down their learning and track their professional development. The teachers were required to employ tools to assist them achieve their objectives.

Some of the tools contained in textbooks include instructional methodologies such as cooperative teaching and learning and project-based learning. These tools were important in promoting a smooth process since they acted as a vehicle for attaining the teachers' defined goals. There are several features that emphasise SDL, are addressed below.

2.2.5.1 Self-directed learning and self-directed learners

In the context of this research, the 'learner' or 'learners' in the term self-directed learner(s)' refer to the participants in this study, i.e., the Life Sciences teachers. SDL, according to Knowles (1975), is oriented toward learner-centeredness. This is because the learner is the one who creates the activities and the learning environment so that they (Gandomkar & Sandars, 2018; Saks & Leijen, 2014) embrace the general approach to learning. Mahlaba (2020) backs up this argument by emphasising that learners who participate in the process always have control over their learning. According to Mahlaba (2020), the explanation for the assertion stems from the assumption that SDL has a lot more to do with the learners' learning and the environment in which the learning takes place. As a result, Leyens et al. (2008) contend that SDL fosters the development of learners' abilities, capacities, and willingness to learn. This is because of the appropriate possibilities for skill development that they provide to another person, the development of skills in an individual who is active in SDL is greatly dependent on another person's self-directedness (Mahlaba, 2020). Furthermore, SDL necessitates a mind-set change and purification of teaching and learning from teacher-directed to learner-directed learning (Mahlaba, 2020; Pearce, 2019).

Written communications are typically employed in learning to connect with teachers and others who monitor this sort of education, which has been shown to be successful and extremely useful, particularly for those pursuing it at a distance (Kapur, 2019). It is worth emphasising that the individuals or teachers participating in the learning usually feel content when they participate in this type of learning because of the authority they have in carrying out the duties that are envisioned in the learning. As a result, people can individually benefit from meaningful learning (Karatas, 2022).

In SDL, there must be a self-directed aptitude, and each learner's experiences must be viewed as a significant source of the learner's learning, which would be utilised while doing activities in their life (Kapur, 2019). Thus, several internal reasons such as curiosity, the desire to accomplish more, and self-esteem motivate learners (Self-Directed Learning [SDL], 2006). These aspects assist learners in being aware of and deliberating on the concept of being ready to learn by providing a favourable learning environment and by implementing what they have learned since they must periodically examine what they have learned (Kapur, 2019).

In addition, learners must be aware of the importance of establishing an interest and the will that is supported by the desire to receive help and guidance (Boyer et al., 2014). As learners engage in a variety of activities, the assistance and supervision will help them develop and improve their performance. Learners in this style of learning have the freedom to create and implement their own learning strategies and approaches (Boyer et al., 2014). If they are certain that the approaches are within the parameters of the grade levels, subjects, and academic goals, motivation will remain the cornerstone. In SDL, there must be a self-directed aptitude, and each learner's experiences must be considered (Karatas, 2022).

Learners are frequently urged to be highly motivated in their SDL, particularly in terms of their objectives and desire to accomplish them, and to employ a variety of sources to supplement their understanding (Gibbons, 2002). Finally, Kapur (2019) contends that motivation motivates learners to devote time and resources in their SDL. As a result, individuals can complete their jobs and activities in a well-organized and systematic manner, allowing them to achieve their goals.

2.2.5.2 Self-efficacy in self-directed learning

Kapur (2019) suggests that in SDL, there should be self-efficacy, which is perceived as the views the individual has concerning their qualifications and capabilities to attain success in the application of the variety of given tasks and activities. According to Kapur (2019) and Karatas (2022), the development of self-efficacy in SDL helps learners overcome anxiety and a sense of vulnerability while raising awareness about what is required of them. As a result, learners are more prepared and resourceful while doing tasks and activities that contribute to the success and fulfilment of the desired objectives (Gibbons, 2002). Self-efficacy influences how an individual approaches a problem and difficulties in defining objectives, which derives from the individual's capacity to observe how others act and respond to their obstacles and difficulties (Kapur, 2019; Karatas, 2022).

2.2.5.3 The significance of self-directed learning amongst the learners

According to Knowles (1975), self-directed learners are affected by a range of internal incentives and rewards such as curiosity, self-esteem, the fulfilment of discovery, and personal pleasure following an achievement. This encourages learners to take more initiative in working more independently to reach their goals by entirely depending on themselves (Jossberger et al., 2018). Self-directed learners, according to Mahlaba (2020), must be honest with themselves. Thus, during exams, pupils must not engage in unethical behaviour, such as cheating, because they are expected to learn rather than simply pass the assessment activity.

The SDL is more slanted to PBL and allows learners to take initiative in their learning, hence, self-directed learners are exceptionally competent in problem-solving and are self-sufficient (Blumberg, 2000; Jossberger et al., 2018; Mahlaba, 2020). Learners have a probability of having long-term memory recall of what they learn, according to Gureckis and Markant (2012) and Knowles (1975). This is because their learning is typically problem-based (Gureckis & Markant, 2012), which gives them an edge.

In addition, S SDL demands learners who are willing to change in situations when adaptation to fresh developments is required. According to Mahlaba (2020), when COVID-19 arrived unexpectedly, self-directed learners were able to evaluate their limitations in remote learning and rapidly made improvements to try to improve and normalise it. Mahlaba (2020) adds that self-directed learners adapt to change and seek resources to aid in their adaption of remote learning to get more learning experience of what is expected of them. This allows them to plan their activities around the submission deadlines specified by their teachers, while still striving for quality in their work and ensuring that they are learning meaningfully (Mahlaba, 2020). In the framework of this study, participating teachers were supposed to create portfolios in which they performed laboratory work using PBL. As a result, they were given submission dates for the portfolios they were required to produce. It was expected that the Life Sciences teachers would work hard and seek to provide high-quality work while also learning meaningfully.

It is worth emphasising that teachers who value SDL in their classrooms are more likely to have learners who are responsible and capable of managing their own learning, while they take on the role of supporting and mentoring the learners as they learn (Knowles, 1975; Mahlaba, 2020). These self-directed teachers would be able to help learners identify their purpose or learning passion and both push and motivate them to pursue it. It is worth emphasising that teachers who value SDL in their classrooms are more likely to have learners who are responsible and capable of managing their own learning, while they take on the role of supporting and mentoring the learners as they learn (Knowles, 1975; Mahlaba, 2020). These self-directed teachers would be able to help learners identify their purpose or learning passion and both push and motivate them to pursue it.

2.2.5.4 Problem-based learning in self-directed learning

PBL is a learning strategy that stresses the use of problems as a tool for the learners to acquire critical and creative thinking abilities in solving real-world situations (Tanjung et al., 2020). PBL uses real-life ill-structured situations as a backdrop for the learners to create knowledge and give numerous answers (Golightly, 2018). This teaching approach allows the learners to work collaboratively to ascertain what they need to learn to solve a problem (Ali, 2019). According to Toh and Kirschner (2020), to find a solution, the learners engage in self-directed learning in which they apply their new knowledge to the problem, and they reflect on what they have learned, and they have more deliberations.

According to Mulaudzi (2021) as well as Mulaudzi et al. (2023), SDL is essential in PBL because it is learner-centred, thereby allowing the learners to uncover and construct the measures that may be used to tackle similar issues that may arise. Kruszelnicki (2020) proposes that the learners' perception of taking control and having an honest effect on the learning settings are two important factors that are essential in the development of self-directedness in learning. This is because they empower the individuals to take control of their education and these elements support the requirement for one to comprehend the learning environment and take control of one's own learning process (Loeng, 2020).

2.2.5.5 Self-directed learning and the integration of IK through short learning programmes

Some skills are needed to address the current challenges, and these include but they are not limited to skills such as problem-solving, social skills and the creative thinking skills which Petersen (2016) refers to as the SDL skills. Teachers who value SDL in their classrooms are more likely to have learners who are accountable and competent of controlling their own learning, while they assist and coach the learners as they study (Knowles, 1975; Mahlaba, 2020). These self-directed teachers would be able to assist learners with identifying their purpose or learning passion and pushing and motivating them to follow it (Petersen, 2016).

The capacity to be a self-directed learner is the most essential and vital component of human growth, since as one grows, so does the wealth of their experiences, which should be tapped into when in need of knowledge (De Beer & Mentz, 2016). A self-directed learner should also be prepared to learn what is required to assist in tackling life issues (De Beer & Mentz, 2016; Silen & Uhlin, 2008). This is because PBL is an effective teaching and learning technique for improving SDL abilities (De Beer & Mentz, 2016). As a result, self-directed learners are never satisfied with rote learning; rather, they are continually on the lookout for profound meanings (Cremers et al., 2014). As a result, SDL may be considered as a process that necessitates features of the learner's attributes as well as certain learning techniques (Cremers et al., 2014).

Other elements that impact SDL include the ability to employ PBL tactics as well as receptivity to learning possibilities (De Beer, 2016). Learner self-reliance, initiative and independence, informed acceptance of responsibility for one's own learning, joy of learning, and creativity (Nokdee, 2007; Peyton, 2023). As research on the affordances of IK for SDL was based on the same characteristics (De Beer, 2016), these factors play a very essential role in the integration of IK in Science classrooms.

Integration of IK in Life Sciences classrooms that encourages metacognition and self-reflection necessitates SDL, which is recognised as critical through SLPs that allow Life Sciences teachers to cooperate in PBL (De Beer, 2016). This style of learning necessitates that teachers choose their objectives; hence, throughout SLPs, teachers were prepared with knowledge and skills, and they would independently explore a range of IK from other cultures (De Beer, 2016). Unfortunately, the majority of Life Sciences teachers used the transmission method of teaching, thus they encountered problem-based tactics that fostered self-discovery among the teachers regarding their weak comprehension of the NOS during the SLPs (De Beer, 2016). During the SLPs, teachers faced problems that required them to implement inquiry-learning techniques by identifying relevant learning opportunities and resources in their classrooms (De Beer, 2016). All of these would be linked to Science tenets, which would help to stimulate goal-oriented persons and professional growth among teachers (De Beer & Mentz, 2016). It is significant because it can be used to demonstrate how IK may provide the context to improve SDL.

In this study, I was also guided by the insights of Hiemstra and Brockett (2012) on SDL. These authors developed the Person-Process-Context (PPC) model for SDL (see Figure 2.9).

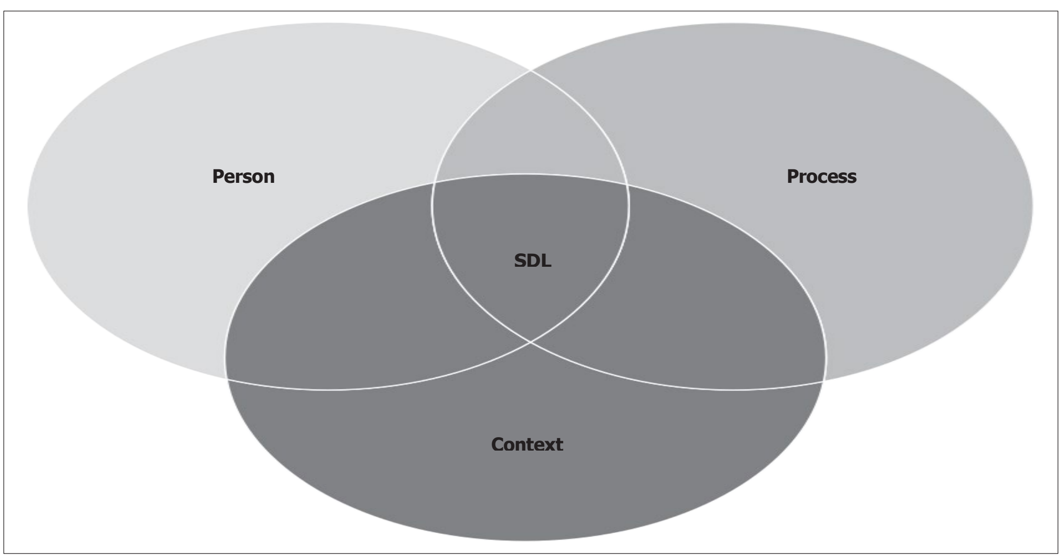

Figure 2.9: Hiemstra and Brockett's (2012, p. 158) Person-Process-Context (PPC) model

A learning intervention must develop the characteristics of a self-directed learner in every participant, such as creativity, critical reflection, motivation, resilience and self-concept as reflected in the model in Figure 2.9 (Hiemstra & Brockett 2012, p. 158). The *Process* dimension is also important, as it involves "the teaching-learning transaction, including facilitation, learning skills, learning styles, planning, organising and technological skills" (Hiemstra & Brockett 2012, p. 158). Often, the context dimension in SDL is marginalised (Merriam, 2001). Candy (1991, p. 311) believes that "the term self-direction has misled many into elevating the individual above the collective – but the nature of knowledge and learning inherently puts learners in relationship with others". In the case of this study, the focus on IK could provide an effective context to enhance SDL, where the participants deliberate on IK related practices and contextualise as they teach Life Sciences. As such the more they integrate IK which is what they are most familiar with the more the need for personal growth pivotal to their pedagogy.

2.2.6 Conceptual change

It is critical to ponder on their conceptual transformation to properly comprehend how Life Sciences teachers might employ CL methods and PBL to incorporate IK in their classrooms. Furthermore, understanding what the conceptual change means is essential for good deliberation. Denis et al. (2015) defines conceptual change as the process of using techniques to align children's thinking with scientists'. Aubrey (2022), on the other hand, defines conceptual change as how a notion evolves when learning and development occur in certain realms of knowledge. According to Lehtimen et al. (2020), there is an emphasis on the difficulties that learners have in grasping more complicated and counterintuitive notions in various realms of knowledge.

Conceptual change became prominent in the Science community as the result of the challenges people encountered when changing from one explanatory framework to the next (Denis et al., 2015). Conceptual change becomes crucial to the learning process whenever the learners' past knowledge and newly introduced concepts and ideas interact (Ruiz-Martin & Bybee, 2022). As a result, the learners' cognitive structures become crucial in this process, and if there is a discrepancy between their past or current knowledge and the new information, they will need to adjust their conceptual framework to resolve the problem (Mason, 2020).

2.2.6.1 Participating Life Sciences teachers' conceptual change

In the context of this study, the Life Sciences teachers were initially not familiar with the activities they were involved in during the SLPs. PBL activities included laboratory work in which the Life Sciences teachers employed the Kirby-Bauer technique and frugal Science to do fermentation, leaf DNA extraction, and PCR, among other things. The teachers were then taught the CL approaches, using instructional tools such as De Bono's six thinking hats and the Jigsaw. The activities they participated in throughout the two SLPs were new knowledge to these teachers, which contradicted their current understanding. Existing knowledge consists of teacher-centred education practices that are unlikely to encourage critical thinking or problem-solving abilities. That is, teachers are unable to incorporate IK to assist in bringing the lesson into the context of the learners. To resolve this discrepancy, Troyer and Greitemeyer (2018) propose that teachers experience a conceptual change.

2.2.6.2 Participation in the Life Sciences teachers' classrooms

The process of conceptual change does not stop with the teachers who took part in the SLPs. Learners who are taught by these teachers are more likely to go through conceptual change (Rasmitadila et al., 2020). This is because these teachers would engage the learners using apparently 'learned' teaching techniques that are new to the learners during the intervention, requiring the learners to engage in activities they had never done before. The learners would be obliged to participate in PBL once more, which would challenge them to be critical thinkers and problem solvers. The learners would next be put through laboratory work to undertake various activities (Denis et al., 2015). This is new knowledge that the learners' previous knowledge must integrate with; as a result, a conflict between the existing knowledge and the new knowledge will emerge. As Troyer and Greitemeyer (2018) point out, amid such conflict, learners must go through the process of conceptual shift. Finally, as described by Troyer and Greitemeyer (2018), the learners' classroom setting is an ideal environment for conceptual change to occur. The social matrix in which conceptual change occurs is comprised of learners, peers, teachers, and adults, and it represents a complex network of interacting attitudes.

Learning is defined as the result of the interplay between the learners' existing conceptions and perceptions, as well as how and what is utilised to convey them (Denis et al., 2015). The process of learning is commonly viewed as the acquisition of new knowledge rather than the interaction of current knowledge with new knowledge. Thus, existing information is overlooked or ignored; yet Ausebel (1968) contends that the learners' previous knowledge is crucial to the learning process.

In addition, to the aforementioned, it remains important that a learner can allow conceptual change to take place. The importance of this process is explained better by Bartlett (1932) that an organism must somehow gain the ability to turn around on its own ‘schema' and rebuild them since this is critical in the organism's evolution. Thus, Troyer and Greitemeyer (2018) suggest that any instructional method that supports a learner's conceptual transformation is an essential component of any effective problem-solving situation.

2.2.6.3 The classroom as an ideal environment for conceptual change

As suggested above, the classroom can serve as an ideal environment for conceptual change, depending on how conducive the environment is. In other words, the teaching approach that is used by the teacher is also central in such a way that it allows for learner interaction, which allows for the process of conceptual change as well as learner development as described in Vygotsky's social constructivism. In reflecting on the fundamental role played by the teaching approach in the process of learning, Dyrbye et al. (2020) suggest that the learner's attitude towards learning might negatively influence how the learner learns. However, the effective teaching approaches would have a positive influence on the learners’ attitude. Furthermore, Li et al. (2019) discovered that several studies suggested that the learning that engages in CL and PBL inclined strategies shows more positive Science attitudes than those taught through the traditional methods.

2.2.7 Pedagogical content knowledge

As mentioned in the preceding parts of this study, pedagogy is significant among the teachers who are taking part in the study as part of the conceptual framework of this study. PCK is a concept introduced into teacher education by Shulman (1986), who was concerned with "how subject matter was transformed from the teacher's knowledge into the content of instruction" (p. 6). According to the author, for almost a century, teacher education focused on content knowledge, and it wasn't until the 1980s that content and pedagogy became important to teacher-training courses (Reddy, 2018).

It is well acknowledged that the subject matter, content knowledge, and curricular knowledge of the teacher have a significant impact on the teacher's PCK (Magnusson et al., 1999). However, as previously said, the PCK will be crucial to the discussion because this study was designed with Life Sciences teachers in mind. Magnusson et al. (1999) provide a PCK for the Science teaching model that has five components. Orientation to Science teaching; knowledge of Science curricula; knowledge of scientific literacy assessment; knowledge of how learners understand Science; and knowledge of teaching strategies (Magnusson et al., 1999). This model is consistent with Cochran et al.'s (1991) assertion about the difference between a Science teacher and a scientist, which states that teachers differ from biologists not only in terms of the quantity and quality of their subject area knowledge but also in how that information is structured and used. According to Demirdöen et al. (2016), I will examine the PCK of Science teachers in various Science areas: Chemistry (Chen & Wei, 2015); Physics (Alonzo & Kim, 2015); and Life Sciences (Mthethwa-Kunene et al., 2015). Hence, the posture taken in this research was to view the participating Life Sciences teachers classroom practice through this PCK for the Science teaching model (figure 2.10), which is deliberated below.

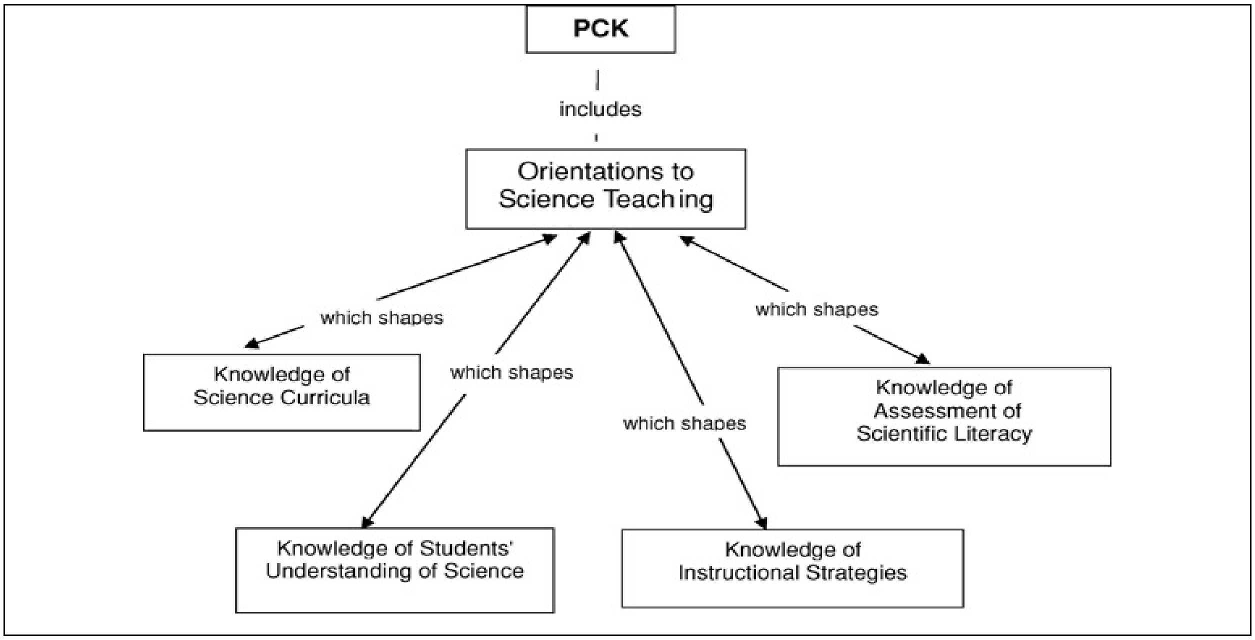

Figure 2.10: PCK for Science teaching (Magnusson et al., 1999, p. 97)

Magnusson et al.'s (1999) PCK for the scientific instruction model (figure 2.10) is identical to Grossman's (1990) model, with two components added to make five. A conceptual definition and illustrated examples are provided below to define the specific knowledge that is represented by each component. As highlighted above, the PCK for Science teaching is comprised of five components (Figure 2.10), which are deliberated upon below.

- "Orientation to Science teaching.
- Knowledge of Science curricula.
- Knowledge of the learners' understanding of Science.
- Knowledge of instructional strategies.
- Knowledge of assessment" (Magnusson et al, 1999, p.97).

2.2.7.1 Orientation to Science teaching

The orientation to Science teaching, according to Magnusson et al. (1999), is the teachers' knowledge and views about the reasons and goals for teaching Science at a certain grade level. Science teachers' knowledge and beliefs are crucial to their classroom practice since they are established in the CAPS document, which is required to integrate IK. They must be attentive to the learners' IK, as it will aid in the integration of information relevant to the context from which the learners come. In other words, Life Sciences teachers' approach towards teaching Life Sciences is a manner of conceptualising Life Science teaching and learning (Lankford, 2010).

- **Knowledge of the Science curricula**

The knowledge of Science curricula refers to the Science teachers' thorough understanding of the "goals and objectives" for the learners' learning, as well as the breadth and order of the scientific concepts to be taught (Lankford, 2010). In the context of this study, teachers were required to have knowledge of the curriculum of the Life Sciences, for example, teachers were expected to be familiar with all three CAPS-specific purposes, including Specific Aim three, which is sometimes overlooked. This goal supports the incorporation of IK in a Life Sciences classroom, albeit the policy statement does not specify how these teachers may do so. The SLPs provided the teaching approaches that do not only advocate for meaningful learning in the classroom but make it possible for the teachers to integrate IK in the process.

According to Magnusson et al. (1999), as well as Lankford (2010, p. 20), "teacher knowledge of curriculum is comprised of two categories: (a) the mandated goals and objectives, and (b) specific curricular programmes, resources, and materials". Concerning the specified aims and objectives, teachers are led in their teaching and learning by these goals and objectives. This implies that when they organise classes, they keep the specified aims and objectives in mind. There are three unique intents in the Life Sciences that function as objectives and goals. The primary goal of the Life Sciences CAPS document (SA, 2011) is to develop learners' subject understanding, while the second goal is to build learners' practical and investigative abilities. The third goal, among other things, urges learners to be aware of the history of science and IK, so pushing teachers to include IK.

- **Knowledge of the learners' understanding of Science**

The knowledge of the learners' understanding of Science is an aspect that is comprised of a teacher's understanding of the needs for the learner's acquisition of certain ideas, as well as the potential learning challenges that a learner may face when learning the topics (Lankford, 2010). This element is primarily interested in the 'teacher repertory' of Life Sciences teachers, the tools, tactics, and models that the teachers employed in their classes to anticipate and cope with the learners' learning issues. The teachers were involved in the SLPs in the framework of this study to develop the Life Sciences teachers' teacher repertoire. These SLPs included activities such as doing experiments (Fermentation, DNA testing, and other tools) that would aid teachers in predicting and coping with the learning issues of their Life Sciences learners.

- **Knowledge of instructional strategies**

Knowledge of instructional techniques relates to teaching approaches such as PBL, which is vital in scientific disciplines such as the Life Sciences and is included in this component of PCK (Magnusson et al., 1999). This comprises topic-specific techniques and various forms used to display concepts such as models, diagrams, and graphs, as well as to teach learners through teaching methods such as inquiries and experiments (Lankford, 2010; Magnusson et al., 1999). This implies that Life Sciences teachers must be prepared with the ability to apply numerous teaching techniques as well as the knowledge to determine which teaching style is appropriate for a certain Life Sciences topic in a Life Sciences classroom. Furthermore, the teaching style employed by the teachers at that specific period in the classroom must be relevant and must advocate for meaningful learning among Life Sciences learners. The abilities in question include but are not limited to, using the Jigsaw, De Bono's six thinking hats, and conducting experiments for which the teachers were trained throughout the intervention.

- **Knowledge of assessment**

The knowledge of assessment as an aspect of PCK posits two ideas, (a) "knowledge of the dimensions of Science learning important to assess and (b) knowledge of assessment strategies and methods through which learners' learning can be assessed" (Lankford, 2010, p. 21; Magnusson et al., 1999). Forms of progressive assessment include informal, formal, formative, and/or summative evaluations that are used to assist in determining learners' grasp of scientific topics (Lankford, 2010). This implies that while the Life Sciences teachers' understanding of the curriculum, subject matter, and related teaching methods is crucial, the teachers must also know what to assess and how to assess it. Teachers in Life Sciences are given three goals to attain, and in order to do so, they must employ Bloom's taxonomy and domains, which are crucial to how Life Sciences learners are assessed. In other words, the taxonomy and the domains guide the teachers on how to ask the learners certain questions to achieve the stipulated outcomes.

2.2.8 Conceptualising the nature of Science

The NOS has had its fair share of controversies, notably among highly respected academic organisations; nonetheless, despite the difficult exchanges, there is still some consensus on its fundamental ideas (Thye & Kwen, 2004). The NOS and its advocacy are known to have been in existence for over 100 years. As a result, the necessity for Science teachers to comprehend the NOS has reached new heights, with robust engagements provided with a greater emphasis on the scientific method and Science processes (Hurd, 1960). Numerous studies have generally demonstrated that mastery of the NOS is a critical cornerstone in Science literacy and a vital objective for Science Education (Klopfer, 1969; Millar & Osborne, 1998). As a result, it is one of the major parts of this study's conceptual framework to assist learners with acceptance, particularly when dealing with IK.

The NOS is defined as a knowledge system that includes Science, its sociology, and the mode of inquiry and comprehension of the natural and physical worlds, as well as the creeds and standards that are used in the scientific setting to grow scientific knowledge (Lederman & Lederman, 2014; Moutinho et al., 2015). Some writers define the NOS as a hybrid theatre that combines many aspects of scientific social study, such as history, philosophy, and sociology, with studies from the intellectual Sciences, such as psychology (Bell, 2009). This combination contributes to a rich understanding of what Science is, how it works, and how scientists interact. Furthermore, how the society perceives scientific operations is influenced by various factors such as the NOS creeds and the social and cultural dimensions of Science (Lederman, 2007). It is worth noting that contemporary discussions about how to improve Science education emphasise scientific literacy as the primary motivator of Science education (Zeidler et al., 2019). Contemporary sources define scientific literacy as the ability to grasp, appreciate, and respect the impact of Science, as well as the ability to make informed judgements about socio-scientific concerns (Bell, 2009).

2.2.9 Conceptualising indigenous knowledge

For many years, the world has embraced the discourse on IK that has sparked major debates, notably in African nations such as South Africa, where indigenous people have historically valued such knowledge (Mawere, 2015). Hoppers (2002) defines IK as a knowledge that is local and traditional and it is void of the Western beliefs, the customs as well as the world views and it is mostly referred to as being alternate and informal (Hoppers, 2002). On the other hand, Zidny et al. (2020) suggest that it has been proposed that there are multiple ways to describe IK, where people are exposed to different terminologies and meanings with culturally, politically, and ideologically oriented definitions. Furthermore, Mawere (2015) posits that in the quest of understanding the concept of IK, it is obvious, that the concept has worn many hats concerning the definitions and the conceptualisations. These definitions have certain aspects in which they differ, which suggests the different ideologies among the authors.

Warren (1991), for example, considers IK to be equal to traditional, local knowledge and suggests that IK is supposed to be devoid of growth since it differs from the western Science created by institutions of higher learning. IK, according to Warren, is static and does not develop. However, Smith et al. (2016) argue that being conventional does not prevent anything from evolving or inventing, which contradicts Warren's (1991) static and uninvolving conception of IK. As a result, Mawere (2015) defines IK as a collection of indigenous community ideas, beliefs, and cultural applications that have become part of the community and have been passed down from generation to generation. Mawere (2015)'s comments are supported by Steenkamp et al. (2019) and Nyana et al. (2007), who define IK as knowledge passed down from generation to generation through drawings, dancing, and storytelling. In other words, such information is likely to change depending on the context of the generation that learns it. Furthermore, such knowledge is unique to a certain indigenous civilization living in a specific place governed by a distinct socio-cultural ecosystem with existing communication between the environment and the people (Anazifa & Hadi, 2017; Shizha, 2013). As a result, the information is more likely to assist the community in which it was generated, because it should have been available to meet specific needs in the community and its environment.

This form of knowledge does not remain static; rather, it evolves and is influenced by external and internal situations via inter-system interactions. This knowledge also incorporates the content and circumstances, such as cultural systems (Santoro et al., 2018; Shizha, 2008). As a result, IK refers to the values and clemencies that indigenous societies form and develop via partnerships with different groups of people in their natural environments (Amuzu, 2022; Sabzalian & Jacob, 2023; Shizha, 2008). It explains how the indigenous setting is controlled using scientific processes that involve goal-driven observations of natural phenomena, and it characterises and addresses problems that encompass all the proceeds of local cultural practices (Banerjee & Arjaliès, 2021; Snively & Corsiglia, 2001).

On the other hand, Ogawa (1995) and Zidny et al. (2020) propose that IK is divided into two levels: personal and cultural. Cultural IK is defined by the authors as knowledge that is culture dependent and is viewed similarly by a group of a specific indigenous people via communication, even though it is culture reliant and self-reliant from individualised thinking (Reano, 2020; Snively & Corsiglia, 2001). Furthermore, IK infers how an indigenous setting functions through a specific cultural practise, which includes indigenous inhabitants who live at home (Snively & Corsiglia, 2001; Zidny et al., 2020). In other words, while IK does not share some concepts of Western Science, it has shown to be durable and trustworthy since indigenous people survived with it before Western Science arrived in any indigenous society. According to Stevenson (1996), IK encompasses the entirety of the content or context of indigenous knowledge. The author goes on to say that IK may be thought of as having two knowledge fountains: conventional and non-traditional knowledge. Indigenous society holds traditional knowledge via experience, but it does not prioritise lifestyle and spirituality (Kading et al., 2019; Stevenson, 1996).

IK is an inclusive knowledge that incorporates indigenous people's technologies and applications as a way of sustainable living and survival while modifying as the environment develops (Handayani et al., 2018; Onwu & Mosimege, 2004). IK is all-inclusive in character, according to Battiste (2002) and Kar et al. (2023), and its indigenous society need enhanced diverse technology that they can support. IK takes place through vocal communication, as well as pictures and paintings (Zinyeka et al., 2016). The tendency in IK that is highlighted is that of collaborative thinking by the indigenous group who recites in a setting where both biotic and abiotic parties collaboratively work together (Alessa et al., 2016).

It provides access to essential principles that are linked and lasts a lifetime (Snively & Corsiglia, 2001). This describes how the indigenous environment works through a scientific procedure that includes an objective observation of a natural phenomenon (Hendayani et al., 2018; Snively & Corsiglia, 2001). Furthermore, it can be distinguished to assist in addressing its flaws that are revealed in cultural practises (Snively & Corsiglia, 2001). Quigley (2009) defines IK as "groups with a long history of deep ties with their natural surroundings that acquire and develop practises." This data is part of a cultural system that also includes local languages, naming and categorising systems, resource utilisation, rituals, and spirituality, and the worldviews.

Regrettably, the literature shows that much of this sort of information has gone unrecorded, meaning it has been lost and has not been handed down to the next generation (Steenkamp et al., 2019). Such loss could be linked to a lack of communication and social cohesiveness between the two generations, particularly the youth, who tend to disregard their culture (Anazifa & Hadi, 2017; Fraser, 2012). The indigenous people's storytelling has dwindled because of socioeconomic trends. Furthermore, the over-concentration of Western Science in schools, as well as the absence of integration of IK by Life Sciences teachers in their pedagogy, contributed significantly to the loss of this information.

- **Nature of indigenous knowledge**

Life Sciences teachers must be well-versed in the values that support epistemologies, especially if they are to teach a topic like Life Sciences at a level that demands them to teach two epistemologies concurrently (Dekker & Mnisi, 2003). This is because knowledge systems that require integration during classroom pedagogy are highly contested structures, and highly qualified Life Sciences teachers are required

(Reddy 2018). Furthermore, Vhurumuku and Mokeleche (2009) characterise each construct as difficult, fragmented, multi-layered, intricate, dynamic, and elusive.

Cronje et al. (2015) proposed a framework that might fit both IK and Western Science to assist Life Sciences teachers with the appropriate cross-border integration of indigenous knowledge systems into classroom pedagogy (Cronje et al., 2015). The NOIK's philosophical foundation, according to Cronje et al. (2015), contains aspects such as ontology, epistemology, methodology, and the volition of IK. Most crucially, according to Cronje et al. (2015), the philosophical framework was designed to compare the two epistemologies or to establish which one was superior.

2.2.10 Comparing the nature of Science and the nature of indigenous knowledge

Like any other knowledge systems, the NOS and the NOIK are comprised of tenets, which are built upon, and they derive their identity from and all these tenets that are based on the work that is done by prominent authors such as Agrawal (1995), Cronje et al. (2015), Lederman (1999), Ogunniyi (2004), and Vhurumuku (2011). As the researcher, I see the two systems, that are namely the NOS and the NOIK as having differences and similarities that can balance one another in a Science classroom (Cronje, et al., 2015). Table 2.2 presents a comparison of the tenets of Science and IK. The focus of Table 2.2 is on the epistemological and the ontological tenets of Science and indigenous knowledge.

Table 2.2: The comparison of the NOS and the NOIK tenets (Cronje et al., 2015, p. 223-224)

Nature Of Science (NOS)	Nature of Indigenous Knowledge (NOIK)
• “Empirical NOS Nature is real, observable and testable. The universe is orderly and predictable” (Cronje et al., 2015, p. 223-224).	• “Empirical and metaphysical NOIK Nature is real, partly or generally tested, observed and a needs-based experimentation” (Cronje et al., 2015, p. 223-224).
• “Tentative NOS Science is subject to change, not absolute, certain and it is challenging for all (Cronje et al., 2015, p. 223-224)	• “Resilient yet tentative NOIK IK has withstood the test of time but is constantly changing as tradition” (Cronje et al., 2015, p. 223-224).
• “Inferential NOS There is a distinction between the observations of nature and the inferences to explain the causes” (Cronje et al., 2015, p. 223-224).	• “Inferential yet intuitive NOIK Facts are both tested and experimental observations made” (Cronje et al., 2015, p. 223-224).
• “Creative NOS Observations and experiments are not the only sources of scientific knowledge” (Cronje et al., 2015, p. 223-224).	• “Creative and mythical NOIK Observations and experimenting are not the only sources of ways of knowing” (Cronje et al., 2015, p. 223-224).
“Subjectivity (theory-laden) of the NOS The scientists strive to be objective and culture free” (Cronje et al., 2015, p. 223-224).	• “Subjectivity of NOIK Indigenous ways of knowing are based on cosmology and they are interwoven with culture, and they are spiritual” (Cronje et al., 2015, p. 223-224).
• “Social and cultural NOS Scientists try to be objective, but Science is a human endeavour” (Cronje et al., 2015, p. 223-224).	• “Social, collaborative and cultural NOIK IK is situated in cultural tradition, and it is within a certain historical–political context” (Cronje et al., 2015, p. 223-224).
• “Methods and the NOS Science knowledge is not generated by a single step-by-step universal method” (Cronje et al., 2015, p. 223-224).	• “Wisdom in action and NOIK IK is generated by practical engagement in life through trial-and-error experiences” (Cronje et al., 2015, p. 223-224).
• “Theories and laws and the NOS The scientists use theories and laws to explain what, why and how things happen in nature” (Cronje et al., 2015, p. 223-224).	• “Functional application and NOIK Indigenous knowledge is concerned with what and why things happen in nature, but also with what ought to happen” (Cronje et al., 2015, p. 223-224).
• “Reductionist approach of the NOS Complex phenomena can be broken down into small parts and analysed” (Cronje et al., 2015, p. 223-224).	• “The holistic approach to IK. IK is a conglomeration of knowledge systems including Science, religion, psychology and other fields” (Cronje et al., 2015, p. 223-224).

2.2.10.1 Elaborating on the tenets of the nature of science

This section presents the deliberation on the tenets of the NOS.

- **The empirical NOS**

Both qualitative and quantitative data are critical to scientific knowledge (Bell, 2009). As a result, this principle implies that scientists see nature and that nature is real, and that their scientific claims should be substantiated by existing data. In other words, there are tests, investigations, observations, and experiments that are warranted to serve as evidence before scientists make assertions; yet the presence of such evidence does not make the claim faultless or indisputable (Cronje, 2015). To illustrate this tenet, Reddy (2018) used an example from Copernicus' (1543-1610) works about a geocentric model representing the solar system that existed in previous centuries. Based on this evidence, there was an argument that the earth was stationary, and the sun moved around it. The author went on to say that such a model had to be changed to a heliocentric model, which recommended the opposite of what the geocentric model argued for (Reddy, 2018). This was the outcome of new and sophisticated telescopes (for example, the Karoo Array telescope), through which fresh observations were obtained and new empirical evidence was made accessible to help contradict what was once thought to be current knowledge. This example also advocates for the tenet that follows, thereby showing that scientific knowledge is not absolute, on the contrary, the knowledge is tentative but durable.

- **The tentative NOS**

Even though all scientific information is reliable and robust, it is subject to change because of new knowledge and new ways of thinking (Bell, 2009). This contrasts with how most Science learners and teachers see scientific information; in other words, most learners and teachers perceive scientific knowledge to be permanent, and scientists to be exclusively objective in their scientific endeavours (Cronje, 2015). A study of pre-service Science teachers discovered that the teachers likewise considered scientific information as infallible and irrefutable, demonstrating the misunderstandings that the teachers have due to their idealisation of Science (Aflalo, 2014).

In addition, it is no secret that new scientific concepts are rarely simply accepted; rather, they are met with scepticism, especially when the new thought contradicts current information about the event in issue (Bell, 2009). Pluto, for example, was once considered a planet, but the International Astronomical Union (IAU) stripped it of that designation in 2006 (Carmen, 2006). According to Johnson (2006), the reclassification of Pluto is an example of how scholars challenge one another, and correct mistakes based on fresh information since Science is an honest human activity. According to Carmen (2006), the union contended that if Pluto remained a planet, then other dwarf celestial bodies such as Pluto would also qualify for planetary status. This is because of new technology breakthroughs, the assumptions based on scientific observations will be revised and altered on a regular basis.

- **The observational and inferential NOS**

Scientific effort is more than just the accumulation of multiple observations; it is a fusion of both observations and conclusions (Bell, 2009; Chanetsa & Ramnarain, 2023). The observations are done utilising an individual's five senses as well as technology devices such as microscopes, which are especially useful when seeing the cells of animals (Baek & Yang, 2023; Vhurumuku, 2011). While deductions and conclusions drawn from observations are used to make inferences, they are not immediately available to the senses (Chanetsa & Ramnarain, 2023; Lederman et al., 2002). In other words, observation is the use of one's five senses to gather knowledge, which is frequently enhanced by technology. The inferences, on the other hand, entail generating explanations from the observations, and they frequently involve entities that are not immediately observable (Bell, 2009; Obert, 2021). This tenet advocates for a conceptual change in Science subjectivity because what is seen can be interpreted differently depending on how it is individually seen and individually interpreted.

- **The creative and imaginative NOS**

According to Bell (2009) and Cronje (2015), the observations and experiments are not the sole sources of scientific information, thus the scientists do not utilise a single universal scientific technique to develop scientific knowledge. On the other hand, many Science teachers reflect contradictory behaviour during the laboratory exercises by

McComas (1998) and McComas and Clough (2020) suggest that scientists' creativity aids them in their pursuit of scientific laws and the development of scientific ideas. McComas (1998) went on to claim that if there was a single scientific technique, reviewers would frequently reach the same findings. This is not the case, and it is not assured, because scientists utilise a range of creativity and imagination with a personal touch (Chanetsa & Ramnarain., 2023; McComas, 1998).

In addition, Bell (2009) suggests that creativity is the fountain of innovation, and it is what mostly inspires the scientists throughout their research, as they employ their imagination and creativity. Hence, the scientists in many cases propose thoughts that may at first appear irrational, because Science at times is anything but a lifeless, logical, and systematic action (Lederman et al., 1999; McComas & Clough, 2020; Vhurumuku, 2011). Most pre-service secondary school teachers identified the importance of creativity in creating scientific concepts, according to a research of pre-service secondary school teachers (Bell et al., 2000; McComas & Clough, 2020). Finally, Vhurumuku (2011) proposed that, just as an artist may use their imagination to create a work of art, scientists can utilise their creativity and imagination to create scientific ideas and information.

- **The theory-laden NOS**

According to Bell (2009), scientists are occasionally unsure of their own abilities, so they self-check, employing peer assessments to aid increase objectivity in their work. Cronje (2015) supports this by stating that scientists want to be objective and culture-free in their scientific work, yet they are subjective as humans influenced by theoretical and disciplinary commitments, prior knowledge, and perspectives. These factors impact the scientists' mindset and how they approach observations and experiments (Cronje, 2015). He who watches will now tend to see what you want to notice and will pay less attention to what is unimportant (Vhurumuku, 2011).

All these ideas are provisional since there is no thought in Science that is substantial and basic to Science that is not subject to revision in light of new evidence (Bell, 2009). This emphasises the significance of conceptual change in Science since what is known now may change considering new information, but this does not impair scientific knowledge in any way. As such, according to Nickles (2017) the scientific theories were described as well established, highly authenticated, and internally coherent systems of explanation. This definition shows that in as much as Science may be tentative, and in as much as scientists at times may be subjective, the scientific knowledge remains robust and thorough.

- **The NOS and the scientific method**

According to Bell (2009), there is no such thing as a universal scientific procedure; scientists employ a variety of ways to produce scientific knowledge, including observation, inference, experimentation, and even accidental discovery such as penicillin. This is a common fallacy maintained and demonstrated by many Science professors and students who believe there is only one recognised scientific technique. The assumption that Science has just one method that all scientists must follow is a very common fallacy that is routinely featured in many high school Science textbooks (McComas, 1998; McComas & Clough, 2020). This myth as highlighted by Vhurumuku (2011), reflected an observation of a phenomenon as the first step; formulating a problem; devising a hypothesis; designing experiments to collect data; making relevant observations; interpreting the observations made; drawing conclusions and reporting on findings.

In addition, when scientists construct hypotheses, they use a lot of imagination and ingenuity, thus there are no formulas to follow. In other words, scientists in their field of work rely heavily on creative thinking and problem-solving abilities. As a result, suggesting that scientists must follow a formula and that there is a particular scientific technique that may yield irrefutable and flawless discoveries is untrue (Bell et al., 2000; Chanetsa & Ramnarai, 2023; Lederman et al., 2002). A "close inspection will reveal that scientist’s approach and solve problems by using imagination, creativity, prior knowledge and perseverance” and any known successful problem solver uses these aspects (McComas, 1998, p. 5). Thus, we must understand that Science, as previously said, is a human journey in which phenomena are investigated using diverse methodologies to make sense of the natural world.

- **The scientific theories and laws and the NOS**

According to Bell (2009), a scientific rule reflects the links and steps that are commonly observed in nature, whereas scientific theory is well and reinforced thinking. In other words, scientists employ ideas and principles to explain what, why, and how things happen in nature. Scientific law outlines what happens, whereas theory explains why and how things happen (Cronje, 2015). According to Bell (2009), scientific law and scientific theory are separate types of knowledge; hence, a scientific theory cannot become a scientific law. However, the evidence reveals that Science teachers and learners believe that a hypothesis leads to a scientific theory and that a scientific theory that has survived the test of time will graduate and become a scientific law (Bell et al., 2000; Chanetsa & Ramnarain, 2023; Vhurumuku, 2011). This might be due to the notion that, despite their differences, scientific rules and ideas are widely recognised and employed in the scientific community.

In addition, while individuals may recognise the distinction between scientific law and scientific theory, they appear to believe that scientific law is preferable to scientific theory in terms of quality. This belief among Science teachers and learners has caused many to believe that there is no room for uncertainty in scientific principles, thereby making scientific laws absolute and infallible (McComas, 1998). The author goes on to say that the tentativeness of scientific knowledge is not a flaw, but rather an opportunity for Science to self-correct considering new findings, resulting in new knowledge.

2.2.10.2. Elaborating on the tenets of the nature of indigenous knowledge

This section seeks to deliberate on the tenets of the NOIK

- **Empirical and metaphysical in nature**

According to Kwanya (2015), IK reflects the results of tens of thousands of years of discovery and invention in all aspects of life in a specific place. As such, IK appears to be the outcome of practical engagement with what happens every day, and it is continually enhanced via trial and error, as well as the use of empirical as well as observational information as opposed to theoretical knowledge (Senanayeke, 2006). In other words, IK, like Western Science, regards nature as a genuine reality that is typically or partially observable, and it regards nature as a tested phenomenon.

However, IK includes metaphysical aspects. For example, the language used by Australia's indigenous community of Aborigines allows for conversation with trees and rocks, which is not permitted in English, and if everything is animate, it must have a spirit and knowledge (Aikenhead & Ogawa, 2007). This is because, by comprehending the natural world, one may comprehend the complexity of the inner man, and similarly, by beginning on a journey to the metaphysical realm, one can comprehend the natural world completely (Ermine et al., 1995).

In addition, De Beer and Van Wyk (2019) caution about the effective plant use that is occasionally misunderstood due to the used vocabulary. For an example, there is a plant called Adenia gummifera (Impinda and magic) that is usually used by black South Africans to “keep evil spirits away” (p. 129-130). However, in fact the plant is an effective antiseptic that inhibits micro-organisms that can only be seen using microscopes, which are tools that the indigenous people may not have, as such they term what they cannot see as an evil spirit (De Beer, 2019; De Beer & Van Wyk, 2019). Lastly, another example can be drawn from the use of Asclepias crispa and Galium tomentosum (Witvergeet and rooivergeet) by the Khoi-San community to cause forgetfulness in persons, especially when the person is grieving (De Beer & Van Wyk, 2016). However, the researchers such as De Beer and Van Wyk (2019) suggest that these plants may “contain chemical substances” that may have an influence on the brain (p. 130-131). As such, attributing the forgetfulness as more “psychological than medical” which maybe empirical and metaphysical in the nature of IK (De Beer & Van Wyk, 2016).

- **Resilient yet tentative in nature**

IK is more than just the replication of a relatively static corpus of data from one generation to the next (Aikenhead & Ogawa, 2007). Individuals in each generation, on the other hand, make observations as they compare their experiences to what their teachers have told them, as well as conduct experiments to assess the dependability of their knowledge, and they also share their discoveries with others (Aikenhead & Ogawa, 2007). As a result of such tests and observations, the IK will adapt in response to new knowledge, making it tentative yet resilient. Cronje et al. (2015) reflect the trepidation and persistence of IK, which spills over into Science. Cronje et al. (2015) stated that, based on the consensus obtained by various researchers, IK has withstood the test of time, but as a tradition, it is always evolving, fluid, and transformational, and it is linked to people's experiences. The ongoing testing and monitoring of IK, like Science, is not to discredit it, but rather to ensure that the information-making IK is dependable and lasting.

- **Inferential yet intuitive nature**

According to Adedeji (2000, p. 143), within the IK corpus, "the senses are not only limited in what they can perceive but also in what is beyond their detection…IK is a form of knowledge that goes beyond the reach of *modus tolens* in logic". In other words, while IK employs inferences during the analysis of a natural event, intuition is important and plays a vital role in the attempt, which is a component of IK that contradicts the NOS tenets. Idowu (1962) lauded Science and its techniques but acknowledged their limitations when he emphasised the benefits the methods gave to scholarship and the reality that Science cannot investigate some subjects. The only phenomena that Science cannot investigate are those that can only be accessible and acknowledged with the necessary apparatus of human capacities. In IK, occurrences now have both natural and unnatural origins, with metaphysical components playing an important role (Cronje et al., 2015).

- **Creative and mythical in nature**

IK, like NOS, is based on observations and experiments as a fountain or source of knowledge; however, IK employs human creativity, imagination, metaphors, and beliefs in what Science refers to as myths, which play a significant part in this epistemology (Cronje et al., 2015). A specific Bapedi group in South Africa thinks that when it rains and there is lightning, one should not wear red clothing should one desire to be struck. These are some of the myths that exist inside the IK data, which contradict scientific data knowledge.

- **Subjectivity in nature**

The process of observation in the IK data is not isolated from the interaction between what or who is observed and the observer, which eliminates the notion of the observer being objective during observation (Aikenhead & Ogawa, 2007). The concept of an impartial observer poses a challenge not just to indigenous elders but also to scientists. According to Reddy (2018), this is because scientists are also human beings with cultural influences, theoretical commitments, and past knowledge and views, all of which contribute to an individual's subjective nature. Hence, Agrawal (1995, p. 425) argued that IK is "embedded in the social, cultural and moral milieu of their particular community… In other words, actions or thoughts are perceived to have social, political, moral and cosmological implications".

- **Social, collaborative and cultural in nature**

According to Cajete (2000), the original people were so in tune with their surroundings that their landscapes became mirrors of their very souls. As a result, the survival knowledge they utilised became part of the culture as well as the other historical and political context. This is because IK is the consequence of activities related with everyday living within a group of people's natural surroundings (Cronje et al., 2015). Furthermore, "it is rooted to a particular place, set of experiences, and generated by people living in those places" (Senanayeke, 2006, p. 87). It is passed down from generation to generation through storytelling, therefore the interaction between an older delivering the narrative and the youth listening to it is crucial. As a result, it is regionally rooted, ecologically oriented, and generated in a specific area by locals (Cronje et al., 2015).

- **Wisdom in action**

According to Senanayeke (2006), IK is the result of the actual participation in daily life, which is continually reinforced by experience as well as by trial and error. This experience is the result of many generations of intelligent thinking, and its success is a particularly excellent gauge of Darwinian fitness since its failure has direct implications for the lives of its practitioners. Furthermore, this information is developed by practical involvement among indigenous community members, and new knowledge and ideas are fully examined and evaluated in the survival laboratory (Cronje et al., 2015). As a result, there is a need to engage knowledgeable elders while new information and ideas are tested.

- **Functional application**

IK is focused on people's daily lives rather than facts, concepts, and laws, according to Reddy (2018). It investigates what, why, and how nature should occur, focusing on practical and functional uses and capacities. On the concept of what, who, and why, Ogunniyi (2004) uses malaria as an example, highlighting how an indigenous individual may ascribe being afflicted with malaria to other circumstances. As a result, asking questions such as, "Who sent the mosquito to bite me so that I could get malaria?" Why me?

- **Holistic approach in nature**

According to Ogunniyi (2007), IK is a corporation of epistemologies made up of Science, religion, psychology, and other related subjects, where issues are debated and handled holistically, and where all matters are treated without limitations. As a result, while looking for answers to an issue, the metaphysical realm might be considered as one of the areas to look.

2.2.11 The three epidemiological perspectives of the NOS and the NOIK

The acquisition of IK as an epistemology was one of the apartheid legacy's traces left in the South African Science teaching system (Taylor & Cameron, 2016). This was particularly visible when 'Black' South Africans got a subpar education in comparison to their "White" peers, where rejecting African worldviews was the norm (Taylor & Cameron, 2016). The indigenous learners' knowledge was regarded worthless until post-apartheid, when the government attempted to right the wrongs by recognising and integrating IK in the Life Science Classroom (SA, 2011).

According to Zinyeka et al. (2016), integrating IK with Life Sciences benefits the Life Sciences curriculum's social-cultural importance. It will also improve the learners' performance. The epistemological distinctions between the NOS and the NOIK, however, remain a source of conflict for such integration. It is also worth noting that including IK would encourage modern Science Education (SA, 2011). According to Webb (2011), most indigenous learners opt against choosing any Science related discipline such as Life Sciences owing to evident unfriendliness and an unwelcoming attitude towards the aspects of their cultural origins that they live by.

There is a persistent difficulty that is felt anytime the two epistemologies are stated in relation to the inclusion or integration of IK (Zinyeka et al., 2016). According to Ogunniyi (2007) and Zinyeka et al. (2016), it is necessary to carefully examine the nature of the two knowledge systems and recognise how naturally inclusive IK is. Furthermore, it provides an advantage to indigenous societies in terms of how it may be confirmed from generation to generation in areas such as spirituality and philosophy. According to Sandoval (2005), Science as a knowledge system includes values that are used to authenticate information and how the scientific community knows and accepts knowledge. Thus, Science teachers must be aware of the distinction between the two epistemologies since one system supports spirituality and welcomes aspects that regard the cosmos as mysterious (Zinyeka et al., 2016). Science, on the other hand, does not accept spirituality and considers the cosmos to be knowable. According to Zinyeka et al. (2016), the basic distinctions between the two epistemologies do not imply incoherence or irreconcilability. There are three viewpoints on incorporating IK into Western Science in the Life Sciences curriculum (Zinyeka et al., 2016, p. 257; Taylor & Cameron, 2016), which are noted here.

2.2.11.1 The inclusive perspective

Figure (2.11) represents the inclusive perspective which reflects IK as part of Science because of some shared tenets between the two systems. The deliberations regarding these stands are made below.

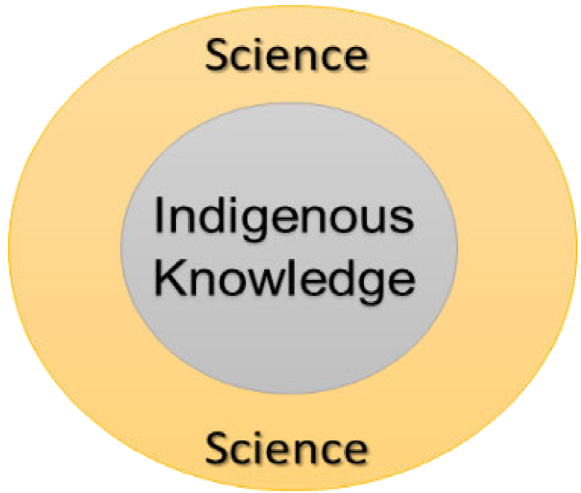

Figure 2.11: The tenets of Science and IK- The inclusive perspective (Steenkamp et al., 2019, p.110)

The issue is that if IK is part of Science, what happens to the tenets that the NOS and the NOIK do not share? It is proposed that the unique individualistic aspect of both IK and Western Science would erode, particularly the identity of IK, because of its holistic nature and being overshadowed and marginalised by Western Science (Steenkamp et al., 2019; Taylor & Cameron, 2016). Scholars believe that IK does not and will not receive the recognition it deserves, and that it will be marginalised in the Science classroom (Cronje, 2015; Diwu & Ogunniyi, 2012).

According to Taylor and Cameron (2016), this will result in IK remaining inferior to Science because IK is frequently seen as pseudo-science, as well as unscientific and as a component of modern life that has passed its prime. According to Snively and Corsiglia (2001), the term "Science" comes from the Latin word "scientia," which means "knowledge." Thus, implying that all nature-related information may be referred to be Science, which legitimises Science's dominance over IK.

2.2.11.2 The mutually exclusive perspective

Figure 2.12 represents the second perspective which is called the mutually exclusive perspective that regards the two systems as being independent from one another

(Zinyeka et al., 2016). Cronje et al. (2015), Lederman et al. (2013), Steenkamp et al. (2019), Taylor and Cameron (2016), as well as Zinyeka et al. (2016) outline that this perspective sees IK and Science as separate domains where one focuses on the material world while the other contains supernatural elements. More deliberations regarding these stands are made below.

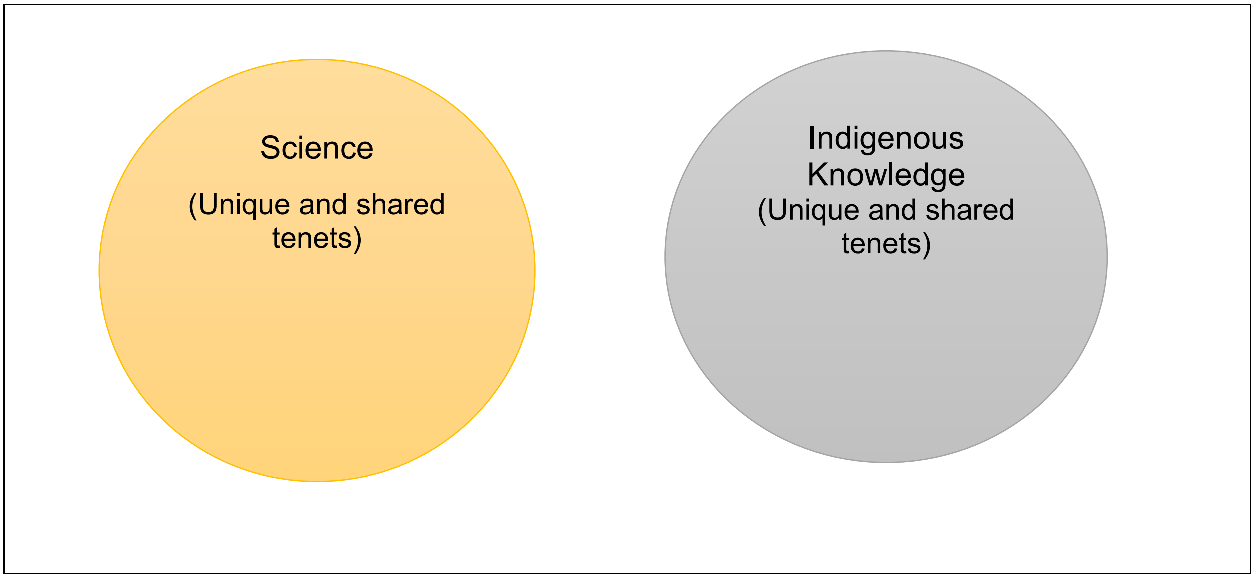

Figure 2.12: The tenets of Science and IK- The exclusive perspective (Steenkamp et al., 2019, p.111)

According to Zinyeka et al. (2016), the exclusive perspective is one in which the two knowledge systems, IK and Science, are viewed as different and independent entities. Science, according to this perspective, is limited to examining and analysing the physical as well as the material world, whereas IK, on the other hand, sees the supernatural as part of its realm (Zinyeka et al., 2016). Unfortunately, the distinctive nature of each epistemology might lose its identity, notably the identity of IK, which is intrinsically holistic and is constantly outperformed by Western Science (Diwu & Ogunniyi, 2012). Furthermore, it is expected that IK will continue to be disregarded and marginalised (Diwu & Ogunniyi, 2012; Steenkamp et al., 2019; Taylor & Cameron, 2016).

This will result in Science retaining its dominance since IK is viewed as pseudo-Science and primitive in certain situations, which is an issue that should not be neglected under any circumstances (Cronje, 2015; Steenkamp et al., 2019). Scholars that advocate for the acknowledgment of IK, on the other hand, see it as a viable epistemology that can function independently (Diwu & Ogunniyi, 2012). As a result, it does not require Science for validation; possibly this perspective is all that IK requires to be accepted (Diwu & Ogunniyi, 2012; Steenkamp et al., 2019). Researchers, particularly those who advocate for this perspective, have continued to see IK as pseudo-Science since it incorporates, among other aspects, the fact that it is metaphysical and holistic. The researchers, on the other hand, stress the stark differences between the two epistemologies (De Beer, 2016; Onwu & Mosimege, 2004). As a result, more researchers continue to urge for IK autonomy, arguing that it is best segregated where it may be fully appreciated (Taylor & Cameron, 2016).

In contrast to the inclusive perspective, the exclusive perspective regards IK as a fundamentally distinct epistemology since what Science perceives as a qualification for pseudo-Science, IK sees as what distinguishes it and as a value for its qualities (Corben & Loving, 2001). According to Zinyeka et al. (2016), once IK is separated from Western Science, teachers who struggle to incorporate IK into Science will no longer have such a barrier. What the scholars who support IK's independence have not addressed is that if teachers who teach IK do not need training, then anybody can teach it; if anyone can teach it, how can this be managed so that teaching retains its integrity as a profession?

2.2.11.3 The overlapping perspective

Figure 2.13 represents the third perspective called the overlapping perspective where IK and Science are shown to share certain tenets although they also have unique tenets (Zinyeka et al., 2016). This perspective is derived from the understanding that IK and the NOS are measurable by the same standards with areas of the interface (Mphofu & Vhurumuku, 2017). More deliberations regarding these stands are made below.

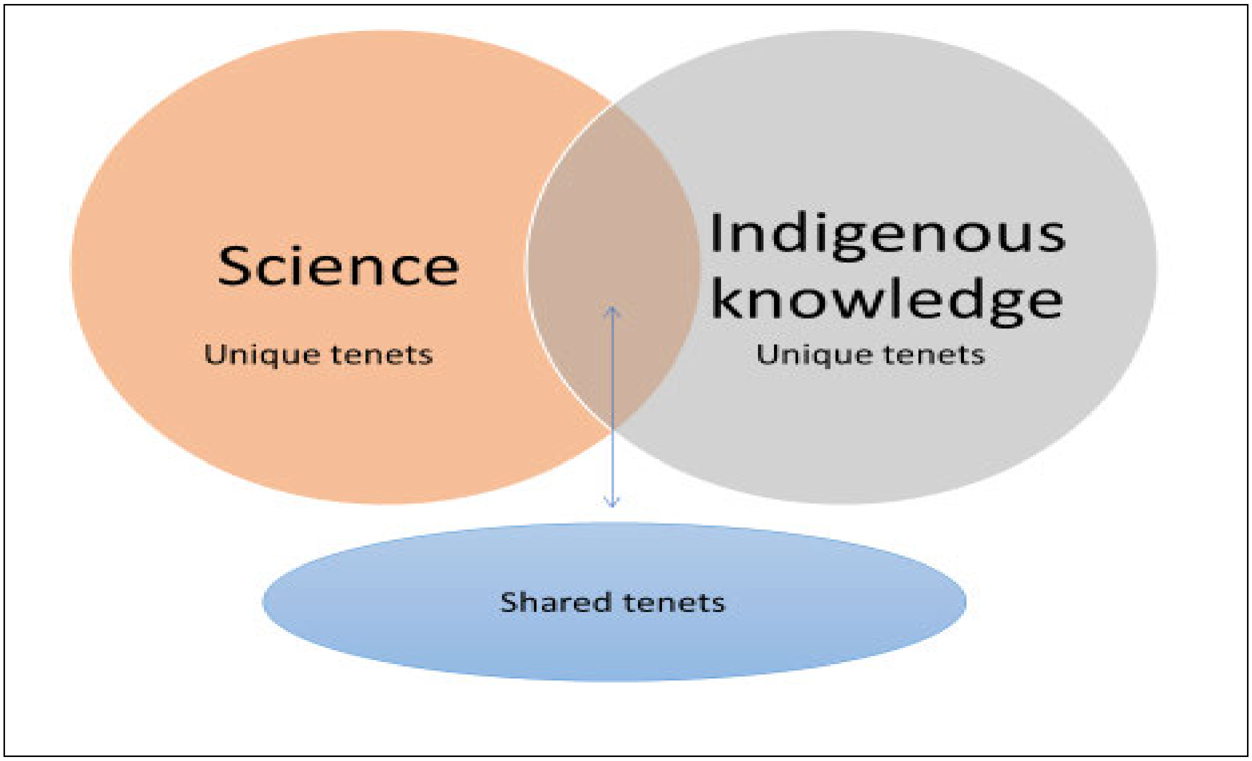

Figure 2.13: The tenets of Science and IK- The overlapping perspective (Steenkamp et al., 2019, p.113)

This perspective advocates for the inclusion of IK in the Science curriculum without dismissing or demeaning IK. The two epistemologies complement one another, and the contrasts between them are critical. This is because they consider the distinctiveness of the two epistemologies so that their identities are not lost (Zinyeka et al., 2016).

According to De Beer and Petersen (2017), even with the introduction of IK, the learners will still conduct an inquiry. The authors emphasised that although an IK phenomenon can be presented, it should be properly researched, or learners should be permitted to create theories. It should be noted, however, that only the common tenets of the two epistemologies may be evaluated. This means that tenets like holistic and metaphysical will be ignored (Steenkamp et al., 2019). According to Cronje (2015), Lederman et al. (2013), Steenkamp et al. (2019), Taylor and Cameron (2016), and Zinyeka et al. (2016), while the two domains share some concepts, they are distinct. Science and IK, in other words, share tenets such as being tentative, inferential, empirical, and creative. As a result, there is overlap and acknowledgement of perspective in the distinct principles of the two systems, but they also accept the shared tenets of the two systems.

This perspective may be very helpful for teachers since it allows them to include IK in Science to assist learners in making sense of the subjects presented in the classroom. Furthermore, the domain functions well in such a way that specific indigenous characteristics may be processed through Science and the claims can be tested (De Beer & Petersen, 2017). This overlapping relationship may be shown in a laboratory investigation into the role of ethylene in seed germination from an indigenous perspective, where Science procedures were employed to examine this phenomenon. De Beer and Petersen (2017) demonstrate how learners may engage with Egyptian and Chinese IK by applying scientific techniques to confirm the IK claims. Another example of this viewpoint may be found in research exploring the role of karrikins in seed germination, which is also the IK of Western Australian indigenous people. The IK procedures were utilised in the study to analyse the phenomena, which was scientifically proven (De Beer, 2012). As a result of the intersecting perspective, both systems are identified, and they can complement each other to increase the teachers' and learners' knowledge.

2.2.12 The position of the NOS in the Life Sciences teaching policy

The Science curricula were altered to Curriculum 2005, which was followed by the National Curriculum Statement (NCS) and the current Curriculum and Assessment Policy Statement (CAPS) when the South African school system revised its curriculum. The Life Sciences CAPS is now more focused on the NOS, and teachers must adopt the constructivist approach, which promotes learner-centeredness and CL methods (Reddy, 2018). This is true since the policy sees Life Sciences learners as having enough expertise. The learners are also seen as problem solvers, and as having the necessary abilities for scientific investigation (SA, 2011).

Learners must be involved in actual activity to successfully acquire skills, such as scientific inquiry. As a result, the DBE made practical tests in the Life Sciences mandatory in Grades 10 and 11 in 2012 (Furiwai & Singh-Pillay, 2020). However, the practical tests necessitated the use of well-equipped teachers, and the research appears to indicate that Life Sciences teachers lack the skills to conduct practical that will inspire learners and advocate for conceptual understanding. Furthermore, there is a contradiction between the intended and realised Life Sciences CAPS policy documents in terms of the types of practical work and the talents that should be cultivated in learners (Furiwai & Singh-Pillay, 2020).

2.2.13 The position of the NOIK in the Life Sciences teaching policy

The political environment changed in 1994, with the installation of a new democratically elected government that was inclusive of all South African citizens, necessitating, among other things, educational revolution (McKnight, 2015). The educational transformation was a necessary "move away from Christian National Education (CNE)" whose aim was to sustain the political and cultural control of pre-democratic dispensation during the apartheid era (Abrahams, 2000; McKnight, 2015, p. 1). This is the era in which the school system was utilised to separate the races through various curriculum by leaving the 'non-whites' disillusioned and their human rights as well as their cultural variety was trampled upon (McKnight, 2015).

After South Africa's new democratic dispensation, there was a need for an education reform and after that there has been several curricula changes. These curricula changes included the Outcomes Based Education (OBE), Curriculum 2005 (C2005); the National Curriculum Statement (NCS) and CAPS. Throughout this journey of curriculum revision, all the policy documents for the Life Sciences were advocating for the integration of IK in their classroom pedagogy.

In the struggle to remedy pre-1994 educational inequities through the South African Constitution, which was ratified in 1996, it became obvious that this country's strength stems, among other things, from its cultural variety. The inclusion of IK in the Life Sciences curriculum recognised and addressed cultural diversity. As a result, comprehending IK helps one to contextualise the constitution's intended acceptance of variety (McKnight, 2015).

In addition, the current Life Sciences policy statement, which is comprised of three specific aims, where Specific Aim three advocates for the inclusion of IK during the process of teaching and learning. The specific aim highlights in detail this necessity to include IK in the Life Sciences classroom in SA: "learners must be exposed to the history of Science and indigenous knowledge systems (IKS) from other times and other cultures…Science should therefore be taught in an integrated way to both enhance the subject and to clarify the relationship between the subject and society i.e. IKS that relate to a specific topic, related history of scientific discoveries and the applications of Science in everyday life"(SA, 2011 p. 17).

2.2.14 Segregation of IK by Western Science

The civilisations worldwide were influenced by their IK, and they depended on it to address their day-to-day issues that were related to the environment and the socio-economic problems, and they were able to solve their day-to-day socio-economic problems (Mawere, 2015). Furthermore, Mawere (2015) cautions of some colonial organisations and their acquaintances who continue to perceive IK as pseudo-Science, irrational and anti-progressive. As such, the concept of 'indigenous' continues to receive criticism, where some academics sees it as being judgmental and scornful particularly to the indigenous people. Consequently, the United Nations had become sceptical and hesitant to use the concept of indigenous regarding a particular group of people (Hountondji, 1997; Mawere, 2015; Turnball, 2000).

The criticism may have resulted from misunderstandings about IK. According to Gorelick (2014), although being as polished and subtle as the Western Sciences, IK has been misunderstood as pseudo-Science on several occasions. Furthermore, IK is sometimes rejected as unconventional since its origins are not as socially, economically, and politically oriented as those of Western Science (Blaut, 1993). Even though the West has no historical, traditional, economic, or knowledge advantages over other nations (Blaut, 1993), this denial is widespread.

In addition, the rejection persists despite research demonstrating that the features of IK comprise a composite of indigenous development and applications such as hypothesising, experimenting, and problem-solving. All of these are substantially related to the dynamics associated with sociocultural difficulties, the body of knowledge of which is comparable to the peer-reviewed research that is generally conducted in Western Science (Handayani et al., 2018). The distinction between IK and Western knowledge taught at higher education institutions is that Western countries see IK with dissatisfaction. This is because there appears to be a lack of understanding about how

IK links to the global community, there is still a need for IK to be integrated with Western Science (Horn, 2005; De Beer & Whitlock, 2009).

According to Senanayake (2006), the majority of IK is being ignored because of the entrance of Western technology and ideas that offer remedies but lack sustainability. That is considered a social wealth for the poor who are struggling for existence, and hence it cannot be regarded seriously. Despite this, the literature reveals that IK is still valid and relevant today, and it aids in the discourse of issues such as sickness, poverty, and hunger that are called for in sustainable development (Cronje et al., 2015; Naidoo, 2010; Odora Hoppers, 2004). The unpleasant reality of IK neglect begins with the indigenous populations that have evolved and lived through it, as well as the issue that occurs when the West lacks answers to specific situations that would require this sort of knowledge (Senanayake, 2006).

As a result, the South African curriculum remains Eurocentric, and it continues to dismiss social activities occurring in the natural environment of indigenous learners. Indigenous learners continue to feel alienated, which contributes to social inequities in terms of cultural values and indigenous wisdom (De Beer & Whitlock, 2009; Handayani et al., 2018). As a result, the neglect and isolation of knowledge itself continue to have an influence on the social and cultural tragedy that gave rise to the humanitarian crisis, bringing us back to the necessity for IK integration (Fedosejeva et al., 2018; Herusatoto, 2012; McInnes, 2017; Handayani et al., 2018).

It is vital to stress that IK is an inherent natural resource that may ease Science teaching and learning for disenfranchised and disadvantaged indigenous people (Ajaps, 2023; Gondo et al., 2023; Vanek et al., 1989). Thus, the incorporation of IK into school-taught Science is critical in preventing cultural clatter. This is because anytime Life Sciences learners attempt to learn meaningfully, a Life Sciences curriculum that is sensitive to integration into IK supports cultural survival (Brown, 2017; Emeagwali, 2003; Shizha, 2008). An IK-integrated Science curriculum facilitates learners' adaptation across cultural boundaries into school Science, which is known as collateral learning, which refers to the inspiration of meaningful learning in the Science Classroom (Aikenhead, 2002; Jegede, 1997; Mitchell, 2020; Ogunniyi, 1988; Shizha, 2008).

When IK is integrated into Science classroom pedagogy, it will include attitudes, knowledge, and skill development elements (Handayani et al., 2018). These are the elements that will aid in bridging the gap and forging a vital link between what learners confront in school and their cultural and natural surroundings. Handayani et al. (2018) go on to say that when IK is specific to a Science classroom, there is always the possibility of establishing meaningful teaching and learning that aids in closing the gap between learner successes in the Science classroom and in the community.

2.2.15 The need to integrate IK into the Life Sciences curriculum content

Encouraging teachers to investigate IK within the context in which they teach will help both the Life Sciences teachers and learners (Quigley, 2009). Using local IK in the learners' immediate surroundings would aid in tapping into the learners' contextual framework, promoting meaningful learning and conceptual comprehension (Lee, 2001; Ogunniyi, 2023). Teachers, on the other hand, will be able to reach a high level of classroom pedagogy by utilising the resources at their disposal.

Recognising IK in Life Sciences is critical for these learners' social identities, sentiments, and emotional well-being, as well as for learners who struggle to embrace a Westernised Science curriculum (Bloom, 1956-1972; De Beer & Whitlock, 2009). Furthermore, IK is unique to a certain natural context and the traditional setup that assists in the protection and promotion of its community (Senanayake, 2006). As a result, it continues to be constructive in the growth of the community, whose ethos, norms, and regulations are all influenced by the same culture (Odora Hoppers, 2021; Senanayake, 2006).

Ramnarain (2014) considers the differences in epistemological perspectives between IK and Western Science. The author emphasises that these discrepancies result in poor performance among learners who must contend with a struggle between their "everyday socio-cultural worldview" and the "Science worldview" that they encounter for the first time in their Life Sciences courses (p.1). According to Ramnarain (2014), such an event forces learners to adjust their existing worldview, forcing them to build a new scientific way of perceiving the world, which is pro-rote-learning rather than meaningful learning.

As much as IK includes all skills and knowledge, indigenous people in a certain civilization value it so that they may profit from their environment (De Beer & Whitlock, 2019). It is worth mentioning that even acknowledging the learners' sociocultural distinctiveness can make a visible impact on their ability to learn meaningfully. According to De Beer and Whitlock (2019), this may be accomplished by including IK within the Life Sciences curriculum. Integrating IK into a Life Sciences curriculum can promote a constructive learning experience and environment for indigenous learners who are not interested in a Eurocentric school Science curriculum (De Beer & Whitlock, 2019). According to Cummins and Swain (1986) and Le Grange (2019), the Western Science school curriculum language is frequently hostile and overly cognitively demanding for most indigenous Life Sciences learners. Despite evidence demonstrating that IK has fewer problems than Western Science (Cummins & Swain, 1986; Klos, 2006), many learners struggle. Because IK has a realism and experience-based character, including it within the Life Sciences curriculum would improve indigenous learners' science comprehension (De Beer & Whitlock, 2019; Klos, 2006).

In addition, Mandikonza (2019) contends that the contextual dynamics of Life Sciences learners have a significant impact on their classroom experiences. As a result, indigenous learners in rural locations, or learners who are more committed and socially disposed to their IK, struggle to apply context between their IK experiences and what they study in Science class (Mandikonza, 2019). This calls for the incorporation of IK within the Life Sciences curriculum to assist learners in understanding the situations in their classrooms. If this fails, most of these indigenous learners will continue to struggle to recognise the relevance of the school Science curriculum in relation to their history and cultural practises (Mandikonza, 2007). The need to make education accessible and consider the learners' past knowledge might be critical in overcoming the classroom deficiencies of Life Sciences learners. Furthermore, it will aid learners' grasp of the scientific principles envisioned in policy papers and curricula (Mandikonza, 2019).

2.2.16 The disenfranchisement of the non-African IKs in the South African Life Science Curriculum

For many years, there has been debate on how to incorporate IK in Life Sciences in South African schools. This discussion became a focal point for many scholars, with the abandonment of other flaws mentioned in the policy statement calling for the inclusion of IK. Reddy et al. (2019) warn that in the endeavour to integrate IK with Western Science, it is important to remember that African IK is not the only IK in South Africa. Indian, as well as Koi and San IK, must be included in the IK to be integrated with the Life Sciences curriculum. As a result of its multiracial and multicultural communities, South Africa is widely regarded as a rainbow nation. De Beer and Van Wyk (2019), and Reddy et al. (2019) argued and demonstrated that there are significant community of Indian Koi and San people and that these people have a rich IK culture whose elements should be included in the integration of IK with the Life Sciences. The writers make readers aware that Africans are not the only indigenous population in South Africa. There is also a request for the incorporation of Indian IK into the Life Sciences to assist in contextualising the Life Sciences for Indian learners.

In addition, Reddy et al. (2019) emphasise that the exclusionary effect of Western Science on IK highlights the need to address the need to decolonize the Science curriculum through the inclusion of IK. Regardless of the adjustments, the South African curriculum has seen this impact since switching to CAPS, thus all South African indigenous people should rejoice in the benefits of these improvements. According to Reddy et al. (2019) and SA (2011), the Life Sciences policy statement (CAPS) has a flaw in that it takes a sporadic attitude with IK biased to African IK (Life Sciences Specific goal 3) as if African IK is the only IK that exists in South Africa.

2.2.17 Challenges amongst the Life Sciences teachers on how to integrate IK in their classrooms

The need to include IK in Science curriculum has long agitated the global and national village, to the point that even Science teachers recognise its value and the necessity for integration in Science classrooms (Cronje et al., 2015). Despite the development of scientific literacy by making Science information widely available to learners in their daily lives, misunderstanding among teachers about how to incorporate IK has developed (Cronje et al., 2015). According to the literature, this uncertainty and lack of integration are driven by the anxiety that Science teachers have that they are teaching pseudo-Science. This is because of not knowing which teaching strategy to employ in their Science classrooms and the epistemological difference between Science and IK (Cronje et al., 2015; De Beer, 2012; Motwa, 2011).

It is reasonable to admit that IK and western Science are two distinct epistemologies, both with a presence on the face of the Science curriculum. Despite this, teachers are required to incorporate them into one in their classes even though they are only qualified to teach one (Barnhardt & Oscar Kawagley, 2005; Cronje et al., 2015). As a result, academics and Life Sciences teachers must develop treatments and teaching practices that respect both epistemologies. Since the beginning of colonisation, IK has been denied the right to vote. Dziva et al. (2011) and Mayana (2020) observed in their investigations that Life Sciences teachers continue to have restricted views of IK and perceive it as less important information to add to the Science classroom.

The authors suggest that the hidden character of the Science curriculum influenced the teachers' perspectives and opinions. Furthermore, while the integration of IK in the classroom is envisioned in the Life Sciences curriculum, teachers tend to do so hurriedly, providing one or two contexts only to maintain the status quo. In other circumstances, Life Sciences teachers have no consideration for IK integration (De Beer & Mothwa, 2014).

According to De Beer and Mothwa (2014), integrating IK in the Life Sciences classroom was much more difficult than meets the eye and it further suggested that this could be due to the lack of the teachers' PCK. The authors wondered if the Life Sciences teachers were equipped to teach the IK perspective (De Beer & Mothwa, 2014) because Petersen (2010) conducted a study that revealed the Life Sciences teachers' dependence on chalk and talk, which remains a challenge. Thus, pedagogically, the teachers have nothing to offer concerning how to integrate IK in their classroom.

2.2.18 The possibility and the challenges of using argumentation teaching for the integration of IK into the South African Life Sciences curriculum

The researchers concluded that when CAPS was introduced, the new curriculum resonated with the concept that true learning is embedded in the context of the learners' life, among other reasons. This includes learners' IK, and each learner's knowledge creation is a product of social mediation via cultural experiences (Hewson & Ogunniyi, 2011). As a result, Life Sciences teachers need applicable techniques to aid in integrating IK inside the Life Sciences, and such an approach necessitates mental innovation on the part of the teachers. This prompted the recommendation that argumentation be included as a method for integrating IK (Hewson & Ogunniyi, 2011). According to Hewson and Ogunniyi (2011), argumentation is regarded as a likely teaching approach for incorporating IK and to transform how Science is traditionally taught in South African schools.

Argumentation is defined as a verbal, social, and logical effort that is intended to persuade a reasonable critic of the validity of a viewpoint by presenting a set of assertions validating or disputing the notion that is conveyed in the stance (Van Eemeren & Grootendorst, 2004). According to Felton (2004), the social and verbal procedures supported through argumentation help in improving the communication skills of the learners, while the rational procedures improve the cognitive process skills.

One of the difficulties in incorporating IK through reasoning is its compatibility with the South African Science curriculum. According to the literature, many Africans negotiate to learn, and in South Africa, it is more ethical to compromise or develop consensus than to be confrontational or contentious with one another (Easton, 2011; Gallard Martnez, 2011). Instead of discussion, many South African cultures resort to forging consensus by corresponding and skilfully combined activities (Nafukho, 2006). Easton (2011) is very critical of this process, questioning the legitimacy of the sort of information established in this type of deliberation and questioning if the produced knowledge is real.

Easton (2011) acknowledges that certain cultures and groups in South Africa employ some form of argumentation but claims that the approach is not as strong as argumentation that strives to decide who is correct or incorrect in a discussion. As a result, the parties finally reached a negotiated agreement. Concerns about the compatibility of the argumentation in South African Science classrooms were raised again in the study, with participants emphasising the importance of learners having appropriate language skills and prior knowledge (Hewson & Ogunniyi, 2011; Gallard Martinez, 2011). The other participants complained about the extra time required for argumentation teaching (Hewson & Ogunniyi, 2011). Considering the many administrative commitments that the South African teachers have, it makes it implausible for the Science teachers to use it for teaching, let alone using it for integrating IK.

2.2.19 Engaging pedagogies to integrate IK in a Life Sciences content

As a known argument that Science classrooms subscribe to social constructivist approaches, for many years the Science teachers have emphasised the importance of prior knowledge during the construction of new knowledge in the Science classroom (Angaama et al., 2016). Indigenous Life Sciences learners bring their worldview to the classroom, and in most cases, that worldview is ignored, depriving these learners of their very own raw material that is responsible for their meaningful learning (Angaama et al., 2016; Corbin, 1996; Ogunniyi, 1988). From a social constructivist standpoint, this highlights the relevance of the learners' past knowledge in the Science classroom. Science classrooms should allow for learners' past knowledge, whether it is cultural background or not, but it should be celebrated and exploited for learners' learning. This is because the indigenous learners' cultural background will serve as a lens which helps them to interpret experiences, as such their IK should be considered when the teachers choose the relevant teaching method for their Life Sciences classroom.

As previously stated, social constructivism may play an important part in indigenous learners' meaningful learning. Consider engaging pedagogies like PBL and CL as teaching-learning tools (Petersen et al., 2019). Engaging pedagogies are any inductive teaching-learning techniques, such as PBL and CL, or contextualised learning, in which learners actively engage in the learning process while developing 21st-century skills

(Petersen et al., 2019). The authors suggest that inductive learning in its nature is learner-centred, and it stimulates active learning (Petersen et al., 2019).

Problem-based learning (PBL)

According to Petersen et al. (2019), the incorporation of IK into the Life Sciences curriculum necessitates the use of novel teaching and learning strategies and one such teaching-strategy is PBL. PBL was originally used in the medical education curriculum, followed by the Engineering and Nursing Education curriculum all over the world and decades later it was presented to secondary school education (De Simone, 2014; Golightly & Muniz, 2013). PBL "is a social-constructivist teaching-learning strategy" (Hassan, 2013, p. 49-51), it uses an unstructured, open-ended real-world problem as a starting point for learning (Hmelo-Silver & Barrows, 2006). PBL undermines the established culture of school teaching and the teachers who function as facilitators may struggle to facilitate conversations in the collaborative learning contexts (Ngeow & Kong, 2001; Petersen et al., 2019).

When the group members are generating the solutions to the stated challenge in PBL, they must overcome the academic disciplinary boundaries (Petersen et al., 2019). PBL implementation can aid in IK integration by concentrating on finding and using local, formal, and informal knowledge in solving local real-world issues in a social environment rather than in a textbook (Dahms & Stentoft, 2008; Petersen et al., 2019). It is where the Life Sciences teacher becomes the facilitator, and the learners take on the role of collaborative researchers who deal with a problem and work out a solution for the problem (Maurer & Neuhold, 2012). This implies that the teacher is a facilitator and the learners become the co-constructors of knowledge. The Life Sciences teachers used PBL to engage in an activity on the post-harvest physiology of cut flowers or to investigate the influence of karrikins on seed germination (De Beer, 2012). Such teaching-learning strategy can also be effective for laboratory work, thus in the context of this study several laboratory works was carried out during the SLPs.

Laboratory work was used to guide the Life Science teachers on how to integrate IK in a Life Sciences classroom. The teachers used laboratory work to integrate IK by using the Kirby-Bauer technique where they tested the anti-microbial activity of *muthi* plants. The participating teachers were also engaged in the fermentation process by using warm water, yeast, sugar, empty 500ml water bottles, mealie meal and balloons to determine the rate of fermentation as depicted on Figure 2.14.

Figure 2.14: Life Sciences teachers engaging in the process of fermentation at the Landmark Protea Hotel in Polokwane (Author's own work).

The participating Life Sciences teachers depicted in Figure 2.14 used water under different temperatures to determine the rate of fermentation. The teachers also used monosaccharides (table sugar) and polysaccharides (mealie meal) to determine the rate of fermentation under different carbohydrates.

In addition, the participating Life Sciences teachers engaged in laboratory work where they used a leaf from a tree in the University of Johannesburg under the guidance of the laboratory scientists to extract the Deoxyribonucleic Acid (DNA). Figure 2.15 depicts the teachers in the laboratory about to extract the DNA of a leaf.

Figure 2.15: Life Sciences teachers engaging in DNA extraction of a leaf at the University of Johannesburg in the ADCB laboratory (Author’s own work).

The participating Life Sciences teachers depicted in Figure 2.15 are the teachers that were engaged in tissue disruption or homogenisation, cell lysis in DNA extraction buffer. Furthermore, the teachers were guided into separating the DNA from the other cellular components, the DNA precipitation or washing

Cooperative learning (CL)

According to Petersen et al. (2019), CL can be viewed as a teaching-learning strategy that is founded on the constructivist values. It is defined as being a learner-centred, approach to active learning that uses organised scenarios in which fixed small groups engage in a non-competitive manner to achieve a common objective (Sandi-Urena et al., 2012). Furthermore, Johnson and Johnson (1994) describe CL as a type of group work in which the learners collaborate in small groups to achieve a common goal. The success of CL is dependent on the presence of basic elements such as promoting positive interdependence, individual accountability, face-to-face engagement, interpersonal small group abilities, and group processing (Johnson & Johnson, 1994; Lubbe & Petersen, 2022; Petersen et al., 2019; Sandi-Urena et al., 2012).

According to Johnson and Johnson (1994), positive interdependence happens when the learners believe that they are inextricably linked with their group mates in such a way that they cannot achieve unless their group mates succeed, and vice versa. On the other hand, through individual accountability to achieve the shared objective, each member of the group is held accountable and responsible for their segment of the task (Johnson & Johnson, 1994). Furthermore, Johnson and Johnson (1994) caution that although the group learns together, it is important that each group member is ready to complete the same task alone. Johnson and Johnson (1994) suggest that the face-to-face promotive interaction is defined as the individual members of the group inspiring and assisting each other in their effort to reach common objectives, while interactive interaction is when the group mates give each other effective and efficient help. Interpersonal and small-group wins are achieved during the given activity, and these skills include supporting each other, using effective communication and the ability to resolve conflicts (Johnson & Johnson, 1994). Lastly, group processing is viewed as the process during the CL activity where the group mates must determine through self-reflection and group reflection if and how well they have achieved their common objective (Johnson & Johnson, 1994).

According to Petersen et al. (2019), directed by the curriculum content, the teacher can use the teaching methods such as the Jigsaw, the group-individual-group, the note-taking pairs, Cooperative graffiti, De Bono’s six thinking hats, and the think-pair-share (Lubbe, 2015; Petersen & Mentz, 2016). In the context of this study, the Jigsaw and De Bono’s six thinking hats were used during the SLP that was held at the Landmark Protea Hotel in Polokwane.

According to Conley et al. (2010, p.130) the Jigsaw “can generate a lot of energy in the classroom when learners are learning about various topics”. The Life Sciences learners can be divided into several groups depending on the number of learners that are in the classroom. Where each group (Home group) is comprised of the learners who will each research a different aspect of the same topic. Then each learner will join a group (expert group) of the other learners in the classroom who research the same aspect (Conley et al., 2010). In other words, each learner in the classroom has the opportunity to be an expert on an aspect of a topic (Johnson & Johnson, 1986). Below as depicted in Figure 2.16 of the Life Sciences teachers, is a photo that was taken during the SLP in Polokwane, while the teachers engaged using the Jigsaw to discuss ethnobotanical plants.

Figure 2.16: Life Sciences teachers engaging in an activity using the Jigsaw at the Landmark Protea Hotel in Polokwane (Author's own work).

The Life Sciences teachers depicted in Figure 2.16 used the Jigsaw to integrate IK by engaging in the discussion of the ethnobotanical plants such as the cancer bush, marijuana, and the African potato. The expert groups researched each plant, and they deliberated, as well as made presentations and by doing so the teachers were effectively learning Life Sciences through the integration of IK. As such, the participating Life Sciences teachers were expected to use the teaching method to integrate IK in their respective Life Sciences classrooms.

In addition, De Bono's six thinking hats is a teaching method that allows the learners to view the same (controversial) topic from different perspectives. This is because different hats represent different perspectives on the same ‘controversial’ issue. The method is comprised of six hats which represent different perspectives. De Beer and Whitlock (2009, p. 209) highlight that, although the teaching method is established for western Science, "it embraces some cultural aspects and IK… It gives practical ideas and how one can address the practices of contemporary Science". The authors suggest, that in the quest to use this method to integrate IK in a Life Sciences classroom, the teachers need to consider the local context. The picture in Figure 2.17 was taken at the SLP in Polokwane during a discussion about the role that is played by the traditional initiation schools in spreading or preventing sexually transmitted diseases.

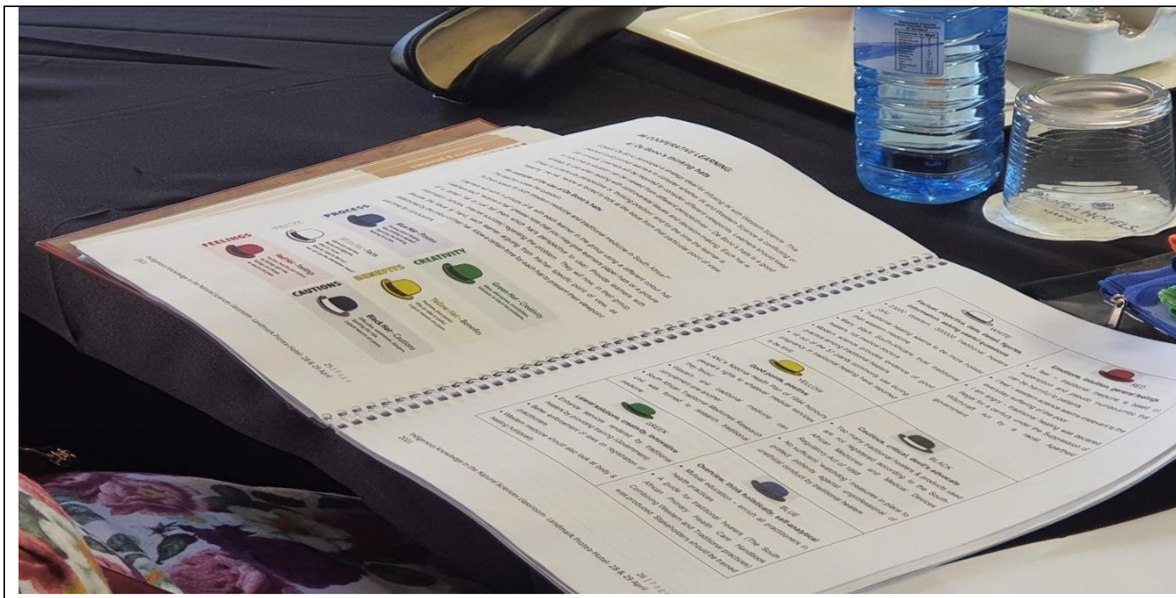

Figure 2.17: The manual used by Life Sciences teachers to engage in an activity using De Bono’s six thinking hats at the Landmark Protea Hotel in Polokwane (Author’s own work).

Figure 2.17 is a manual that is used by the Life Sciences teachers to integrate IK, by engaging about a topic on the viruses or a topic that is related to diseases. The teachers were facilitated while deliberating on the role the initiation schools (a traditional passage to manhood in Xhosa, Pedi, Tsonga, and Venda cultures) play in the prevention and in the spread of sexual and other transmissible diseases. The teachers discussed how circumcision is necessary and helpful in the prevention of some diseases. On the other hand, the others deliberated about how the unsterilised blades that are used to perform the process of removing the initiate's foreskin during the initiation ceremonies can promote the breeding for blood transmissible diseases from one initiate to the other. By including the role that is played by the initiation schools in promoting or preventing the spread of STDs, the teachers will be integrating IK in their Life Sciences classrooms.

2.2.20 Teacher development programmes for the integration of IK in Life Sciences

There is a lack of direction on how to integrate IK in a Life Sciences classroom by the Life Sciences CAPS document and the lack of consultation with the Life Sciences teachers who are the foot soldiers with regards to the implementation by those developing policies (Angaama et al., 2016). On an encouraging note, recent literature has suggested that the teacher development programmes have what it takes to deliver the Life Sciences teachers out of this quagmire which the Life Sciences policy document has failed to provide proper guidance to the teachers in question (De Villiers et al., 2016; Jacobs, 2015; Mabasa & Singh, 2020; Vaughn & De Beer, 2020). According to Mhakure and Mushaikwa (2014), the teachers' identities are significant in influencing the educational policy, curriculum, classroom pedagogy, and assessments and how this professional development needs their commitment to the profession.

In a study on contextualising Science and Mathematics teacher professional development in rural areas, Vaughn, and De Beer (2020) argue that South Africa fails to address the teachers' pedagogical topic understanding or competence to incorporate IK into the curriculum appropriately. In the very same study, the authors found that teacher professional development is significant in preparing the Life Sciences teachers in the quest to integrate IK. They also found that the professional development initiatives work to their optimum best when the cultural context of schools that are based in the rural areas is considered because that is central in helping to meet the needs of the teachers based in those settings (Vaughn & De Beer, 2020). These findings help in addressing the dilemma of the teachers that do not know how to integrate IK.

Furthermore, another study that was carried out on the teachers’ affective development during IK professional development by Jackson et al. (2016) found that the teachers are more driven, and they show more interest in integrating IK in their Life Sciences classroom after a teacher professional development programme. The authors further warned that there is a need for continuous teacher professional development to help in the continued scaffolding of the teachers' PCK. This study echoes similar knowledge that is shared by the study on the impact of professional development and IK education officers on the Australian teachers' indigenous teaching and learning by Craven et al. (2014). The study found that "the more frequently teachers are involved in professional developments in indigenous teaching, the higher self-concept they had in teaching indigenous children and the more they adopted indigenous teaching strategies" (p. 85). The frequent teacher professional development will help the teachers to realise that like Science, IK evolves in light of new knowledge and as such there is no way that IK can be (Onwu, 2009) old, degraded, degrading, and incompatible with contemporary or present thought. As such it is evident that the recommendations and the findings made by some of the researchers address the issues that were raised by Onwu (209).

De Villiers et al. (2016) conducted a study on the problem-based and self-directed learning outcomes during an IK teacher professional development training for Life Sciences teachers. The authors found that the professional development workshop contributed positively to the teachers' development of their PCK, and it improved their attitude in integrating IK in their Life Sciences classroom. The teachers' ability to use the teaching strategies that will make integrating IK easier come as a victory to the indigenous learners. Furthermore, this finding addresses the suggestion that is highlighted by (Onwu, 2009, p. 25-26), "teachers lack models to emulate and appropriate teaching strategies to handle IK integration". Therefore, the more frequently Life Sciences teachers' professional development toward integrating IK in their classroom is carried out, the more facilitators and researchers can identify the gaps that need to be addressed for successful professional development.

2.3 Summary of Chapter Two

This chapter sought to review the literature where I ventured into Vygotsky's social constructivism and its significance in promoting the Life Sciences teachers' understanding of the NOS and the NOIK during the SLPs. Furthermore, this is shared on the ZPD which led to the adaption of Warford's ZPTD as the basis for the scaffolding of the Life Sciences teachers' learning during the SLPs. The deliberation of the CHAT was used as the lens to view the findings of this study.

The conceptual framework of this study focused on the aspects such as SDL as the study intended to explore the influence of an intervention on the Life Sciences teachers' perceptions of their own SDL abilities, thus the concept had to be explored and deliberated. The aspects such as conceptual change would be central to the Life Sciences teachers’ understanding and acceptance of the new knowledge that is acquired during the SLPs. The other aspects that were deliberated upon were PCK, the conceptualisation of NOS and IK as well as the NOIK.

In addition, I further deliberated on the three epistemological perspectives of the NOIK and the NOS, the inclusive perspective, the mutually exclusive perspective and the overlapping perspective, the position of the NOS and the IK in the Life Sciences policy. I also deliberated on the appropriate teaching methods for the integration of IK. Lastly, there was a deliberation on the Life Sciences teacher professional development in the integration of IK in Life Sciences classrooms.

This point precedes Chapter 3of the study which gives centre stage to the research methodology driving this study. The chapter will share a detailed deliberation of the research design, how data was collected and how data was analysed.

CHAPTER 3: METHODOLOGY

3.1 Introduction

When doing research, various authors and researchers use a number of terms to describe different concepts that are related to research methodology, or they use the terms interchangeably (Maree 2016). Some of these terms include but are not limited to the method(s), the methodology, the paradigm, and the theoretical perspectives/assumptions. This study follows Maree's description of what the concept methodology entails. The author makes use of a 'bridge' as a metaphor to describe my research journey (see Figure 3.1). Maree (2016) says that the methodology acts as a strategic, yet adaptable guide, and that it consists of the techniques by which the academics go about their task of acquiring data, analysing, re-counting, and clarifying phenomena. My own interpretation is therefore that the methodology concept is an encapsulating term describing all the aspects of the research process.

In the paragraphs that follow, the research questions, as well as the different aspects that encapsulate the methodology are unpacked under the following sub-headings; the research approach (mixed methods); the research paradigm (pragmatism); the research design (concurrent transformative design); sampling; methods; analysis (using Cultural Historical Activity Theory (CHAT) as research lens); reliability and validity matters, and lastly the ethical considerations.

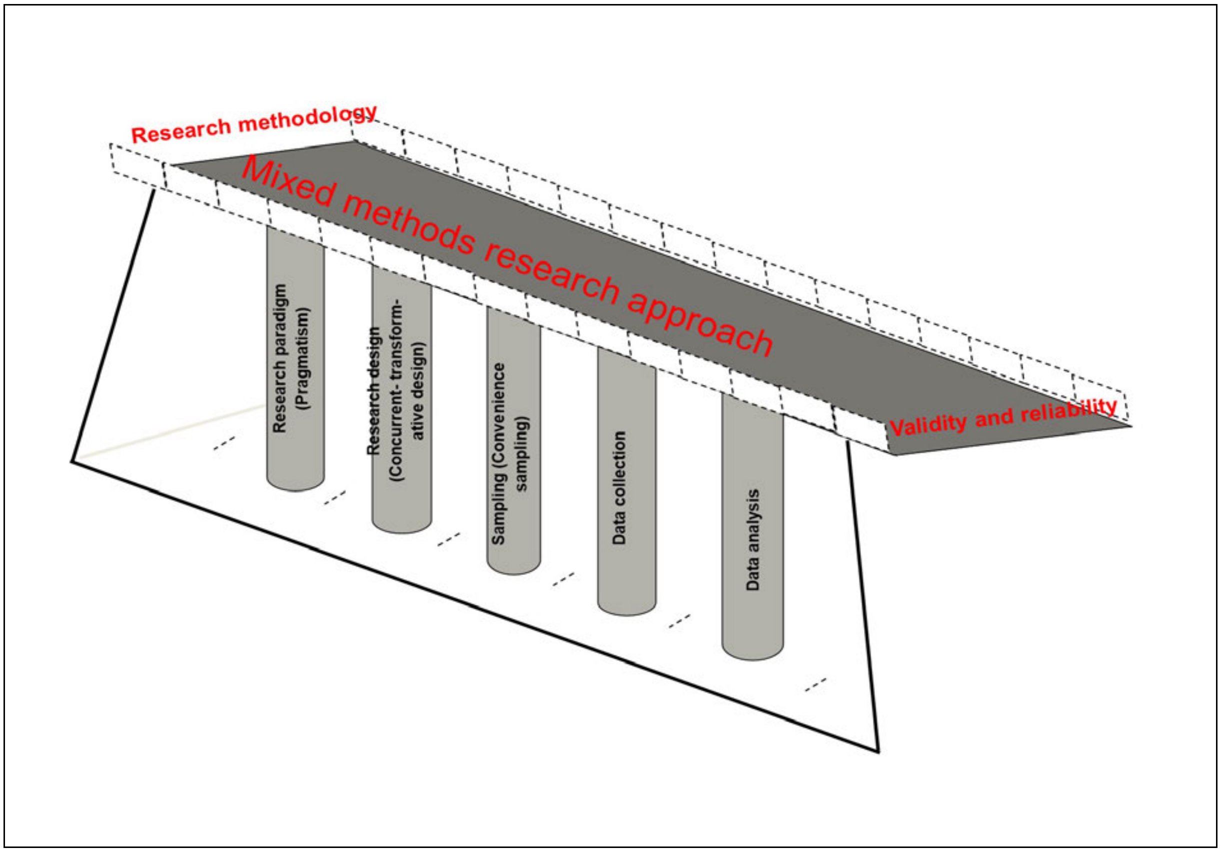

Figure 3.1: Contextualised bridge metaphor (Author's own construct based on Maree, 2016, licensed under CCBY 4.0 p. 51)

3.2 The research aims and research questions

3.2.1 The aim of the study

The main aim of the research was:

To investigate the influence of an intervention on the Life Sciences teachers' perceptions of the Nature of Science (NOS) and the Nature of Indigenous Knowledge (NOIK), as well as the influence thereof on their pedagogy and Self-Directed Learning (SDL).

3.2.2 Secondary aims

a. To determine how the Life Sciences teachers teaching in the urban, in semi-urban and in the rural-based schools perceive the NOS, and how these perceptions influence their pedagogy pre- and post-intervention.

b. To determine how the Life Sciences teachers teaching in the urban, in semi-urban and in the rural-based schools perceive the NOIK, and how these perceptions influence their pedagogy before and after the intervention.
c. To determine what (if any) transfer of new knowledge and skills occur in the classroom post-intervention.
d. To determine how the Life Sciences teachers' perceptions of their SDL changed post-intervention.

3.2.3 Primary research question

What is the influence of an intervention on the Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and the implications for their pedagogy and self-directed learning?

3.2.4 Secondary research questions

a. How do the Life Sciences teachers teaching in the urban, in semi-urban and in the rural-based schools perceive the NOS, and how do these perceptions influence their pedagogy before and after the intervention?
b. How do the Life Sciences teachers teaching in the urban, in semi-urban and in the rural-based schools perceive the NOIK, and how do these perceptions influence their pedagogy before and after the intervention?
c. What transfer of new knowledge and skills occur in the classroom, post-intervention?
d. How did the Life Sciences teachers' perceptions of their own SDL change, during their participation in this research?

3.3 Mixed methods research approach

The type of research method that is used in a research study is fundamental. Firstly, this is because the research approach is central to the failure or to the success of a research study as it outlines which research design the study can follow (Amaratunga et al., 2002). Secondly, it influences the targeted group to take part in the study, which instruments would be used to collect data and how each instrument would be used to respond to the research questions (Kulatunga et al., 2006). Lastly, it affects how the data would be gathered and examined. Hence, as briefly deliberated in Chapter 1 of this study, it was indicated that a mixed methods approach was followed to find the answers to the research questions.

Generally, the mixed methods research embodies a study that is comprised of gathering, examining, and inferring qualitative and quantitative data in a single study. Furthermore, it offers a comprehensive understanding of a research study (Cameron, 2014; Creswell, 2007). In other words, as emphasised by Creswell and Clark (2007), in MM research, the fundamental principle is that the use of the qualitative and the quantitative approaches combined provides a more comprehensive answer to the research problems than whichever approach alone. Furthermore, the application of the MM in this study provided new knowledge in the Life Sciences teaching because the findings gathered from the amalgamation of both approaches have what it takes to enrich the comprehension of Life Sciences teaching.

The rationale for selecting the MM type of approach is that it provides a better comprehension of the research problem of this study than the qualitative or the quantitative approach alone. Hence, Schensul (2008) suggests that the methodology that is used in a research ought to define how the study is executed with explanations on why some techniques were used to accomplish the general objective of conducting the research. This requires the research design that provides direction on which instruments should be used to collect data, how each data collection instrument is intended for use, how each data set will be used to address each research question, and how the data will be analysed. Hence, a study on incorporating both qualitative as well as quantitative data in MM research by Almalki (2016) found that the MM research was a suitable study approach to any given project. This was because of this approach's potential to offer greater depth and breadth of data, which may be impossible to get if only qualitative or quantitative methods were used in a study. Consequently, the study used multiple research instruments to collect data, which needed to be analysed both qualitatively and quantitatively to address the research questions and the research aims that were developed for the study. According to Poudel (2014), qualitative data is viewed as sensitive, nuanced, detailed and contextual, whereas quantitative data is viewed as hard, rigorous, credible, and scientific.

According to the Merriam-Webster Dictionary (2023), a typology is the study of, or an analysis or classification based on the types or categories. In the context of this study, a typology is viewed as a classification that is based on the types or categories. This is because this section sought to categorise which mixed methods typology was used in this study. In an attempt to classify the approach, people have to think about the three-dimensional typology of MM which explains the level of mixing, time orientation and the emphasis of methods (Leech & Onwuegbuzie, 2009). In other words, firstly, the intention is to determine whether the approaches are partially or fully mixed. Secondly, the intention is to also determine if the time orientation of the approaches is concurrent or sequential, as well as to determine whether the emphasis of the methods is equal or there is one dominant method (Leech & Onwuegbuzie, 2009).

In an attempt to determine the relevant typology for this study, I first deliberated on the types of instruments that were used in this study, and how each instrument relates to each approach. The study used six data collection instruments, with five qualitative instruments and one quantitative instrument. The data was collected concurrently and for that reason, the study is qualitatively driven (Hesser-Biber et al., 2016) or dominant. As such, the study is a partial MM research with an emphasis on the qualitative aspects (Walker & Baxter, 2019). Both sets of data (qualitative and quantitative) were collected alongside, and they are independent of one another thereby making the typology of the study a partially mixed concurrent dominant status or partially mixed concurrent QUAL + quant (Leech & Onwuegbuzie, 2009). The rationale for using this typology is on the basis that all the five qualitative and the one quantitative instrument were qualitatively and quantitatively analysed, respectively (Poudel, 2014).

3.3.1 The research paradigm

The search and development of a research paradigm that equally caters for the qualitative and the quantitative aspects of the MM research has received a lot of attention from various researchers such as Creswell and Clark (2007), as well as Greene (2007). Lincoln et al. (2011) defines a 'paradigm' as the term that is used to refer to the philosophical assumptions or the core ideas that influence My actions and determine their worldview. On the other hand, Teddlie and Tashakkori (2009) define a paradigm as a worldview that is composed of various philosophical expectations that are elated to that point of view. Furthermore, Morgan (2007) defines a paradigm as the organisation of the views that have an influence on how the researchers choose both the questions they study and the methods they use to study them.

In MM, Creswell and Clark (2018) make mention of the paradigms such as post positivism, constructivism, and interpretivism. The paradigm befitting this study was pragmatism, which was initially coined by Peirce (1839-1914) and further developed by James (1842-1910) and Dewey (1859-1952). According to Creswell and Clark (2011), pragmatism is defined as a paradigm that purports to bridge the gap between the scientific method and the structuralist orientation of the earlier approaches and the naturalistic techniques as well as the freewheeling attitude of the contemporary approaches. The rationale for using this paradigm was that it encourages multiple uses of the research methods where the researchers can utilise the research methods that work best for a specific research problem which is being examined and it is often associated with MM research (Biesta, 2010; Kaushik & Walsh, 2019; Tashakkori & Teddlie, 1998). Secondly, quantitative research fails to give voice to the participants, particularly their background, as well as the personal views and interpretations, while qualitative research has the in-depth views that were made by the participants (Creswell & Plano Clark, 2011). All these deficiencies are non-existent in MM research because of the complementary aspects of each approach to one another.

Lastly, Biesta (2010), Kaushik and Walsh (2019) as well as Tashakkori and Teddlie (1998) posit that the paradigm in question places its emphasis on the consequences of the research and the research questions. Having said that, this study focused on the influence of an intervention of which the findings depended on the outcomes of the intervention.

3.3.2 The research designs

As highlighted in the previous section that due to the qualitative dominance of this MM research, that is, out of six data collection instruments only one is a quantitative instrument. As such, the pragmatism paradigm was relevant in addressing both the qualitative and the quantitative aspects of the research for the reasons that were aforementioned. In their second edition of "designing and conducting MM research", Creswell and Clark (2011) provide a variety of MM research designs such as “convergent design, explanatory design, exploratory design, and embedded design” (p. 73). Akhdar et al. (2016) posit that a research design can be well-thought-out as the arrangement of research, or as the “glue” that holds all of the fundamentals in a research study together.

The research design that underpinned this study was a concurrent transformative design. According to Merriam-Webster dictionary (2023), concurrent describes things that are taking place, or persons who are doing something at the same time. Creswell and Clark (2012, p. 127) posit that “the transformative design is used when the researcher frames a MM study within a transformative theoretical perspective to help address injustices or bring about change to marginalised group” of people. I used four points to deliberate on how this research design is suited for this study. Firstly, according to Creswell and Clark (2018, p. 38) this design is "based on different social and cultural positions". Contextualising these aspects to this study is to say that the participating Life Sciences teachers brought with them a wealth of varying cultural backgrounds and social interactions which was a central aspect of their training during the intervention.

Secondly, the design is collaboration driven if the "researchers must actively involve participants as collaborators, build trust and honour participants standpoint" (Creswell & Clark, 2018, p.38). In this research, the participants contributed to this study by completing the six data collection instruments including the classroom observations and the semi-structured interviews. During the intervention, the teachers were afforded the opportunity to be hands-on.

Thirdly, in a transformative design, the researcher assumes the position of being considerate and sensitive to the needs of the participants and suggests the ways to improve the livelihood of the participants after the conclusion of the research (Creswell & Plano Clark, 2011). As discussed in Chapters 1 and 2 that although the Life Sciences teachers have no form of direction on how to integrate indigenous knowledge in their classrooms, the western Science is given preference, and it is seen as the only true

Science. This serves as a barrier to the indigenous Life Sciences learners' meaningful learning. It is for this reason that this study sought to provide two short learning programmes training for the Life Sciences teachers, so that they may be able to accommodate the indigenous learners in their classroom practice.

Fourthly, Creswell and Plano Clark (2011) posit that the resolution of transformative design is to carry out research that is change-oriented and it pursues to promote the social justice causes by recognising the power inequities and by empowering persons and/ or communities. In this study, the social injustices are the lack of integration of IK in a Life Sciences classroom, the lack of proper teacher training for the integration of IK and the lack of provision of direction on how the teachers can Integrate IK in their classrooms. Therefore, in an attempt to address these social educational ills, the study resorted to investigating the influence of an intervention (that is comprised of two SLPs) on the Life Sciences teachers' perceptions of the NOS, the NOIK and the implications on their pedagogies and SDL.

3.3.3 Sampling

The American Heritage College Dictionary (1993) defines sampling as the procedure of choosing a ration, piece, or section that is representative of a whole. This is a fundamental part of any research practice because it is significant in informing the standard of implications that are made by the researcher emanating from the core findings (Onwuegbuzie & Collins, 2007). Furthermore, the literature suggested that there are "two major groupings of sampling practices" in MM research, namely, probability or random sampling and nonprobability or non-random sampling (Gay et al., 2014; McMillan & Schumacher, 2010, p. 129; Onwuegbuzie & Collins, 2007; Teddlie & Yu, 2007). Lastly, in the context of this study, one type of sampling from the nonprobability category was used, which is namely convenience sampling (Onwuegbuzie & Collins, 2007).

Teddlie and Yu (2007) posit that convenience sampling “involves drawing samples that are both easily accessible and willing to participate” (p. 78) and in this type of sampling an assembly of participants is chosen based on accessibility (McMillan & Schumacher, 2010). Convenience sampling is used extensively in qualitative and quantitative research because a researcher may encounter the challenge of the participants' accessibility and the participants' efficiency (McMillan & Schumacher, 2010).

Initially the study targeted 42 Life Sciences teachers with a minimum of three years of teaching experience in Life Sciences. The teachers needed to be teaching in high schools under the Capricorn North and South Districts from the rural, the semi-urban and the urban settings. However, out of the 42 Life Sciences teachers who met the requirement, at the time only 38 were willing to participate voluntarily in the said study. Thus, the 38 teachers were requested to complete the Self-Directed Learning Instrument (SDLI), where 26 of the 38 served as a **controlled group** and 12 served as an **experimental group.** The 12 participants were requested to further complete the VNOIK and the VNOS-D+ open-ended questionnaires as well as the Pedagogy of Science Teaching Test (POSTT LFSC). The 12 Life Sciences teachers who served as the experimental group, participated in the first SLP that took place at the Landmark Protea Hotel in Polokwane.

The 12 participants who formed part of the experimental group were intended to participate in the second SLP that was scheduled to take place at the African Centre for Deoxyribonucleic acid (DNA) and Barcoding (ACDB) at the University of Johannesburg (UJ). Very much like the first SLP, the second SLP also took place during COVID-19 where the participants were required to vaccinate to gain access to any university. Out of the 12 participating teachers serving as an experimental group, only six were willing to continue taking part in the study. As such convenient sampling was used on the basis of the six teachers’ availability and willingness to continue with the study (see Onwuegbuzie & Collins, 2007; Teddlie & Yu, 2007). Each pair of the six teachers who went to ACDB were either based in a rural or in a semi-urban or urban setting. These six teachers also made themselves voluntarily available for the classroom observations and they participated in the semi-structured interviews which took place on the same day of the classroom observations after school hours.

3.3.4 Data collection

In research, the collection of data is more than just gathering information; as it entails a series of interconnected procedures, particularly in MM research, where data is collected qualitatively and quantitatively using different, convincing and methodical ways (Creswell & Plano Clark, 2011). Kabir (2016) defines data collection as the pattern of collecting and interpreting information on the variables of interest that help the researchers to address the objectives that are outlined in the research questions.

Any process of data collection intends to obtain first-class evidence that can be interpreted and decoded into a rich data analysis and can be utilised in constructing a convincing and credible response to the addressed questions (Creswell & Plano Clark, 2011; Teddlie & Yu, 2007). The different data collection instruments that were used in this MM study are further deliberated below.

3.3.4.1 Qualitative data collection instruments

Ivan (2021) defines qualitative data as the expressive and conceptual information that is collected through open-ended questionnaires, interviews, or observations. Furthermore, the open-ended questionnaires, the documents, the non-participatory classroom observations, and the semi-structured interviews are all bases of qualitative data (Gay et al., 2014). Hence, this research has used these instruments to collect qualitative data in this MM approach of which some have been used in qualitative research (see Chuene & Singh, 2024; Cronje, 2015; Sebotsa, 2020). Furthermore, in their development of POSTT (POSTT LFSC), Cobern et al. (2014, p. 2283) suggested that this "instrument could easily be used both qualitatively and quantitatively", hence I found it fitting to view the instrument as a qualitative instrument.

- Views on the Nature of Science (VNOS-D+) and the views of the Nature of Indigenous Knowledge (VNOIK) questionnaires

A total of two open-ended questionnaires (VNOS-D+ and VNOIK) were used to determine the Life Sciences teachers' perceptions about the NOS and the NOIK. The VNOS questionnaire was developed by Lederman et al. (2002) to determine the Science teachers' views about the nature of Science. As of 2021, the questionnaire has had six versions (VNOS A, B, C, D, D+ and E) (Ayala-Villamil & Garcia, 2021) and in this study, I administered the VNOS-D+ which was an improvement from the VNOS C (Lederman & Lederman, 2010). According to Ayala-Villamil and Garcia (2021, p. 14), the VNOS-D+ has 10 questions that are influenced by the tenets of the NOS, and it is "less extensive than VNOS C, because it has more direct questions than VNOS C".

The second open-ended questionnaire the VNOIK, is a qualitative instrument that was developed by Cronje et al. (2015) to investigate the Science teachers' views about IK. Dekker and Mnisi (2003) highlight the need for the Science teachers to be furnished with the foundation and knowledge of epistemology if those teachers have to teach the different epistemologies (IK and Western Science) at the same time. Hence, with the VNOS-D+ amongst other Science instruments, Ogunniyi (2007) developed an instrument with six items for IK and Webb (2013) also developed a questionnaire, but both instruments did not address some of the aspects that are addressed in Science (Cronje et al., 2015). The development of the VNOIK instrument was influenced by the framework that was used to develop the VNOS and its validity took place when it was piloted using the teachers in a SLP on the integration of IK (Cronje et al., 2015; Lederman et al., 2002). This instrument has been used many times in the Science teachers' professional development before, hence it is suitable for a study that is intervention-orientated (Jackson et al., 2016). The instrument was administered to the experimental group pre- and post-intervention.

- Pedagogy of the Science Teaching Test for Life Sciences (POSTT LFSC)

The third qualitative instrument that was used in this study was the adapted POSTT developed by Cobern et al. (2014). This instrument was developed to address a fundamental facet of Science teacher education, which is "gaining pedagogical content of how to teach Science for conceptual understanding" and exposing the Science teachers to more Science themes (Cobern et al., 2014, p. 2265). I combined four versions of the test (POSTT 1 to POSTT 4) and ensured that he does not repeat items that appear in more than one POSTT which in this study is referred to as the POSTT LFSC.

This instrument as suggested intended to determine whether the Life Sciences teachers from the three different settings in the Capricorn North and South Districts of Limpopo province have a pedagogical orientation towards their teaching practice (Cobern et al., 2014). Hence, the instrument was administered to the experimental group before and after the intervention.

- Classroom observations

The fourth instrument that was used to collect qualitative data was the classroom observations. According to Gay et al. (2014), and Kabir (2016), when the qualitative researchers collect data from the participants by observing them, the emphasis during the observation is on understanding the natural environment as it is experienced by the participants rather than influencing it. When a researcher collects data through observation, they can obtain more objective data that can be compared to the research participants' self-reports (own reflection) (Gay et al., 2014).

Research highlights two forms of observation namely, participatory observation and non-participatory observation. In this study, I used non-participant observation, which is an observation "that involves observing the behaviour in a normal setting… where no efforts are made to bring any type of change in behaviour of the observed" (Kabir, 2016, p. 240). The rationale for using this type of observation is that the "observer is less intrusive and less likely to become emotionally involved with participants than participants observers" (Gay et al., 2014, p. 334).

In the recording of the observations, I recorded data descriptively, because the intention was to record what is directly seen or heard on-site throughout the course of the study (Gay et al., 2014). I used the adapted version of the Reformed Teaching Observation Protocol (RTOP) which is an observational instrument that was designed to measure "reformed" teaching which was initially developed by Piburn et al. (2000). The observational instrument is comprised of three aspects, the lesson design and implementation, content, as well as classroom culture (Piburn et al., 2000). The adapted version is comprised of a comments section under each aspect to allow me to describe the classroom occurrences for the collection of meaningful and rich data.

The classroom observations were done with six Life Sciences teachers who were able to participate in both the IK SLPs that took place at the Landmark Protea Hotel and at the ACDB laboratory at the UJ. The teachers were only observed after the intervention had taken place and they were all observed once in their classroom. The observations were carried out to help to determine if the intervention had any influence on the teachers' classroom pedagogy.

- Semi-structured interviews

The fifth and last qualitative data collection instrument that was used in this study was the semi-structured interviews. Gay et al. (2014) defines an interview as a purposeful communication in which one person acquires information from the other, while Kabir (2016) highlights that an interview includes asking questions and receiving answers from the participants in a research study.

The researchers can get important data from the interviews that they can't get from observation alone, so pairing the observations with the interviews is still a good way to get comprehensive and complementary data (Gay et al., 2014). I opted to use semi-structured interviews. Kabir (2016) highlighted that the semi-structured interviews provide the interviewers with a clear set of instructions, and they can provide reliable, comparable qualitative data after classroom observations. Consequently, only the six teachers who were observed in their classrooms are the ones who were interviewed, which is why each teacher was interviewed after school the same day after being observed to help to respond to the classroom occurrences while they were still fresh.

3.3.4.2 Quantitative data collection instrument

In quantitative research, the researchers can have their participants fill out a self-report instrument such as a close-ended questionnaire that is designed to measure their skill because a close-ended Likert scale questionnaire is used by the researchers to gather information about a research participant's attitude and behavioural intentions (Edmonds & Kennedy, 2016). A close-ended questionnaire is a type of research instrument that consists of a series of questions and other prompts such as the Likert scale, and the surveys that are used to collect information from the respondents and they are typically used to analyse the responses statistically (Kabir, 2016). The closed-ended questionnaire is the most used procedure for gaining data from the participants because it is cost-effective, contains the same questions for all the subjects and it ensures anonymity (Creswell & Plano Clark, 2018; Gay et al, 2014).

In the context of this study, the questionnaire that was used is the Self-Directed Learning Instrument (SDLI) that was developed by Cheng et al. (2010). The instrument has four domains with items to respond to, namely, the motivation for learning that has six items, planning and implementation that also has six items, as well as self-monitoring, and interpersonal communication that each have four items. The instrument allows the respondents to either extremely disagree (1) to extremely agree (5) to each item within each domain (Cheng et al., 2010).

The rationale for using this instrument was to determine the influence of an intervention on the Life Sciences teachers' perceptions of their own SDL abilities. The instrument was administered to 38 Life Sciences teachers, 12 of whom formed part of the experimental group, while 26 served as the control group. Lastly, all of these teachers were administered the questionnaire just before the intervention started and 30 minutes after the second SLP and by doing so I was able to determine if the intervention had any influence on the Life Sciences teachers' perceptions of their own SDL abilities. On the other hand, the control group was administered the SDLI two weeks later, because I needed to arrange with the teachers about the venue and the time to collect the SDLI responses.

3.3.5 Data analysis

According to Creswell and Plano Clark (2011), the MM data analysis comprises of the logical systems that are used in both the qualitative and the quantitative data as well as to the mixing of the two types of data concurrently and sequentially in a single research project. According to Creswell (2009); as well as LeCompte and Schensul (1999), once data is collected, the step that follows is to analyse it. This includes making meaning of the data by digging deeper to make meaningful sense where the researcher condenses the data to a story and interpretation. Hence, data analysis is the process whereby the researcher reduces the large amount of data that was collected so that a meaningful sense is made out of it (LeCompte & Schensul, 1999). According to Patton (1987), there are three aspects to be considered during data analysis, and that is, whether data is organised; data is condensed by means of summary and categorising where patterns and themes in data are identified, related, and where statistical representations are made.

In the context of MM, data analysis comprises analysing distinctly the qualitative data by means of qualitative methods and quantitative data utilising quantitative methods (Creswell & Plano Clark, 2018). The authors further outlined that in the MM studies, the analysis includes merging both the data sets using mixing, or integrating both qualitative and quantitative data, as they are analysed to address the research aims and the questions that are related to the study (Creswell & Plano Clark, 2018). In the context of this study, the following paragraphs deliberate on how the collected data from each data collection instrument was analysed.

3.3.5.1 Qualitative data analysis

Data analysis is a fundamental step in qualitative research because whatever the type of data that is used, it is through analysis that the researcher can make valid inferences to answer the research questions (Flick, 2013). Furthermore, qualitative data analysis is mainly inductive in nature where the data is organised into themes using identifying general patterns and relationships among the themes (Creswell & Plano Clark, 2018; McMillan & Schumacher, 2010). Hence, Flick (2013) defines qualitative data analysis as the organisation and explanation of linguistic (or visual) data to make statements about implicit and explicit proportions and structures of making sense of the material and what is represented in it. The definition can be subjective or social, furthermore, this type of analysis is used for discovering and describing matters in the arena and procedures in routines and practices (Flick, 2013). In the context of this study, the data that was analysed qualitatively was generated from the VNOS-D+, the VNOIK, the POSTT LFSC questionnaires, the classroom observations and from the semi-structured interviews.

- **Coding**

Saldana (2009) defines a code as a term or a shortened phrase that metaphorically allocates a summative, relevant, essence capturing, and/or evocative attribute to a ration of language-based or visual data. The interview transcripts, the participant observation field records, the notebooks, and the papers are examples of the data sources (Saldana, 2009).

Coffey and Atkinson (1996) propose coding as a typical combination of data synopsis and impediment, by breaking the data apart in logically appropriate ways to lead toward further questions about the data. Furthermore, Richards and Morse (2007) define coding as more than simply labelling as it takes one from the data to the idea, and from the idea to all of the data that is associated with that notion.

In addition, coding plays a significant role in enabling the researcher to organise and group similarly coded data into categories or 'families' due to shared characteristics (Saldana, 2009). Furthermore, there is the use of classification intention, as well as implicit and instinctive sense to determine which data shares characteristics when grouping them together (Lincoln & Guba, 1985). Hence, Richards and Morse (2007) suggest that when people categorise, they move from the multiplicity of the data to the shapes of the data, which is the kind of phenomena that is represented. Saldana (2009) posits that the themes are the outcomes of coding, categorising, and analytic reflection, hence, after data was analysed in this study, the themes that emerged were deliberated upon.

In the context of this study In-Vivo, coding was significantly used during the analysis of the responses that were provided by the participants in this section. According to Manning (2017) In-vivo coding is a type of qualitative data analysis that stresses the actual spoken words by the participants. Several researchers use this type of coding as an initial form of analysis to help lead to more sophisticated analysis (Manning, 2017). This is because In-vivo coding does not demand the researcher to assign or generate codes to data. I was able to use it to support some of the deliberations that were made during the analysis.

- **Views on the nature of Science and the views on the nature of indigenous knowledge**

In an attempt to analyse the VNOS-D+, Lederman et al. (2002) highlight that this can be done by categorising the teachers' responses as either "very naïve views or very informed views" (p.514). In the context of this study, a rubric developed by Cronje (2015, p.134-138) with three views namely, uninformed view, partially-informed view and informed view was adapted using the work done by Yoon et al. (2014, p.2676-

2677) by adding the “no classification” category. Hence, the four categories were as follows: ***No Classification (NC)*** which means that ‘there has been no response; they claim that they are unsure: the answer does not respond to the request’, scored (0); ***Uninformed Views (UV)*** which means the ‘replies that demonstrated a lack of comprehension of a topic,‘ scored (0); ***Partially-Informed Views (PIV)*** which means the ‘answers demonstrate some comprehension of an idea, but also persisting misunderstandings’, scored (1); and ***Informed Views (IV)*** which means the ‘the participants’ replies reflect more thorough knowledge, and there are no contradicting answers’, scored (2) (Yoon et al., 2014). The average score represents the Life Sciences teachers' overall perceptions of the NOS. To score the participants' responses, Table 3.1 of the adapted rubric was used.

Table 3.1: Rubric for coding Life Sciences teachers' responses to the VNOS-D+ (Author's own work based on Cronje et al., 2015; Yoon et al., 2014)

NO.	VNOS D+ questions and related tenets	No classification (NC) (0)	Uniformed views (UV) (0)	Partially-informed views (PIV) (1)	Informed views (IV) (2)
		There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)	Replies that demonstrated a lack of comprehension of a topic (Yoon et al., 2014)	Answers demonstrate some comprehension of an idea, but also persisting misunderstandings (Yoon et al., 2014).	The instrument replies reflect more thorough knowledge, and there are no contradicting answers (Yoon et al., 2014).
1	'What is science?" **(Empirical NOS)** (Lederman et al., 2010, p. 1-7; Akerson & Donnelly, 2010, p. 12; Yoon et al., 2014, p. 2676-2677)	There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)	"Science is everything" (Yoon et al., 2014, p. 2676-2677)	"Science is a way of exploring and studying topics, such as chemistry, insects, batteries, etc." (Akerson & Donnelly, 2010, p. 12)	"Science is a way of knowing about the world" (Akerson & Donnelly, 2010, p. 12)
2	"What makes Science (or a scientific discipline such as physics, biology, etc.) different from other subjects/disciplines (art, history, philosophy, etc.)?" **(Empirical NOS)** (Lederman et al., 2010, p. 1-7; Akerson & Donnelly, 2010, p. 12; Yoon et al., 2014, p. 2676-2677)	There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)	"Science is everything and follows one method" (Yoon et al., 2014, p. 2676-2677)	"Science investigates things" (Akerson & Donnelly, 2010, p. 12)	Science uses data to make claims and create ideas (Akerson & Donnelly, 2010)
3	"Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example." **(Tentative NOS; Social and cultural influence; Subjectivity NOS)** (Lederman et al., 2010, p. 1-7; Akerson & Donnelly, 2010, p. 12; Yoon et	There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)	"Science does not change" (Yoon et al., 2014, p. 2676-2677)	"As we learn more or have new technology Science changes" (Akerson & Donnelly, 2010, p. 12)	"Science changes as we learn more or scientists reinterpret existing data" (Yoon et al., 2014, p.2676-2677)

	al., 2014, p. 2676-2677)				
4	(a) "How do the scientists know that the dinosaurs really existed? Explain your answer. (b) How certain are the scientists about the way the dinosaurs looked? Explain your answer. (c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, the scientists disagree about what caused this to happen. Why do you think they disagree even though they all have the same information? (d) If a scientist wants to persuade other scientists of their theory of dinosaur extinction, what do they have to do to convince them? Explain your answer." **(Empirical NOS; Observation and inferences)** (Lederman et al., 2010, p. 1-7; Akerson & Donnelly, 2010, p. 12; Yoon et al., 2014, p. 2676-2677)	There has been no response; they claim that they are unsure: the answer does not respond to the request *(*Yoon et al., 2014)	"Scientists saw dinosaurs; Scientists read about dinosaurs; They are sure, If they had more information they would all agree" *(*Yoon et al., 2014, p.2676-2677)	"Scientists have collected evidence of dinosaurs (bones; fossils). They are pretty sure.; Scientists have different interpretations of the facts" *(*Yoon et al., 2014, p.2676-2677)	"Scientists made observations of evidence (bones, fossils) and inferred that dinosaurs existed; Scientists have different interpretations of the facts because of their background knowledge and experiences" *(*Yoon et al., 2014, p.2676-2677)
5	"In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns. (a) Do you think weather persons are certain (sure)	There has been no response; they claim that they are unsure: the answer does not respond to the request *(*Yoon et al., 2014)	"They are certain, because they have data" *(*Yoon et al., 2014, p. 2676-2677)	"They are not certain, they might, and they use data to determine the weather" (Akerson & Donnelly, 2010, p.12)	"They are not certain; they might get new information or reinterpret the existing data that would change their prediction" (Akerson &

	about the computer models of the weather patterns? (b) Why or why not?" **(Empirical NOS; Creative NOS; Scientific theories vs laws)** (Lederman et al., 2010, p. 1-7; Akerson & Donnelly, 2010, p. 12; Yoon et al., 2014, p. 2676-2677)				Donnelly, 2010, p. 12)
6	"The model of the inside of the earth shows that the earth is made up of layers called the crust, the upper mantle, the mantle, the outer core and the inner core. Does the model of the layers of the Earth *exactly* represent how the inside of the earth looks? Explain your answer." **(Empirical NOS; Creative NOS; Scientific theories vs laws)** (Lederman et al., 2010, p. 1-7; Akerson & Donnelly, 2010, p. 12; Yoon et al., 2014, p. 2676-2677)	There has been no response; they claim that they are unsure: the answer does not respond to the request *(*Yoon et al., 2014)	Yes, Scientists say so (Yoon et al., 2014)	No, they used theories to investigate (Yoon et al., 2014)	"No, scientists, used scientific models, which helped them to estimate, determine and predict how the earth looks like" (Akerson & Donnelly, 2010, p.12)
7	"Scientists try to find answers to their questions by doing investigations/experiments. Do you think that scientists use their imaginations and creativity when they do these investigations/experiments? a. If **NO**, explain why. b. If **YES**, in what part(s) of their investigations (planning,	There has been no response; they claim that they are unsure: the answer does not respond to the request *(*Yoon et al., 2014)	"No, they cannot imagine things because it wouldn't be real" (Akerson & Donnelly, 2010, p.12)	"Yes, they use their imagination to design investigations" (Akerson & Donnelly, 2010, p.12)	"Yes, they use their imaginations to design investigations, interpret their data and create explanations" (Akerson & Donnelly, 2010, p.12)

	experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can." (Lederman et al., 2010, p.1-7; Akerson & Donnelly, 2010, p. 12; Yoon et al., 2014, p. 2676-2677) **(Creative NOS)**				
8	'Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example." **(Creative NOS; Scientific theories vs laws)** (Lederman et al., 2010, p.1-7; Akerson & Donnelly, 2010, p. 12; Yoon et al., 2014, p. 2676-2677)	There has been no response; they claim that they are unsure: the answer does not respond to the request *(*Yoon et al., 2014)	Theories become law in light of new information or evidence (McComas, 1998; Lederman et al., 2002)	"Description of either law or theory, but some contradictory response provided" (Yoon et al., 2014, p. 2676-2677)	Theories are used to explain phenomena using inferences. Theories cannot be directly tested. Laws are descriptive statements of relations between observable phenomena (McComas, 1998; Bell, 2009; Lederman et al, 2002)
9	"After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example." **(Tentative NOS; Social and cultural Influence; Subjectivity NOS)** (Lederman et al., 2010, p. 1-7; Akerson & Donnelly, 2010, p. 12; Yoon et al., 2014, p. 2676-2677)	There has been no response; they claim that they are unsure: the answer does not respond to the request *(*Yoon et al., 2014)	Theories become law in light of new information or evidence (McComas, 1998; Lederman et al., 2002)	Theory can change if discoveries are made about the theory (Bell, 2009; Lederman et al., 2002)	Theory can change in light of new information or old data is reinterpreted (McComas, 1998; Lederman et al., 2002)

10	'Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples." **(Social and cultural Influence)** (Lederman et al., 2010, p.1-7; Akerson & Donnelly, 2010, p.12; Yoon et al., 2014, p.2676-2677)	There has been no response; they claim that they are unsure: the answer does not respond to the request *(*Yoon et al., 2014)	"If they had more information they would all agree" (Akerson & Donnelly, 2010, p.12)	"Scientists have different interpretations of the facts" (Akerson & Donnelly, 2010, p. 12)	"Scientists have different interpretations of the facts because of their background knowledge and experiences" (Akerson & Donnelly, 2010, p.12)

Table 3.1 is comprised of 10 itemised questions whose intentions were to draw the respondents' views about the NOS. The 10 questions are the reflections of the seven tenets of the NOS such as empirical NOS, tentative NOS, creativity and imaginations (see Ayala-Villamil & Garcia-Martinez, 2021; Lederman, 2007).

With regards to the VNOIK, Cronje (2015); as well as Cronje et al. (2015) demonstrate that there are "anticipated responses to the VNOIK questionnaire" (p.126) that can be used to decipher the Life Sciences teachers' views of the NOIK. Furthermore, the same authors developed a rubric which was used to categorise the Life Sciences teachers' views and this rubric is deliberated upon later on in this section. Table 3.2 contains the questions from the VNOIK questionnaire with the responses that would be given by a person with informed views of the NOIK.

Table 3.2: VNOIK questionnaire with the responses that are deemed as correct (Cronje, 2015, p.126-129)

Question	VNOIK questionnaire and the correct responses from each question
1	*"What is indigenous knowledge*?" It is the methods of knowing nature and the skills that are used by the individuals living in a certain location (local) and society to improve their daily life. The result of the interactions between the individuals and their surroundings. The result of a realistic meeting in ordinary life. Folklore about flora and animals. Songs, rituals, dances, and sacred locations are examples of the people's cultural beliefs and history. Spiritual beliefs (metaphysical) are as significant as are ancestors. Rituals, myths, practices, and values should all be included. Mostly handed down verbally through imitation and demonstration, as well as through paintings and artefacts from one generation to the next. Language, medicine, ecology, Science, religion, agriculture, astronomy, and architecture are the examples of the knowledge systems that are more than merely the therapeutic plants. Nature is holistic and inclusive, with the spiritual, the natural, and the human realms coexisting.
2	*"What is the role of the experiments?* Indigenous knowledge generates the facts via experimental observation and testing. Success and failure were achieved through the trial-and-error experimentation. Life's laboratory has been tested through countless generations. Indigenous knowledge is actual as opposed to being theoretical.

	It is based on intuition and evidence.
3	*"What are the natural and the unnatural causes?* It is impossible to separate indigenous knowledge from spirituality, beliefs, and metaphysics. The explanations for the observations in the indigenous knowledge may not necessarily have expected natural or logical origins. In explanations, one can refer to things such as bad spirits, visions, and stories. In the explanations, the ancestors are honoured. The use of medicinal plants, for example, involves a holistic approach that covers the metaphysical and the spiritual as well as focusing on the chemical reactions that occur in the body.
4	*"Stays the same or changes over time?"* The majority of this wisdom in action has been passed down through generations and it has stood the test of time (resilience), but each generation adjusts and adds to this knowledge as their circumstances and surroundings change in order to survive and solve the challenges. The following generation inherits this new way of knowing. Indigenous knowledge is dynamic and ever-changing, although it is sometimes portrayed as stagnant.
5	*"How is knowledge generated? (Hoodia)"* It is founded on personal experience and everyday necessities. It is created via trial and error. Many generations of testing and transmission from one generation to the next. Collective library of visible knowledge. Repetition aids in retention. Ancestors or dreams guide the traditional healers and the elders in the usage of herbs.
6	*"Used to solve contemporary problems?"* Indigenous wisdom may be used to tackle modern challenges. Has a significant function to play in countries where modernisation has failed. Has withstood the test of time, has been tried over ages, and can be applied to ta ckle modern challenges.
7	*"Methods and advice?"* Methods: Physical systems are investigated holistically from social, historical, and spiritual perspectives. The significance of seeking assistance from the forebears. To establish healing, look for a trigger that caused the ailment - it might be metaphysical. Advice/treatment Make available medicinal herbs or *muthi*. Healing extends beyond medicine (muthi) to incorporate energy and spirituality.

	Rituals and beliefs are also important. Treatment is also comprehensive, treating both spiritual and bodily concerns.
8	*“Role of myths?”* Oral transmission of indigenous knowledge occurs through stories and myths. Imitation, display, and rituals all play significant roles. Metaphorical expressions. Indigenous wisdom is made accessible through the stories that carry teachings.
9	*“Reflect social and cultural values?”* Indigenous knowledge does represent a community's social and cultural values. Knowledge is an important component of culture and is tailored to a certain culture and environment. It is ingrained in a certain set of people's local social and cultural values. Indigenous knowledge is embedded in cultural traditions; it is not culture-agnostic. Is it used locally or globally? Indigenous wisdom is passed down from community to community, as well as from culture to culture, and country to country. Exploitation threat Can be altered to meet modern challenges yet it is culturally specific. When applying to different communities, the functionality must be considered. Sometimes information is delivered in pieces rather than in its whole. Contributions can help to address the issues in a variety of sectors including ecology, medicine, agriculture, mathematics, and fisheries.
10	*“Imagination, creativity?”* Indigenous knowledge is a dynamic, living knowledge foundation that uses creativity and innovation to support people's existence. As new concerns emerge such as HIV/AIDS, new information is generated. Indigenous knowledge is continually created and replicated. As the requirements of the community evolve, it is constantly adapted.

Table 3.2 reflects the ten itemised questions whose intentions are to draw the respondents’ views about the NOIK. These questions unlike the itemised questions from the VNOS-D+, among the other tenets reflect the metaphysical nature of IK, and the holistic nature of IK which are unique to IK as a knowledge system. Lastly, each

question is comprised of a few responses that would classify the respondents as those with informed views about the NOIK.

Table 3.3 is a rubric that was used to categorise the teachers' VNOIK questionnaire responses. This rubric was originally developed by Cronje et al. (2015) to categorise the Life Sciences teachers' views of the NOIK in an attempt to ensure consistency with the VNOS-D+ rubric. The rubric was adapted from the rubric that was initially comprised of 'uninformed views' which scored (0); followed by 'partially-informed views' which scored (1); and 'informed views' which scored (2), by adding ***"no classification"***, which means that "there is no response; they state that they do not know: the response does not address the prompt" scored (0), (Yoon et al., 2014, p.2676). As such, the rubric's categories were adapted from how Cronje scored them to the following: NC=0; UV=0; PIV=1; and IV=2, which is similar or the same as the rubric that was used to categorise the Life Sciences teachers' views of the NOS. Just like the VNOS, the average score represents the Life Sciences teachers' overall perceptions of NOIK.

Table 3.3: Suggested rubric for coding Life Sciences teachers' responses to the VNOIK questionnaire (Author's own work based on Cronje et al., 2015; Yoon et al., 2014)

No	Tenets related to the question	No classification (0)	Uninformed views (0)	Partially-informed views (1)	Informed views (2)
		There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)	*"Answers that showed lack of understanding of a concept"* (Cronje et al., 2015, p.329)	*"Answers show some understanding of a concept, but then also show persistent misconceptions"* (Cronje et al., 2015, p.329)	*"Answers show more complete understanding, and there are no contradictory answers present in instrument responses or other data sources"* (Cronje et al., 2015, p.329)
1	"Empirical and Metaphysical based; resilient yet tentative; Inferential yet intuitive; Creative and Mythical; subjective; Social, Collaborative and Cultural; Wisdom in action; Applicable and Functional; Holistic by nature" (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"Mentions one or none of the anticipated answers or other tenets of indigenous knowledge"* (Cronje et al., 2015, p.329)	*"Mentions at least two of the anticipated answers or other tenets of indigenous knowledge"* (Cronje et al., 2015, p.329)	*"Mentions at least four of the anticipated answers or other tenets of indigenous knowledge"* (Cronje et al., 2015, p.329)
2	"Empirically and Metaphysically Based" (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"Answers no or not sure"* (Cronje et al., 2015, p.329)	*"Answers yes without explanation or with reason that is not acceptable; Answers no with acceptable explanation"* (Cronje et al., 2015, p.329)	*"Answers yes, with an acceptable reason or example"* (Cronje et al., 2015, p.329)
3	'Empirically and Metaphysically based; Inferential yet intuitive" (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request*	*"Answers no just natural causes"* (Cronje et al., 2015, p.329)	*"Can include supernatural to explain causes. Does not give examples of possible unnatural causes or gives irrelevant explanation"* (Cronje et al., 2015, p.329)	*"Can include supernatural to explain causes. Gives examples of possible unnatural causes"* (Cronje et al., 2015, p.329)

		(Yoon et al., 2014)			
4	"Resilient yet tentative" (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"Answers yes or not sure without any explanation"* (Cronje et al., 2015, p.329)	*"Answers just yes with correct explanation of why it stays the same or no with correct explanation of why it changes"* (Cronje et al., 2015, p.329)	*"Answers yes and no or yes, but, and explains the resilience of indigenous knowledge but that indigenous knowledge can be modified as needs of society changes"* (Cronje et al., 2015, p.329)
5	"Empirically and metaphysically based; Inferential yet intuitive; Wisdom in action; Applicable and functional' (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"Not sure or unsuitable explanation"* (Cronje et al., 2015, p.329)	*"Short suitable explanation including at least one mentioned method in Table 7"* (Cronje et al., 2015, p.329)	*'Comprehensive suitable explanation including at least two of the methods explained in Table 7"* (Cronje et al., 2015, p.329)
6	"Creative and mythical; Wisdom in action" (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"Not sure or no"* (Cronje et al., 2015, p.329)	*"Yes with no explanation or unsuitable explanation"* (Cronje et al., 2015, p. 329)	*"Yes with suitable explanation/ example"* (Cronje et al., 2015, p.329)
7	'Applicable and functional; Holistic by nature" (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"Not sure or unsuitable explanation"* (Cronje et al., 2015, p.329)	*"Provides either method or treatment/advice as suggested in Table 7"* (Cronje et al., 2015, p.329)	*"Provides one of the methods Mentioned and advice/treatment. Suggests one of the possible responses in Table 7"* (Cronje et al., 2015, p.329)
8	"Creative and mythical; Social, collaborative and cultural" (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"Not sure or unsuitable explanation"* (Cronje et al., 2015, p.329)	*"Answers yes without suitable explanation or with an example"* (Cronje et al., 2015, p. 329)	*"Answers yes with an explanation or with an example"* (Cronje et al., 2015, p.329)

9	"Subjective' (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"No to both questions or unsuitable explanations"* (Cronje et al., 2015, p.329)	*"Yes it reflects social and cultural values plus an explanation/example Does not believe it can be transferred with no explanation"* (Cronje et al., 2015, p.329)	*"Yes it reflects social and cultural values plus an explanation/ example Believe it is universal/ transferrable/ partially transferrable with suitable explanation/example"* (Cronje et al., 2015, p.329)
10	"Resilient yet tentative; Creative and mythical; subjective; Social, collaborative and cultural" (Cronje et al., 2015, p.326-327)	*There has been no response; they claim that they are unsure: the answer does not respond to the request (Yoon et al., 2014)*	*"Not sure or no"* (Cronje et al., 2015, p.329)	*"Yes or partially but the explanation is not suitable"* (Cronje et al., 2015, p.329)	*"Yes it can change with suitable explanation, or it can be modified with explanation and/or example"* (Cronje et al., 2015, p.329)

Table 3.3 reflect the 10 itemised questions whose intentions were to draw the respondents' views about the NOIK. These questions unlike the itemised questions from the VNOS-D+, among the other tenets reflect the metaphysical nature of IK, the holistic nature of IK and the wisdom in action which is unique to IK as a knowledge system. Lastly, each question comprised of a few responses that would classify the respondents as those with informed views about the NOIK. The rubric is important in that it assists the research to categorise the participating Life Sciences teachers' responses of the VNOIK and score their responses. Meaning that the teachers' responses can either be categorised as; no classification, uniformed views, partially-informed views or informed views with scores ranging from 0 to 2.

- **Pedagogy of Science Teaching Test for Life Sciences (POSTT LFSC)**

The South African Department of Basic Education has emphasised the significance of an active and critical approach to learning and thus it is important that the Life Sciences teachers can choose suitable teaching methods for their classroom pedagogy (Sondlo & Ramnarain, 2019). Studies have been conducted around the world to help to develop a framework and an instrument that measures, among other things, the Life Sciences teachers' pedagogical orientations and the instrument is called the POSTT LFSC (Sondlo & Ramnarain, 2019; Cobern et al., 2010). Table 3.4 reflects the types of methods a Life Sciences teacher uses in a given classroom scenario, which served as the categories for the type of responses the Life Sciences teachers gave in their responses to the POSTT LFSC.

Table 3.4 is comprised of four categories namely; didactic direct, active direct, guided inquiry and open inquiry. These categories sought to describe the participating Life Science teachers' pedagogical orientation. As the teachers responded to the POSTT LFSC multiple-choice questions, each answer the teachers provided was categorised in either one of the suitable categories.

Table 3.4: Descriptions of Science teaching orientation (Ramnarain & Shuster, 2014, p. 632)

Didactic direct	"The teacher immediately introduces and discusses the Science subject or the principle. Uses an example or demonstration to demonstrate. There are no student activities, but the teacher responds or explains the learner inquiries" (Ramnarain & Schuster, 2014, p. 632).
Active direct	"The first presentation is the same as the direct exposition b, but it is followed by a learner activity that is based on the offered Science, such as the hands-on practical proof of a law" (Ramnarain & Schuster, 2014, p. 632).
Guided inquiry	"Topics are approached by the learner exploration of a phenomenon or idea, with the teacher guiding them toward the desired Science concept or principle arising from the activity. The teacher may explain further and give examples to consolidate. Questions are dealt with by discussion" (Ramnarain & Schuster, 2014, p. 632).
Open inquiry	"The learners are minimally steered by the teacher; they are free to investigate a fact or idea as they see fit and invent methods for doing so. The teacher assists but does not prescribe. The most significant aspect is the investigation procedure. The students present their findings and activities" (Ramnarain & Schuster, 2014, p. 632).

To analyse the teachers' responses, a rubric based on Table 3.4 was developed by Cobern et al. (2010) to help to categorise the teachers' responses. Considering the nature of the instrument where the items are in the form of multiple-choice, the teachers' responses are represented by letters that are associated with their responses in the multiple-choice questions.

In an attempt to analyse the teachers' responses from the POSTT LFSC, the responses were coded and categorised into either DD (Didactic Direct); AD (Active Direct); GI (Guided Inquiry); or OI (Open Inquiry). After the responses were categorised, deliberations were made based on the trends that were reflected in both the pre-intervention and the post-intervention responses. By so doing it became evident as to whether the participants' responses were more inclined to either DD or AD or GI or OI. Hence, Table 3.5 represents the rubrics with the letters and their categories.

Table 3.5: POSTT LFSC rubric for categorising the Life Sciences teachers' responses (Cobern et al., 2010)

Item no.		Descriptions of Science teaching orientation			
	Item	**Didactic Direct**	**Active Direct**	**Guided Inquiry**	**Open Inquiry**
1	Frog dissection	D	B	C	A
2	Organisms respond to the environment	C	B	D	A
3	Structure and function	B	D	A	C
4	Field trip	C	A	D	B
5	Predator and prey	A	B	C	D
6	Inheritance	D	A	C	B
7	Succession	A	B	C	D
8	Varieties of wheat	C	B	A	D
9	Planets and life	B	D	A	C
10	Animal sorting	B	D	A	C
11	Fossils provide evidence for change	A	B	C	D
12	Hand sanitisers: A teachable moment	D	A	B	C
13	Plant misconceptions	B	A	D	C
14	Bacteria	D	B	C	A
15	Microbes	D	C	B	A
16	Animal classification	D	A	B	C
17	Chlorophyll	C	B	A	D

Table 3.5 represents a rubric that is comprised of 17 multiple-choice items that present the classroom scenarios where the participating teachers can either choose A, B, C or D as an answer. The responses were then categorised into either DD, AD, GI or OI which reflect how the teachers would approach their classrooms or the orientation to their classrooms.

- **Reformed Teaching Observation Protocol (RTOP)**

With regards to analysing the RTOP, Piburn et al. (2000) suggest that the researchers use a holistic approach to analyse the collected data and to view the RTOP as an inductive instrument so that comprehensive findings can be made up of the categories of different aspects. The RTOP allows the observer to not only score the teacher's performance but also it allows the observer to describe what is happening in the classroom to help provide context. I used intelligent transcription which allowed him to transcribe every word, but it was interpreted to exclude pauses, status, and filler words as well as to potentially clean up the grammar (Given, 2008). Despite the instrument allowing for scoring, in the context of this study, I focused more on the descriptions of what transpired in the classroom which provided richer data that allowed for an analysis to be done qualitatively. This helped to determine inductively if the intervention (Cronje, 2015) had any influence on the teachers' abilities to integrate IK in their classrooms.

- **Semi-structured interviews**

In an attempt to analyse the semi-structured interviews conducted on the six Life Sciences teachers who participated in the classroom observations, I used verbatim transcription. Verbatim transcription is defined as the transcribing of every word that includes the stutters, the pauses and the filler words as uttered by the interviewee (Saldana, 2009). After transcribing the teachers' responses, I then used In-vivo coding to help me make deliberations.

3.3.5.2 Quantitative data analysis

Quantitative data is a piece of realistic information that involves numbers and sets, which often refer to the choices between options such as a personal opinion ranging from strongly disagree to strongly agree (Samuels, 2020). Thus, quantitative data analysis is defined as a methodical procedure which caters for both the collection and the evaluation of measurable and verifiable data whereas the statistical mechanism of assessment and analysis of data is central (Ali, 2021; Creswell, 2007). In the quantitative analysis of data, the researchers are more interested in the objective reality that needs to be uncovered where the cause-effect relations are developed and the participants are chosen as randomly as possible (Gay et al., 2014). The drive of a quantitative research analyst is to measure a conjectural condition which is typically undertaken by the researchers who are well-furnished with the techniques of quantitative analysis either manually or with the aid of the computers (Cowles, 2005). Lastly, an approach to a phenomenon in a quantitative manner means that the researcher must methodically classify, sum up, and demonstrate the observations which make it possible for the researcher to understand and conclude a studied phenomenon (Ali, 2021).

The SDLI was analysed by using the 26th Version Statistical Package for the Social Sciences (SPSS). The SDLI helped in analysing the teachers' views (perceptions) on their own self-directed learning. I made use of the services of a biostatistician at the University of Limpopo in this regard. Mean scores were obtained. An independent t-test was used to compare the SDL count between the experimental and the control groups' pre- and post-intervention data. Thereafter, dependent t-tests were used to determine the difference between the pre- and the post-SDL counts in both the experimental and the control groups. An ANCOVA controlling for the differences pre-intervention was used to compare the SDL count between the experimental and the control groups' post-intervention data.

3.3.5.3 Using CHAT as a research lens to interpret data

Teaching and learning Life Sciences is a social endeavour that is comprised of stakeholders who play individual roles and at times for the better output of these roles, tensions emanate. Each role player has objectives set out for them to achieve, for example, the teachers were expected to provide meaningful classroom pedagogy so that the learners may learn meaningfully, while the principals were expected to monitor these teachers' performances. In other words, the "teacher will experience conflicts, on the other hand having to act as a mediator" of learning in a classroom where the integration of IK was expected to take place (Cronje, 2015, p.89). This is where the teacher has to undergo teacher's learning and professional development, as such their classroom practice and content knowledge is enhanced and to determine if indeed the teacher's learning and professional development took place, the CHAT was used as a research lens for analysis. This is because by considering the contextual factors, or the specific variables that characterise any given intervention, the CHAT provides unique insight into the teachers' learning and professional development (De Beer & Kriek, 2018).

In the context of this study, the teachers' learning, and professional development took place in two folds, the first SLP focused on training the teachers about the integration of IK took place at the Landmark Protea hotel. The second SLP which focused on immersing teachers in western Science contexts ("real" research in a research centre) took place at the ACDB laboratory at the UJ. Both SLPs (intervention) amongst other things intended to improve the teachers' classroom pedagogies and their self-directed learning. The two interventions strived to provide teachers with more nuanced understandings of the NOS and NOIK, in order to better equip them to facilitate epistemological border-crossing in their classrooms.

The Life Sciences teachers who served as the sample were requested to complete a number of data collection instruments which included classroom observations and semi-structured interviews. This was done to help to investigate the influence of an intervention on the teachers' perceptions of the NOS, the NOIK and their classroom pedagogy and their self-directed learning and the CHAT served as a lens of analysis on a personal, interpersonal, and institutional level. The rationale for using the CHAT was that it was a relevant tool to cover all the contextual factors that the Life Sciences teachers experienced on a personal level, where the teacher's classroom pedagogy was challenged. Furthermore, on an institutional level where the two knowledge systems were scrutinised and on an interpersonal level where the teachers' from different settings and their classroom pedagogies were compared.

3.4 Validity of the study

In this section, I deliberate on the validity of the study where the reader is taken into confidence regarding the steps I took to ensure that the study maintains its integrity.

3.4.1 Validity

According to Creswell and Plano Clark (2018), and McMillan and Schumacher (2010), validity is defined as the accurate interpretation and application of the information that is collected via measurement, and it is important to determine the degree of validity that exists based on the available data. Therefore, the validity in the MM research is described as using the schemes that address the possible issues in "data collection, data analysis, and the interpretations that might compromise the merging or connecting of the quantitative and qualitative strands of the study and the conclusions drawn from the combination" (Creswell & Plano Clark, 2011, p. 239). Gay et al. (2014) on the other hand, define validity as the extent to which collected data can accurately measure what the researchers are attempting to measure. According to Creswell and Plano Clark (2011), many terms are used in the MM research, but validity is a common term emerging from both the qualitative as well as the quantitative approaches, and as such it remains the relevant term to use. Furthermore, to address the validity of this study, the deliberations of the steps below were considered as recommended by Creswell (2009), as well as by Eisenhart and Howe (1992).

- **Data triangulation**

According to Gay et al. (2014), and McMillan and Schumacher (2010), triangulation is the practice of employing a variety of procedures, data gathering tactics, and data sources to acquire a full picture of what is being investigated and to cross-check information. Hence, Frambach et al. (2013, p.552), define data triangulation as the "use of multiple data sources", while Maree and Van der Westhuizen (2011) caution that data triangulation is central to ensuring validity in a research project. In the context of this study, data triangulation was achieved using collecting data using multiple instruments such as open-ended questionnaires, classroom observations using RTOP and the individual open-ended interviews as well as the SDLI. These interviews were conducted after each classroom observation and all the aforementioned assisted in achieving data triangulation to ensure validity in this study.

- **Theory triangulation**

Frambach et al. (2013) defines theory triangulation as the utilisation of multiple theories in a study in an attempt to ensure validity. Furthermore, De Vos (2002) suggests that using multiple theoretical frameworks as the research lenses in the planning stage of data collection and in the analysis stage of the collected data helps to ensure validity because new ideas can be developed. In the context of this study, theory triangulation was used by including theories such as social constructivism where the CHAT was used as a lens of data analysis. In addition, PCK, the NOS, the NOIK and conceptual change were used as transitional theoretical concepts and Warford's ZPTD was used as a theory for the Life Sciences teachers' professional development. All of these theories contributed to ensuring theory triangulation in this study and they are discussed in Chapter 2 of this thesis.

- **Methodological triangulation**

Methodological triangulation is described is the usage of more than two methods in studying the same phenomenon under investigation and it is usually used in data collection and data analysis (Hussein, 2009; Mitchell, 1986). In an attempt to triangulate the qualitative and the quantitative data, I used the qualitative data that was drawn from the classroom observations and the semi-structured interviews to triangulate the quantitative data drawn from the SDLI pre- and post-intervention. In other words, the classroom observations sought to determine if there was any transfer of new knowledge from the teachers and the semi-structured interviews which sought to determine if the teachers could reflect on their own practices. The reflection of the teachers' transfers of knowledge during the classroom observations and the ability to reflect on their own practice during the semi-structured interviews or the lack thereof provided credibility to the SDLI responses.

- **Validation of data collection instruments**

Creswell (2009) as well as Eisenhart and Howe (1992) suggest that there are many ways to ensure validity in research, and one of those ways that the researchers can use is the data collection instruments that have been validated. In the context of this study as highlighted in the data collection section, the VNOIK questionnaire was validated in a study conducted by Cronje (2015), and the VNOS-D+ questionnaire was validated in the study conducted by Lederman and Lederman (2010). While SDLI, POSTT LFSC and RTOP were all also validated by Cheng et al. (2010), Cobern et al. (2014), and Piburn et al. (2000), respectively.

- **Prolonged engagement at the study site**

Frambach et al. (2013) posit that a prolonged engagement is a process where the researcher "collects data for an extended period" (p.552). The aforementioned aspect is done to help to "overcome distortions produced by the presence of researchers and provide oneself with the opportunity to test biases and perceptions" (Gay et al., 2014, p.344). In the context of this study, the process of data collection was done over a period of a year in two different provinces where two SLPs and classroom visits were used to collect data.

3.4.2 Transferability

Transferability refers to the degree to which the research results can be transferred or applied in diverse settings (Frambach et al., 2013; Younas et al., 2023). This component seeks to determine how the research findings are in harmony with the experiences of the researcher and thus seem transferable in the eyes of the reader (Terharne & Riggs, 2015). To address the component of transferability the research used the aspect of a thick description which is deliberated below.

- **Thick description**

The thick descriptions of the qualitative findings are crucial to increasing the transferability of the qualitative research findings because they allow the researchers to assess their application to various contexts and settings (Younas et al., 2023). According to Merriam and Tisdell (2016), a thick description is important in improving transferability and analytical generalisation of qualitative research findings since it allows the researchers to examine their application to various contexts. According to Younas et al. (2023), a thick description is defined as the process of providing a detailed explanation of the participants' perspectives, intentions, circumstances, reasons, meaning, and understandings. In the context of this study, a thick description was addressed through the use of In-vivo coding to analyse the VNOS-D+ and the VNOIK.

3.5 Reliability of the study

In this section, I deliberate on the reliability of the study where the reader is taken into confidence regarding the steps I took to ensure that the study maintains its integrity.

3.5.1 Reliability

According to Frambach et al. (2013, p.552) reliability "is the extent to which the results are consistent if the study would be replicated or the extent to which the findings are consistent concerning the context in which they were generated". Creswell (2009) describes reliability as the regularity that governs the way the researcher can collect data the same way from different contexts. In the context of this study, as suggested by Frambach et al. (2013), the following aspects were considered.

- **Data saturation**

Mwita (2022, p.414) suggests that "in the process of collecting qualitative data, a researcher must decide on whether the data have been sufficiently collected". Frambach et al. (2013) defines data saturation as the process where the researcher collects data until no new themes arise. In the context of this study, data saturation was ensured using the use of multiple data collection instruments before and after the intervention where the participants were also interviewed, and this is when data saturation was reached. This assisted in ensuring that no new themes of data are formed.

- **Iterative data collection**

According to Kekeya (2016), iterative means one has to repeatedly revisit the data or go back and forth frequently on the data. On the other hand, Frambach et al. (2013) define iterative data collection as the continuous analysis of data during data collection to help inform the researcher how data can be further collected. In the context of this study, data was collected using six data collection instruments (VNOS, VNOIK, SDLI, POSTT LFSC and classroom observations) where interviews were intended for the post-classroom observations. Although planned, the data that was collected pre-intervention informed how data would be collected post-intervention.

- **Iterative data analysis**

Qualitative data can be analysed using many techniques to reveal the reality and an iterative process refers to one of the techniques that are used by the researchers to analyse qualitative data (Kekeya, 2016; Matthew & Ross, 2010). An iterative data analysis refers to the continuous re-examination of the data that is analysed using great insights which arises during data analysis (Frambach et al., 2013). In the context of this study, I analysed the data and the supervisors advised on how the data could be better analysed. Thus, requiring me to continuously reflect and re-examine the data to the satisfaction of the supervisors.

All the above aspects were considered to ensure the validity and the reliability of the collected data in the study.

3.6 The Intervention

3.6.1 Landmark Protea Hotel Polokwane

The intervention was comprised of two SLPs, the first being an IK SLP which took place at the Landmark Protea Hotel for two days where 15 Life Science teachers (5 from each setting) were invited and only 12 (four from each setting) were able to attend. On day 1, upon arriving at the Landmark Hotel, the teachers were invited to participate in a feel-good activity where a *world café* method was used to engage in a topic titled: *Being a teacher*. The teachers were then requested to complete the SLDI, the two open-ended questionnaires (VNOIK and VNOS +D) as well as the POSTT LFSC. All these data collecting instruments were completed before the commencement of the SLP.

The SLP started with an introduction of IK in a Life Sciences classroom, after the introduction the teachers were tasked with two laboratory activities. In the first (laboratory) activity the teachers were required to participate in a Kirby-Bauer technique for testing the antimicrobial activities using indigenous plants. The teachers were further required to work in groups to do an Ethnobiological survey using the Matrix method using an ethnobotanical book titled: "T*he people's plants: A guide to useful plants of Southern Africa"* (Van Wyk, 2017). In an attempt to encourage frugal Science (Science on a shoestring) among the teachers, on the second activity, the teachers were grouped into three members, and they were provided with kitchen products such as sugar, warm water, cold water, yeast sachets, empty 500ml spring water bottles and deflated balloons to perform an experiment of fermentation. During the experiment, the teachers were required to determine the variables determining the rate of fermentation and the constituencies of the products needed to perform the fermentation and later make presentations of their findings.

Figure 3.2: The Life Sciences teachers are attempting to engage in the process of fermentation (Author's own work).

The teachers were further engaged in a PBL activity in Life Sciences where an activity of the post-harvest physiology of cut flower was presented. Lastly, the teachers engaged in a cooperative learning approach, where the Jigsaw teaching method was used on the lesson about ethnobotany where the people's plants (Van wyk, 2017) were used by the teachers to study the indigenous plants using the Jigsaw teaching method.

On day 2 of the SLP at the Landmark Protea hotel, the teachers were further engaged in another CL approach where they used De Bono's six thinking hats teaching method (Petersen et al., 2019). The teachers were required to use the method to deliberate on the role played by initiation schools in the prevention and in the spread of the sexually transmitted and other related diseases. The main focus was on how traditional circumcision can help to prevent the STDs if performed properly when the blades that are used are sterilized and how the unsterilized blades can help to spread the STDs and the other diseases.

The last activity of the day engaged the teachers about puppetry in the Life Sciences classroom and how this method can encourage the learners to participate more without being victimised by the other learners. Furthermore, the teachers were required to perform puppetry in groups of three where they made presentations to the community Chief about the issues that take place in the community and that can also be used to bring context to the indigenous learners in a Life Sciences classroom. Lastly, after the SLP at the Landmark Protea hotel, the Life Sciences teachers (experimental group) were then requested to complete the SLDI, the two open-ended questionnaires (VNOIK and VNOS-D+) as well as the POSTT LFSC. On the other hand, the teachers participating as a control group were only contacted individually where I planned for a week and a half before the intervention for them to complete the SDLI.

3.6.2 African Centre for DNA and Barcoding at the University of Johannesburg

The second SLP as part of the intervention, took place at the ACDB laboratory at the UJ. The study initially intended for all the 12 participants who attended the first SLP to also participate in the second SLP that was scheduled to take place at the ACDB. However, due to the COVID-19 restrictions, only six teachers who were vaccinated were allowed to attend the second SLP at the UJ.

The second SLP took place from the 28th to the 29th of March 2022 where the programme started at 10h30 and the first presentation was done by two DNA specialists. The presentation was about the background on the DNA technologies. Furthermore, the presentation deliberated upon DNA Barcoding and the species identification, the DNA analysis and data interpretation, and the Forensic use of DNA Barcoding and the challenges therein. Furthermore, the teachers were exposed to real laboratory work where two real laboratory scientists engaged the teachers on the general sampling procedure and laboratory protocol. The teachers were further taken through the university campus where they collected plant material, which was used for DNA extraction.

Figure 3.3: The plant material was combined with sand and ground together for DNA extraction (Author's own work).

On day 2 of the SLP at the UJ, the two laboratory scientists continued to engage the teachers on laboratory work, where the teachers were taught and trained about the Polymerase Chain Reaction (PCR) that was set up and experimentation. Once the two laboratory scientists were done with the laboratory work, the two DNA specialists introduced the teachers to a life-scanner. The two DNA specialists deliberated on the background of the life-scanner, the life-scanner kit, the life-scanner application, the kit usage as well as proper sampling procedures. Lastly, the two laboratory scientists took the teachers through the cycle sequencing that was set up and experimentation while the Bioinformatics presenter wrapped up with Bioinformatics.

3.7 Ethical parameters of the study

This section deliberates on the steps that were taken to ensure good ethics during data collection and how understanding was built between me and the participants.

3.7.1 Ensuring good ethics

In an attempt to ensure that good ethics were adhered to in this research, I completed four ethics modules with Training and Resources in Research Ethics Evaluation

(TRREE). The TRREE is an online platform which aims to give fundamental training on the ethics of human health research while increasing skills, so that the research satisfies the highest ethical standards and supports the welfare of the participants (TRREE, 2019). I obtained four certificates in ethics, the ethics evaluation, the informed consent and a South African certificate on ethics. The proof of ethics training is compulsory to all the researchers of the NWU.

This research was categorised as being medium risk by the NWU (scientific committee of the Unit of SDL), because it involved human participants and because the data collection involved travelling from province to province. Thus, I also applied for ethical clearance at the “North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics” Office (NWU-EMELTEN-REC) and it was granted (ethics no: NWU-01115-20-A2).

According to Ivan (2021), and McMillan and Schumacher (2010), the research ethics are concerned with what is morally right and wrong when working with participants or when accessing archival data. On the other hand, Creswell (2009) cautioned about the significant role that is played by the ethical issues in research because of their responsibility in protecting the participants. Furthermore, they see to it that the participants are safe from harm and their identities as well as their integrity are protected. Their human rights took preference of the research. Furthermore, Cohen et al. (2002), allude that the ethics are an issue of principled attention to the others' rights. Furthermore, being ethical restricts the options in the search for truth. Although the truth is beneficial, the ethics say that the respect for human dignity is preferable, even if in extreme situations, the regard for human nature leaves one uninformed of human nature.

As highlighted in this and in previous chapters, this study involved the Life Sciences teacher participants situated in two districts (Capricorn North and South districts) in the Limpopo Province. The researcher wrote a letter to the Limpopo Department of Basic Education (DBE) requesting permission to conduct the study and was granted permission. The permission from the DBE was used as the covering letter to further request permission from the two circuit managers and the schools' principals and in an attempt to avoid coercing and influencing the teachers. I instead requested his colleague to be the one communicating the research intentions to the principals and their School Governing Bodies (SGBs) which is statutory body made up of parents, teachers, non-teaching staff, and learners (in Grade 8 or above) who aim to collaborate in order to improve learning and teaching by promoting the well-being and effectiveness of the school community (Sayed, 1999). This is done to promote voluntary participation, which means “that participants cannot be compelled, coerced or required to participate or no one should be forced to participate in research” (McMillan & Schumacher, 2010, p.118).

In addition, once the Life Sciences teachers responded with interest to participate in the study, a meeting was set where full disclosure was made regarding the intentions of the study. Hence, Creswell and Plano Clark (2018), and McMillian and Schumacher (2010) caution that in general, the researchers should be open and honest with the volunteers about all the elements of the study, and this generally entails a thorough disclosure of the research's goal. According to McMillan and Schumacher (2010, p.118), informed consent is accomplished by giving the participants an explanation of the research, with the option to withdraw at any time without penalty, and there must be a full disclosure of any risks that are involved with the study. The invitation letter to the participating Life Sciences teacher contained all the relevant information regarding the study, for them to provide voluntary informed consent to participate. It was expected that the Life Sciences teachers who wanted to participate must sign the voluntary informed consent letter.

Lastly, all the necessary measures that ensured good ethics were followed in the data collection process and as highlighted above, some participants felt unsettled to continue participating in the study due to the uncertainties that were posed by COVID-19. As such they opted to discontinue the study, while on the other hand, the other participants opted to continue with the study and none of those participants were harmed. Furthermore, to protect their identities, I used pseudonyms throughout the data collection. This is because it is pivotal that the privacy of the research participants must be protected, and this does not only refer to their names (Creswell & Plano Clark, 2018McMillan & Schumacher, 2010).

3.7.2 Building understanding among participants

The teachers were initially visited individually at their schools by my colleague. From there I went to each school to explain to each teacher the intention of the research and each teacher's cell phone number was stored, and a WhatsApp group was created. Due to the COVID-19 restrictions, the participating teachers were communicated with through the WhatsApp group for any new developments and they were further assured that the two SLPs (forming the intervention) would eventually take place. Although the teachers were assured, some of the teachers withdrew from the study where only 12 teachers who were to serve as the experimental group remained with 26 who served as the control group. Of these 12 teachers, four teachers were from the rural setting and district, four teachers were from the semi-urban setting and the last four teachers were from the urban setting of the Capricorn district.

After the teachers received their training, they were given manuals that would be useful in their classroom when teaching the topic of genetics and DNA. Each teacher was further awarded a UJ certificate of attending training on DNA and Barcoding, which would also contribute towards their development as deemed by the South African Council of Educators (SACE). The teachers were also given teaching aids such as DNA kits. The relationship between me and the teachers has developed in such a way that when the teachers need support they do not hesitate to contact me.

3.8 Summary of Chapter Three

This chapter focused on the research aims and the research questions. It elaborated on the theoretical parameters of the study as well as the methodological parameters, which dealt with the research design, and also provided the details about the intervention of the study. Furthermore, this chapter looked into the process of sampling, data collection, and deliberation on using the CHAT as a research lens to interpret and analyse data from each data collection instrument. Lastly, the validity and the reliability of the study were also deliberated upon as well as the ethical parameters of the study.

The following chapter deals with the presentation of data, the analysis, and the discussion of the findings.

CHAPTER 4: DATA PRESENTATION AND ANALYSIS

4.1 Introduction

In Chapter 3, I thought carefully about some aspects of the research methodology, such as the research objectives as well as the research questions and also examined the theoretical confines of the study which aimed to unpack the paradigm. The methodological parameters were also discussed in the chapter which aided in explaining the research design of this study and the data collection process. I also considered reliability and validity, and how data from each instrument was analysed. Finally, the chapter discussed the study's ethical guidelines. I talked about how the participants were safeguarded and how mutual understanding and trust were fostered. This is so that the study could address the ethical concerns which were the intentions.

This chapter presents an analysis of the gathered data (Mbambo, 2005) from the two open-ended questionnaires namely: the Views of the Nature of Indigenous Knowledge (VNOIK) and the Views of the Nature of Science (VNOS-D+). An adapted Pedagogy of Science Teaching Test (POSTT LFSC) a multiple-choice item questionnaire and the Self-Directed Learning Instrument (SDLI as quantitative questionnaire was called the). Lastly, classroom observations using the Reformed Teaching Observation Protocol (RTOP, a heuristic to guide observations) as well as semi-structured interviews are discussed. The first four instruments were completed by the teachers on a pre-intervention and post-intervention basis. The classroom observations and the semi-structured interviews were only conducted post-intervention with only six teachers (two from each setting: urban, semi-urban and rural).

The goal of data analysis is to produce useful information. Furthermore, regardless of whether the data is qualitative or quantitative, both the presentation and the analysis aim to describe and summarise the data, so that they may find the connections between the variables and to provide in-depth accounts of events (Rogers et al., 2007).

I also used the data to compare the findings from the participants who teach in schools that are situated in rural, in semi-urban and in urban settings. Furthermore, I used the data to find the connections between the variables and compare them particularly during the analysis of the SDLI (Cheng et al., 2010). Lastly, I analysed the data using two stages, where the first stage was a holistic analysis from the VNOIK to the semi-structured interviews. For the second stage of the analysis, I utilised the CHAT and applied the three planes (personal, institutional, and interpersonal) to examine the findings.

4.2 Participants' biographical information

In Table 4.1 the profiles of the twelve teachers that were involved in the research are summarised. As can be seen, the participants are diverse in terms of age, qualifications and teaching experience.

Table 4.1: Participants' profiles (Author's own creation)

Participant	Gender	Age	Highest qualification	Teaching experience	Subjects teaching	Setting
001	F	53 yrs	STD	10 yrs	Life Sciences	Rural
002	M	26 yrs	B. Ed FET	3 yrs	Life Sciences	Rural
003	F	26 yrs	B. Ed FET	3 yrs	Life Sciences	Rural
004	F	30 yrs	B. Ed FET	4 yrs	Life Sciences	Rural
005	F	29 yrs	B. Ed FET	4 yrs	Life Sciences	Semi-urban
006	M	28 yrs	B. Ed FET	4 yrs	Life Sciences	Semi-urban
007	F	31 yrs	B. Ed FET	7 yrs	Life Sciences	Semi-urban
008	F	49 yrs	HED	16 yrs	Life Sciences	Semi-urban
009	M	40 yrs	BSc HED	13 yrs	Life Sciences	Urban
010	F	55 yrs	B. Ed Hons	23 yrs	Life Sciences	Urban
011	M	52 yrs	STD	15 yrs	Life Sciences	Urban
012	F	NP	NP	NP	Life Sciences	Urban
KEY: STD = Secondary Teacher Diploma; B. Ed. FET = Bachelor of Education Further Education and Training; HED = High Education Diploma; BSc HED = Bachelor of Science High Education Diploma; B. Ed. Hons =Bachelor of Education Honours; F= Female; M = Male; Yrs = Years, NP = Not provided						

4.3 Presentation and analysis of data from both the VNOIK and the VNOS-D+

In an attempt to analyse the participants' responses to both the VNOIK and the VNOS-D+, firstly, I adapted a rubric that was initially developed by Cronje et al. (2015) to classify the participants' responses using the codes as explained in Chapter 3. I adapted the rubric by adding the fourth classification (Not Classifiable) which was drawn from the rubric that was used to classify the responses from the VNOS which was developed by Yoon et al. (2014, p.2676). Hence, the fourth classification serves as one of the contributions of this study. Secondly, in an attempt to classify the participants' responses to the VNOS-D+, I used the rubric that was developed with contributions from Akerson and Donnelly (2010, p.12), Ayala-Villamil and Garcia-Maritnez (2021, p.10-14), Lederman et al. (2002), and Yoon et al. (2014, p.2676) as highlighted from the previous chapter.

The collected qualitative data was initially coded holistically (the sum of all the participants and deliberations from the participants were made using in vivo coding to determine all the participants' perceptions about the NOIK and the NOS). A comparison of both the pre-intervention and the post-intervention responses using the scores from the classifications of each instrument was used to determine the influence of the intervention. This was done by determining the overall score average, the total number of either No Classification (NC) (0), Uninformed Views (UV) (0), Partially Informed Views (PIV) (1) or Informed Views (IV) (2). Furthermore, the percentage of increased or decreased numbers per classification from the pre-intervention and the post-intervention were also used to determine the influence of the intervention. Below is a presentation and an analysis of the generated data from the VNOIK and the VNOS-D+ on a pre-intervention and post-intervention basis.

4.3.1 Presenting and analysing pre-intervention data from the VNOIK

Table 4.2 presents the pre-intervention VNOIK responses of the participating Life Sciences teachers from the three settings. The participants' responses were coded, weighted and scored from the lowest score of 'No classification and Uninformed views' (0) to a high score of 'Informed views' (2).

Table 4.2: Summary of coded pre-intervention VNOIK responses of participants from the three settings (Cronje, 2015).

Summary of coded pre-intervention responses of participants										
Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Overall Score
001	PIV	UV	IV	PIV	PIV	IV	IV	NC	PIV	IV	
Weighing	1	0	2	1	1	2	2	0	1	2	1.2
002	UV	PIV	NC	IV	UV	UV	IV	IV	IV	IV	
Weighing	0	1	0	2	0	0	2	2	2	2	1.2
003	PIV	PIV	IV	PIV	IV	UV	PIV	UV	IV	PIV	
Weighing	1	1	2	1	2	0	1	0	2	1	1.2
004	IV	UV	PIV	UV	UV	IV	NC	IV	NC	UV	
Weighing	2	0	1	0	0	2	0	2	0	0	0.7
005	IV	IV	IV	PIV	IV	IV	UV	IV	IV	IV	
Weighing	2	2	2	1	2	2	0	2	2	2	1.7
006	UV	UV	PIV	PIV	IV	UV	UV	PIV	PIV	PIV	
Weighing	0	0	1	1	2	0	0	1	1	1	0.7
007	UV	PIV	IV	IV	IV	IV	PIV	IV	PIV	UV	
Weighing	0	1	2	2	2	2	1	2	1	0	1.3
008	PIV	IV	IV	PIV	IV	IV	IV	IV	PIV	UV	
Weighing	1	2	2	1	2	2	2	2	1	0	1.5
009	UV	IV	IV	PIV	IV	IV	PIV	IV	PIV	IV	
Weighing	0	2	2	1	2	2	1	2	1	2	1.5
010	IV	UV	IV	UV	PIV	UV	PIV	IV	IV	UV	
Weighing	2	0	2	0	1	0	1	2	2	0	1.0
011	IV	UV	NC	UV	IV	IV	PIV	IV	PIV	UV	
Weighing	2	0	0	0	2	2	1	2	1	0	1.0
012	IV	PIV	PIV	PIV	PIV	IV	PIV	IV	PIV	PIV	
Weighing	2	1	1	1	1	2	1	2	1	1	1.3
Total NC	0	0	2	0	0	0	1	1	1	0	5
Total UV	4	5	0	3	2	4	2	1	0	5	26
Total PIV	3	4	3	7	3	0	6	1	7	3	37
Total IV	5	3	7	2	7	8	3	9	4	4	52

[**KEY:** Q = Question; NC = No Classification; UV = Uninformed Views; PIV = Partially-Informed Views; IV = Informed Views]

From Table 4.2, it can be seen that the overall scores range from 0.7 to 1.7 out of the possible 2.0, thereby making the overall range for the overall score (0.7 +1.7)/2 = 1.2, which suggests that most of the participants' responses reflected IV. This is evident from the total number of IVs compared to the total number of NC, UV and PIV. Out of a potential 120 answers, the participants provided five total responses that were NC, accounting for 4.2% of the total responses, and 26 total responses that were UV, representing 21.7% of the total responses. Additionally, as can be seen from the table, 37 PIV in total—or 30.8% of all potential responses—were represented in participant responses. Finally, the overall number of IVs among the participating teachers is 52, which represents 43.3% of the potential 120 answers. As a result, the replies appear to indicate that the teachers have an IV of the NOIK. The deliberations on the teachers' responses are made below.

Question 1: What is indigenous knowledge and what makes it different from the other types of knowledge systems?

The participants' responses from the first question, showed that the majority of the participants ranged from PIV to IV, while only four participants showed UV. In response to the question, Participant 002 stated that,

> *IK is the knowledge that is native to us, we do not acquire it in our lifetime. There is a broad difference between IK and Western knowledge. For example, IK we learn things according to our understanding as African people*.

The participant's response regarding what IK is seems to suggest that IK is not acquired rather, the native people are born with it, which in turn nullifies the idea that IK is passed down from one generation to the next orally. Grey (2014, p.3230) suggests that "some IK will be held by the community as a whole, while other teachings will be held by specific individuals, families, or groups of practitioners". IK is a living knowledge base, which changes over time.

Participant 002's response on what makes IK different from the other types of knowledge systems showed that the participant understood the question, but the views are uniformed. The participant's response,

> *No, they do not test it, because they do not have scientific knowledge and equipment to do so*

reflected the awareness that there are differences between IK and Western Science, but they were unable to account for the distinction between the two systems, as such the response reflected UV.

On the other hand, in response to the same question, Participant 005 stated that IK *"is people's knowledge/ local knowledge about a particular phenomenon"*, the participant further highlighted that

> *IK is different for each group of people, while Western knowledge seems to be the same/ common for all groups of people*.

The participant's response showed that they are aware of IK being a local knowledge, furthermore, the participant is aware that IK differs from one community to the next, hence, IK "iterations and mechanisms are unique to each community" (Grey, 2014, p.3230), unlike western Science whose methods are common across the spheres. For this reason, Participant 005's response reflected IV.

Participant 011 again stated that,

> *IK is the norms and values of a particular group of people that were used and carried from generation to generation….. It is not properly recorded as it is carried from generation to the next, some information is lost*.

This response reflects the knowledge that is held by the participant that IK is passed on from one generation to the next orally. The participant further highlighted the concern that some of the knowledge is lost due to how it is recorded and hence the generational disjuncture between the current and the previous generations. Hence, according to Senanayake (2006, p.87), "IK is passed from generation to, usually by word of mouth and cultural rituals", as such both participants (005 and 011) reflected IV.

Question 2: As the practitioners of IK observe nature to generate knowledge, do they do experiments and tests to verify or validate this knowledge?

The participants' responses to this question reflected five UV, with four participants' responses reflecting PIV and three showing IV.

In response to the question Participant 001 stated that,

> *practitioners do not use experiments or tests, because they do not know anything about measurements when giving their patients medicines"*. This refers to the traditional healers. Participant 010 stated that, "*practitioners do not use experiments or tests and all of their behaviours are based on beliefs*.

In addition, Participant 011 stated that,

> *The traditional healers' knowledge is based on how it was used previously*.

The responses from the participants reflected that the participants view experiments, tests or measurements as only being done in a formal (western Science) setting. Furthermore, the participants seem to view IK as being mostly metaphysical and they struggle to see the empirical nature of IK. Lastly, Participant 011's response reflected the awareness of the knowledge used being passed from one generation to the next, however, the participant's response reflected the oblivion of observations, experiments and the tests that were run by the previous generation. This knowledge "is produced through an organised process of observing local conditions, experimenting with solutions" (Senanayake, 2006, p.87), which is a dimension that is not observed in these respondents' feedback. Hence, the three participants reflected UV.

In response to the question, Participant 005 stated that,

> *Practitioners tests or validate their knowledge by constantly observing what seems to work and what conditions, even though their tests or experimentation are not in a scientific way which involves laboratories and chemicals,* while Participant 009 stated that, *the practitioners do experiments tests through trial-and-error methods*.

Participant 005's response reflected that they are aware that the type of experiments and tests that are done by the IK practitioners are done in the laboratory of life, not in scientific laboratories (Cronje et al., 2015). Furthermore, the participant acknowledged the intense observations and the tests done by the practitioners where the conditions are also considered for what works and what does not.

Lastly, Participant 009's response reflected the idea that for the practitioners to decipher what works and what does not, they had to do a lot of trial and error. In other words, the trial-and-error phenomenon required test after test until the correct mixture is made, by so doing, new knowledge is formed (Cronje, 2015). Therefore, the responses by the two participants (005 and 009) reflect IV.

Question 3: Do the elders always use the natural causes to explain their observations such as lightning, or do they sometimes include supernatural causes in their explanations?

The responses from the majority of the participants show IV, with only three participants that reflected PIV while two of the responses were appraised as NC. In other words, two participants did not attempt to respond to the question.

In response to the question Participant 007 like most of the participants stated that

> *We grew up with both natural and supernatural causes… We were told that burning fruit plants, the fumes from the fires caused blindness. This helped to preserve food sources in our communities*. While Participant 003 stated that *they sometimes use supernatural causes because they believe human beings are capable of causing lightning*.

The responses from the two participants like the majority of the responses from the participants reflected that the participants cannot separate the natural and the supernatural elements that characterise indigenous knowledge. Hence, while developing the VNOIK Cronje et al. (2015) highlight that like the NOS, the NOIK is empirical in nature, but the NOIK is also metaphysical in nature. Furthermore, according to Smith and Wobst (2005) the indigenous practitioners "who may inherit this role within the family line; it is their responsibility to monitor and mediate human interactions with the ancestral landscape" (cited in Bruchac, 2014, p.3816).

Lastly, Participant 007 highlighted that some of the reasons behind the supernatural explanations were intended to plant fear amongst the children in an attempt to preserve the plants. This agrees with Cronje et al. (2015) who highlight that IK is mythical in nature. Hence, the responses that were provided by the majority of the participants reflected IV.

Question 4: Does this knowledge stay the same or does it change over time?

The responses from the majority of the participants reflected PIV, with few UV, and even fewer participants who reflected IV.

In response to the question, Participant 004 stated that,

> *The knowledge stays the same because whatever is transferred from one generation to the other has been happening for the past years without any change of knowledge*.

Based on the response from Participant 004, it is clear that the participant is not aware of the tentative nature of IK (Grey, 2014; Kaya & Seleti, 2013), as such the response reflected a UV. On the other hand, the response by Participant 003 who stated that

> *The knowledge changes due to the forever changing environment that we live in. People start believing in theories that can be proven*,

showed that the participant is aware of the tentative nature of IK. However, the participant seemed to suggest that the knowledge changes due to only the changing environment and it does not reflect on the fact that the discoveries could also change the knowledge. As such, the response reflected a PIV.

In an attempt to respond to the question Participant 007 stated that,

> *The knowledge changes because as we move from time to time we gain more knowledge, and this influences the way we further transfer IK*.

It is deductible from the response that the participant recognised the tentative nature of IK. Furthermore, the participant's views reflected that in light of new information, knowledge is subject to change or improvement. In other words, the response by

Participant 007 reflected the knowledge that IK is tentative, and the participant has also been able to reflect the understanding on what makes IK tentative. Thus, the response by the participant reflected IV.

Question 5: How do you think the Khoi-San people came to know that the *hoodia gordonii* has the properties to suppress hunger and thirst?

There are seven responses from the participants which reflected IV, three responses which reflected PIV and two responses that reflected UV. As such, the majority of the participants' responses reflected IV.

In an attempt to respond to the question, Participant 004 stated that,

> *I think they have been instructed by nature that the plant can be used for that purpose*, while Participant 002 stated that, *Khoi-San people as they were living in the bush, it was easy for them to identify it easily as they use to feed on it*.

The participant seemed to suggest that nature spoke to the Khoi-San people, while the other participant seemed to suggest that it was not a challenge for the Khoi-San people to feed on the plant because they have been living in the bush. These responses are oblivious to the observations that might have been made by the Khoi-San community or the knowledge that has been passed from one generation to the next. Considering the metaphysical aspect of IK, it is not nature that speaks to the people but rather the ancestors (Bruchac, 2014), hence the responses by the two participants reflected UV.

In response to the question, Participant 001 stated that,

> *They may be taught by their elders which carry the information from one generation to the other*, while Participant 010 stated that *those people, the only lifestyle they knew was desert life. So, they had ways of survival… thus, it was easy for them to experiment with everything in the desert for survival purposes*.

The views reflected from this response are partially informed, as the participant acknowledged the notion that the Khoi-San community lived in the bush as such experimenting with plants was their way of survival. However, the participant's response did not seem to acknowledge that the trial and error or observations and as well as receiving such knowledge from the elders played a part in the discovery of the use of the plant (Senanayake, 2006). Hence, PIV is reflected in the responses.

In an attempt to respond to the question Participant 007 stated that,

> *The plants might have been discovered by someone who was stuck in the wilderness and had to rely on plants for survival, thus, the knowledge was made public to other members of the community*.

Furthermore, Participant 003 stated that

> *I think they saw other, animals using them to suppress hunger and thirst and went on to test the plant on themselves*, while Participant 006 stated that *the Khoi-San people might have known by observing herbivores feeding on them as it was believed any plant eaten by an animal and can also be eaten by human beings.*

The responses from the three participants highlighted that the Khoi-San people used trial and error to discover the use of hoodia due to the need to survive, and the use of the observation of the other animals, where the knowledge was then passed on to the next generation. Lastly, the belief that if other plant-eating animals can survive through the plant, then it might be safe for human consumption, as such observation, trial and error and the passing down of knowledge from one generation to the next played a role (Cronje et al., 2015). Therefore, the responses by the three participants reflect IV by the majority of the participants.

Question 6: Do you think IK can be used to solve contemporary problems such as hunger, poverty and underdevelopment?

Out of the responses provided by the participants, four of those responses reflected UV, while eight reflected IV, and the majority of the responses provided by the participants are of IV.

In an attempt to respond to the question Participant 003 stated that

> *I don’t think IK can be used, because with the ever-growing population and high demand needs such as food and only Science and technology can be the*

> *solution to produce fast and large amounts of food*. While Participant 006 stated that *No, because IK produce is only available in seasons and the population is growing rapidly, so there is going to be a shortage in terms of alleviating poverty and hunger*.

The two participants' responses disagree with the idea that IK can be used to solve contemporary problems, one participant believes that only Science and technology can address such problems. On the other hand, the other participant's responses reflect the misconception that food production in IK is seasonal. The participant appears oblivious to the fact that IK has stood the test of time, and it has survived for centuries as such it remains relevant in dealing with the contemporary issues, as such their responses reflected UV.

In an attempt to respond to the question, Participant 005 stated that,

> *Yes, this would provide the idea of what enabled people before to live without hunger, poverty, and underdevelopment. This is because indigenous people survived through nature's resources in all areas of their lives including cures to illnesses*. While Participant 008 responded by saying that, *Yes because locals always know how to protect and conserve natural resources to ensure that those resources are always available for the community to use*.

The responses from the two participants seem to acknowledge the role played by IK in addressing issues such as hunger and conservation to mention a few. Participant 005 acknowledged the affordances provided by IK for people to survive through nature's resources and its ability to provide the cures for illnesses. Lastly, Participant 008 seemed to acknowledge the idea that IK can help in preserving nature and the availability of food provision for many indigenous communities. Therefore, the views reflected by the majority of the participants are informed.

Question 7: What methods do you think the traditional healer will apply to diagnose the problem when consulting with the athlete and what possible treatment or advice do you think he will give the athlete?

The responses to this question had the majority of the participants reflecting PIV, followed by three participants whose responses reflected IV and two UV. The trend where the majority of the participants' responses reflected PIV are also seen in question four where seven of the participants' responses reflected PIV.

There were two participants whose responses reflected uninformed views that attempted to answer the question, with Participant 005 stating that

> *The traditional healer will use traditional methods and the traditional healer will also give the athlete the traditional medicine/ muthi*. While Participant 006 responded to the question by stating that *the traditional healer will apply some herbs on the athlete's legs to stop the pains…. The use of some plant leaves to increase the flow of blood on his legs*.

The responses from the two participants acknowledged the use of *muthi* in attempting to heal the athlete, however, the responses provided by the participants are not clear on which methods could be used to address the athlete's problem. Furthermore, the participants did not substantiate what informs the traditional healer about which medicine or herb to use and how much of the herb to use. Therefore, the responses by the two participants reflected UV.

In an attempt to answer the question, two of the six participants whose responses reflected partially informed views stated that: Participant 003

> *In most cases, the traditional healer will diagnose the athlete with just assessing the foot with his/her hands and eyes…. The traditional healer might cut small holes around the area and let blood out and mix whatever herbs to rub on the wood*. On the other hand, Participant 009 stated that *the traditional healer can massage the area and observe the response of the patient… The healer can mesh leaves and apply as a typical ointment to the affected area*.

The responses from the two participants highlighted the acknowledgement from the participant that the healer would assess the foot and the herbs to help in healing the foot or even apply a typical ointment. However, the responses are void of the methods that are used by the healer to determine which herb to use and what the healer may use to diagnose the foot. The participants showed that the healer would be able to use herbs, cut the affected area and massage, but the participants have not been able to highlight the how part, as such their responses reflected PIV.

A total of two of the three teachers whose responses reflected IV stated that: Participant 002

> *The traditional healer can say that the cause of the pain is supernatural or spiritually related… the treatment by traditional healer will be through the use of indigenous ways and the healer may also seek advice from the ancestors*. On the other hand, Participant 001 stated that *"the traditional healer will use bones to check the problem, provide herbs to drink and use a razor blade to allow blood to flow out of the body… the blood flow helps to remove the cursed blood or bewitched by witches… Boiling some herbs according to the knowledge that can heal the athlete's legs*.

The responses from the three participants reflected the metaphysical nature of IK and the purpose for performing certain rituals such as the use of a razor to allow a flow of blood to remove the curse from the foot. Furthermore, the healer sought pieces of advice from the ancestors using the bones in an attempt to diagnose the foot, therefore the responses by the three participants reflect the IV of the majority of the participants.

Question 8: Do you think that the myths and rituals play an important role in IKS? Explain your answer with examples if possible.

The trends immerging from the participants' responses with regards to this question are similar to those in questions three, five and eight where the majority of the participants' responses reflected IV. The only difference is that nine out of the 12 participants had IV as opposed to eight and seven participants from the other questions.

In an attempt to answer the question Participant 003 stated that

> *Myths and rituals play no role in IK because myths are made up stories that never happened so they would play no role in IK*.

The response by Participant 003 seemed to suggest that the myths play no role in IK, but the participant does not seem to realise that the myths play a significant role in the passing of IK from one generation to the other, as such the response reflects uninformed views. In this regard, Dugmore and Van Wyk (2008) show how the metaphor of the black-shouldered kite and the plant *dicoma schinzii* serves as a mnemonic device to transfer knowledge to the next generation.

There were two of the nine participants whose responses reflected informed views and they stated that: Participant 011

> *Yes, myths and rituals play an important role in IK, because some myths were used for discipline purposes, for example, pregnant women were not allowed to eat eggs, this was to ensure that the baby does not overgrow which will be a problem during birth*. On the other hand, Participant 007 responded to the question by stating that *yes, the myths mostly encouraged people to respect the environment and take care of our environment*.

The responses from the two participants show the important role that is played by the myths in IK. The fact is that the myths are used to pass IK from one generation to the next. The myths are also used to protect the indigenous people, for an example a pregnant woman being prohibited from eating eggs as well as to preserve the environment. These aspects suggested that the responses by the participants are of IV.

Question 9: Some think IK is infused with social and cultural values. Do you believe IK reflects the social and cultural values of a specific community? Do you believe IK can only be used in specific areas or do you believe it can be used in other areas or globally to solve problems?

The trend reflecting from the participants' responses with regards to the question shares similarity with question four, where the majority of the participants' responses reflected PIV, followed by IV.

There were two of the seven participants whose responses reflected partially informed views stated that: Participant 008

> *I think it can be used globally to solve global problems… Cultural people have been able to live without machines and they can solve their problems so these solutions can be used effectively to solve global problems*. On the other hand, Participant 006 stated that *yes, IK reflect the social and cultural values of Africans, because it is only Africans that mostly rely on IK…. I believe it can be used globally to solve the problems*.

The response from Participant 008 seemed to suggest that IK reflects the social and the cultural values, but it also seems to suggest that the machines are the cause of most of the problem. On the other hand, the response from Participant 006 seemed to acknowledge the idea that IK reflects the social and the cultural values, however, the participant also seemed to suggest that the Africans are the only people with IK. In South Africa, there are people of Indian descent (Reddy, 2018) and there are white Afrikaners who also have their IK that is different from the black South Africans. Lastly, there are Native Americans and Aboriginals who have their own IK. Therefore, the responses of the two participants reflected PIV.

In an attempt to answer the question, two of the four participants whose responses reflected informed views stated that: Participant 002

> *IK can reflect the social and cultural values of a specific community, because each community have its own culture and how they should practice it, for example, in Venda culture, boys dance Tshikuna which is completely different from other tribes*. On the other hand, Participant 003 stated that *yes IK can reflect social and cultural values, for example, Bapedi and Zulu people… in Bapedi community, a new-born baby needs to cut hair once they get home from hospital or else the baby will get sick, while in other cultures the baby might cut hair when he is a toddler…. IK can be used globally if it's adopted by other cultures*.

The responses from the two participants share similar reasoning with different examples. The first Participant 002 acknowledged the idea that IK reflects the social and the cultural values and the participant further highlights that the social and the cultural values embedded in IK are societal, community or tribally based. Hence, the dance ritual performed in the Venda culture differs from the other tribal or societal communities.

In addition, Participant 003's response also acknowledged the idea that IK reflects the social and cultural values, which are relevant to a particular group, society or community. Furthermore, there was an example of a particular ritual that is performed by the Bapedi tribe, which the other communities or tribes do not perform. The participant further highlighted that IK can be used globally provided as it is adapted so that it may also be able to cater for the other communities, thus the responses by the participants reflect IV.

Question 10: Do you believe that the IK practitioners can or cannot change knowledge? Explain your answer with an example.

The participants' responses to this question reflected five UV, with four participants' responses reflecting PIV and three IV.

In an attempt to answer the question, three of the five participants whose responses reflected uninformed views disagreed with the idea that the IK practitioners can change knowledge. Participant 011 stated that,

> *IK should not be changed, because if it is changed or modified, it means that there will be an influence from other knowledge systems that might be against IK, for example, the use of home-brewed beer instead of using a bought beer when doing traditional rituals*.

On the other hand, Participant 008 stated that

> *It should not be changed, because it might be the problem, for an example, allowing doctors to come to initiation schools to sanitise and sterilise the utensils*.

On the other hand, Participant 004 highlighted that

> *Changing the knowledge might cause a problem, especially that there are certain practices that can be done from one culture but cannot be done by another*

culture, for an example, there are wrappers that can be worn on the head by one group of people but cannot be worn by another group.

The responses from the three participants seemed to suggest that IK cannot be adapted, and it cannot be tentative even if needs be. Furthermore, Participant 008 seemed to also suggest that the presence of physicians in initiation school would temper with IK or the practice. However, the presence of physicians is to ensure that the tools that are used to perform the ritual are safe for the initiates, and this does not alter the practice or the knowledge, therefore the responses by the three participants reflect uniformed views. Furthermore, Senanayake (2006, p.88) argues that IK "is constantly changing, being produced as well as reproduced, discovered as well as lost; though it is often represented as being somehow static". Hence, Participant 008's misconceptions about the IK remain the same.

One of the four participants whose responses reflected IV agreed that the IK practitioners should be able to change their knowledge when the need arises. In answering the question, Participant 001 stated that,

Practitioners can change the IK if they find out that the knowledge used creates some problems, they should try to come up and modify the knowledge… for example, the use of the so-called 'Lengana' in healing coughs, it was discovered that frequent use of this can damage the liver.

The response by Participant 001 shows that at times there may be a need to change the knowledge because of the danger it may pose to the community it is meant to serve. Hence, Senanayake (2006, p.88) highlights that IK is the result of the practical engagement in "everyday life and it is constantly reinforced by the experience and trial and error". The participant agreed with the idea that the IK practitioners may change the knowledge, and used an example of an herb that is used to heal coughing, which if too much is consumed may damage the liver. In this case, the participant shows the need for IK to change so that the practice may serve the community the way it is meant, to as such the response by the participant reflects IV.

4.3.2 Presentation and analysis of post-intervention data from the VNOIK

Table 4.3 presents the post-intervention VNOIK responses of the participating Life Sciences teachers from the three settings. The participants' responses were coded, weighted, and scored from the lowest score of 'No classification and Uninformed views' (0) to a high score of 'Informed views' (2).

Table 4.3: Summary of coded post-intervention VNOIK responses of the participants from the three settings (Cronje, 2015).

Summary of coded post-intervention responses of participants										
Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Overall Score
001	PIV	UV	PIV	UV	IV	PIV	IV	PIV	IV	IV	
Weighing	1	0	1	0	2	1	2	1	2	2	1.2
002	UV	UV	IV	IV	IV	UV	PIV	PIV	PIV	IV	
Weighing	0	0	2	2	2	0	1	1	1	2	1.1
003	PIV	UV	UV	PIV	IV	IV	IV	IV	IV	UV	
Weighing	1	0	0	1	2	2	2	2	2	0	1.2
004	IV	UV	IV	UV	IV	IV	IV	UV	PIV	UV	
Weighing	2	0	2	0	2	2	2	0	1	0	1.1
005	IV	IV	IV	UV	IV	IV	PIV	PIV	IV	IV	
Weighing	2	2	2	0	2	2	1	1	2	2	1.6
006	PIV	UV	IV	UV	IV	UV	IV	IV	IV	UV	
Weighing	1	0	2	0	2	0	2	2	2	0	1.1
007	PIV	UV	IV	IV	IV	IV	PIV	IV	IV	PIV	
Weighing	1	0	2	2	2	2	1	2	2	1	1.5
008	PIV	IV	IV	IV	IV	UV	UV	UV	PIV	IV	
Weighing	1	2	2	2	2	0	0	0	1	2	1.2
009	IV	UV	IV	UV	IV	IV	IV	IV	IV	IV	
Weighing	2	0	2	0	2	2	2	2	2	2	1.6
010	IV	UV	IV	IV	IV	PIV	IV	IV	PIV	IV	
Weighing	2	0	2	2	2	1	2	2	1	2	1.6
011	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	
Weighing	2	2	2	2	2	2	2	2	2	2	2.0
012	PIV	UV	PIV	IV	IV	IV	IV	UV	PIV	IV	
Weighing	1	0	1	2	2	2	2	0	1	2	1.3
Total NC	0	0	0	0	0	0	0	0	0	0	0
Total UV	1	9	1	5	0	3	1	3	0	3	26
Total PIV	5	0	2	1	0	2	3	3	5	1	22
Total IV	6	3	9	6	12	7	8	6	7	8	72

[**KEY:** Q = Question; NC = No Classification; UV = Uninformed Views; PIV = Partially-Informed Views; IV = Informed Views]

From Table 4.3, it can be seen that the overall scores range from 1.1 to a perfect 2.0, thereby making the overall range for the overall score (1.1 +2.0)/2 =1.6. This suggests that most of the participants' responses have reflected the improved number of IVs. This is evident from the total number of IVs compared to the total number of NC, UV and PIV. The participants' responses indicated 0 as the total number of NC out of the possible 120, accounting for 0% of the total number of responses. In contrast, the other responses indicated 26 as the total number of UV, accounting for 21.7% of the total number of responses. Additionally, the data shows that the participants' replies corresponded to a total of 22 PIVs, which is 18.3% of all potential responses. Lastly, the participating teachers' total number of IVs is 72 out of the potential 120, which accounts for 60%. The responses appear to show that the teachers have IV of the NOIK as the discussions on the teachers' responses are made below.

Question 1: What is indigenous knowledge and what makes it different from the other types of knowledge systems?

The responses from the majority of the participants reflected IV, followed by PIV and one response from the participants reflected UV.

In response to the question Participant 002 stated that,

> *IK is a knowledge that cannot be tested and cannot be proven to be wrong or right*.

It can be deciphered from the response that the participant only recognises the tests that take place in the laboratory, and IK has no direction, and it serves no meaningful purpose to the community that practices it. Thus, the view that is reflected in the response is uninformed, because according to Senanayake, (2006, p.898) IK is "tested in the rigorous laboratory of life", which is contrary to the responses by the participant.

In response to the question, two of the participants whose responses reflected partially informed views stated that: Participant 001

> *IK is a knowledge that one acquires from the society he is living, the knowledge can be acquired from the elders, traditional healers, based on the natural*

resources…. IK is an informal system of obtaining knowledge where information was never tested to check the reality of the information.

On a similar note, Participant 006 responded to the question by stating that

IK is the use of the natural phenomenon to explain things and how they come into existence on earth… IK is different from Western knowledge in that it does not rely on the use of chemical substances.

The two participants acknowledged that IK is acquired from the society and that it is passed from one generation to the next. However, the common misconception that is reflected by both the participants is that IK is not tested and that unlike western Science there are no chemicals that are used. Medicinal (muthi) plants have active ingredients that hold therapeutic value, and in most cases it is alkaloids. The participants' responses reflected both IV coupled with some misconceptions, thus, their responses show that they hold PIV's.

In an attempt to respond to the question, three of the six participants whose responses reflected informed views responded by stating that: Participant 005

IK is people's knowledge/ local knowledge, a knowledge that belongs to a particular culture/ group of people… IK is localised and can only be practised by a certain group of people. Whereas western knowledge is globally practised. On a similar note, Participant 009 responded by stating that *IK is related to the people and cultural values of the people staying in a particular area… It is not adopted, but home-grown knowledge*.

The responses by the two participants reflect the acknowledgement from both participants that IK is limited to the community or to the society that practices it, contrary to western Science that can be globally practised. Furthermore, the participants highlighted the integral role played by IK in the development and in the practice of the social and the cultural values that are reflected in a particular society or community, thus the responses reflect IV.

Furthermore, Participant 011 responded to the question by stating that, *IK is a knowledge that, is not formally documented and it is transferred from generation to generation in the form of storytelling… This kind of knowledge differs from ethnic groups.*

The response from Participant 011 agrees with the response shared by both Participants 005 and 009, that IK is limited to a particular society or ethnic group. The participant highlighted that IK is at times not formally documented but it is passed from one generation to the next verbally, thus like the previous participants the response reflects IV.

Question 2: As the practitioners of IK observe nature to generate knowledge, do they do experiments and tests to verify or validate this knowledge?

The responses from the majority (nine participants) of the participants reflected UV, while only three of the participants' responses reflect IV.

In response to the question, three of the nine participants whose responses reflected uninformed views stated that: Participant 001

No, the knowledge is not tested, information was obtained from their elders who experienced that from a long time ago. Similarly, participant 002 stated that *the knowledge is not tested as they do not have scientific knowledge pieces of equipment to do so*.

On the other hand, Participant 003 stated that

The knowledge is not tested, because IK is passed down from one generation to another through cultural rituals.

The responses from the three participants reflected two concerning aspects: 1) that since IK is passed from one generation to the next it means that it was never tested by the previous generation. However, in actual sense, before IK was passed to the next generation it was tested in the laboratory of life, hence it has stood the test of time. 2) Only the knowledge system with scientific pieces of equipment can be tested, contrary to this, the indigenous communities have over the years used trial and error as well as observations to test phenomena. Thus, the responses of the three participants reflected UV.

In an attempt to respond to the question, two of the three participants whose responses reflected IV stated that: Participant 005

> *Test the knowledge, because they can get a certain plant or animal and use it to treat a certain condition. By doing so they try to test/validate if the plant or animal works or not. If it works, they will stick to the procedure and eventually pass it from generation to generation*. Similarly, Participant 011 stated that *yes, they use trial and error method until they are convinced that what they are doing is of use… They also use spiritual knowledge of understanding*.

The responses from the two participants reflected that the knowledge passed from one generation to the next is a sign that the knowledge is reliable and durable. The reliability and the durability of the knowledge are the results of the tests. Furthermore, the observations as well as trial and error appear to be the most used methods to validate phenomena, thus, the responses reflected IV.

Question 3: Do the elders always use the natural causes to explain their observations such as lightning, or do they sometimes include the supernatural causes in their explanations?

The responses from the majority (nine participants) of the participants reflected IV, while only two of the participants' responses reflected PIV and the one participant's response reflected UV.

In response to the question, one participant whose response reflected UV stated that: Participant 003

> *They use natural causes and I give an example of when there are many green grasshoppers in different fields it indicates that is time for short rain.*

On the other hand, one participant out of the two participants whose responses reflected PIV stated that: Participant 012

> *Elders use natural to supernatural causes in their explanations*.

The response shared by Participant 003 seems to suggest that IK is not metaphysical in nature as it is a tenet that separates IK from the other knowledge systems. On the other hand, Participant 012 acknowledges the metaphysical nature of IK, but it does not provide an example of how the metaphysical tenet benefits the knowledge system, thus the responses by the two participants reflected UV and PIV respectively.

In an attempt to answer the question, two of the nine participants whose responses reflected IV stated that: Participant 006

> *Sometimes they use supernatural causes because they can mix some herbs and burn it, the direction of the smoke serves as a guide as to which position lightning will come from*.

Similarly, Participant 009 responded by saying that

> *If they use natural causes they will explain the cause in terms of the difference in the accumulation of clouds due to observation of these events over time and yes, they can explain events in a similar way to Science… Yes, the use of supernatural causes can be used when they want to instil cooperation in the community, for example, the community may be encouraged not to whistle at night, because it may bring bad luck*.

The responses from the two participants have shown when the IK practitioners use the supernatural and when they use the natural. Participant 009 has also been able to highlight that the intention of using the supernatural, is to encourage the community to behave acceptably to either preserve or instil the morals that are acceptable to the community. Hence, the responses by the two participants reflected IV.

Question 4: Does this knowledge stay the same or does it change over time?

The responses from the majority (six participants) of the participants reflected IV, while only one of the participants' responses reflected PIV and five participants whose responses reflected UV.

In response to the question, three of the five participants' responses reflected UV. Participant 001 stated that, *The knowledge does stay the same, as scientists go on with their research based on the knowledge the dangers and benefits are discovered*.

On the other hand, Participant 004 stated that

The knowledge does not change because it is transmitted genetically from one generation to another.

Similarly, Participant 006 responded to the question by stating that

Yes, the knowledge stays the same, because practitioners believe that this knowledge should not be changed as it is what their forefathers left for them to continue with.

The responses shared by the three participants suggested that IK is not tentative, because most of its knowledge is metaphysically based, while one participant believes that the knowledge is genetically transferred. Thus, the views reflected in the participants' responses are uninformed.

Contrary to the responses shared above, three of the six participants' responses that reflected informed views shared the following: Participant 002 stated

No, the knowledge does not stay the same as every generation comes with their new way to explain their knowledge.

Similarly, Participant 007 argued that

The knowledge changes, because more information is added to the knowledge, and this changes the knowledge being transferred.

On the other hand, Participant 011 agrees that the knowledge changes as

Some information become distorted as it is not formally documented, as such different people will tell the same story differently.

The responses shared by the three participants suggest that since IK is not formally recorded it is passed from one generation to the next (verbally), and at times the knowledge gets distorted along the way as the world changes. Despite its durability, these two aspects allow for IK to change when the need be. Thus, the responses by the three participants reflected the tentative nature of IK, as such their views are informed.

Question 5: How do you think the Khoi-San people came to know that the *hoodia gordinii* has the properties to suppress hunger and thirst?

The responses from the majority (12 participants) of the participants reflected IV, this means that all the 12 participants had an idea of how the Khoi-San people came to know about hoodia. Out of the 12 responses reflecting IV only four participants' responses are shared.

In an attempt to answer the question, Participant 005 stated that

> *The Khoi-San people knew once they have tried it for the first time, hence they continued using it since it had proved to suppress hunger and thirst*.

Similarly, Participant 011 responded to the question by stating that

> *The Khoi-San people used trial and error*.

On the other hand, Participant 006 responded to the question by stating that,

> *The Khoi-San people observed animals who fed on it as they believed that eating the animals is the same as eating what the animals fed on*.

Similarly, Participant 007 responded to the question by stating that,

> *I think they were out hunting and during the hunt they were hungry and thirsty, so they opted for the plant because the plant looks like a cactus and cactus are known for their ability to hold water*.

The above four responses from the participants reflected that IK uses trial and error, observation, and hypothesis to test phenomena and these are the three aspects that the participants' responses reflected. The first two responses show that the trial-and-error methods are driven by the urge to eat and drink which encouraged the Khoi-San people to eventually try to eat the hoodia. On the other hand, the last two responses reflect the participants' knowledge of the role played by observation, hypothesis, and the similarities of the body structure amongst the mammals, hence, the responses by all the participants reflected IV.

Question 6: Do you think IK can be used to solve contemporary problems, such as hunger, poverty, and underdevelopment?

The responses from the majority (seven participants) of the participants reflected IV, while only two of the participants' responses reflected PIV and three participants' responses reflected UV.

In an attempt to answer the question, two of the three participants whose responses reflected uninformed views stated the following: Participant 002

> *IK is based on scoring a small number of populations, which cannot be used, because now there is an increased number of the population*.

Similarly, Participant 006 stated that

> *IK cannot be used to alleviate some of these problems, because IK relies on natural resources, and we only relied on IK to alleviate hunger it would lead to the extinction of some plant species*.

The two responses seemed to suggest that, due to the idea that IK is only limited to the ethnicity or the society which practices it, then it cannot be adapted for use by the other ethnic groups. Furthermore, the responses shared by the two participants seemed to also suggest that the indigenous people only depend on the plants, and they have no form of knowledge about planting and crop rotation and other activities. Despite the idea that the durability and reliability of IK cannot be questioned, the other knowledge systems such as Western knowledge seem to be failing. As such, the responses by the participants reflected UV.

In an attempt to answer the question, there were two of the seven participants whose responses reflected IV. There was Participant 004 who stated that

> *Yes IK would help with sustainable development because there are plants that are known from different cultures that can cure certain diseases…. Government*

can work with traditional healers to dig and sell the plants so that jobs can be created to help fight poverty.

Similarly, Participant 005 responded to the question by stating that

IK will provide some of the ideas in terms of plants and animals that were used before for survival. Therefore, considering such ideas can have a great impact on the survival of the current and future generation, including cures to different illnesses.

Contrary to the responses by Participants 002 and 006, Participants 004 and 005 agree with the idea that IK can be the answer to addressing the sustainability issues that are currently facing the world. The participants highlighted the idea that there are some diseases whose cure can be derived from the IK community, which can also help to create jobs if the government gets involved, thus, the views reflected from the responses are informed.

Question 7: What methods do you think the traditional healer will apply to diagnose the problem when consulting with the athlete and what possible treatment or advice do you think he will give the athlete?

The responses from the majority (eight participants) of the participants reflected IV, while only three of the participants' responses reflected PIV and one participant's response reflected UV.

In an attempt to answer the question, Participant 008 whose response reflected UV stated that

The healer will tell the athlete to drink the medicine.

The participant has not shared which method the healer used to diagnose the athlete and the possible treatment to use in an attempt to help the athlete, thus the response reflected UV.

On the other hand, Participant 005 and Participant 007 whose responses reflected partially informed views respectively stated that

The healer would use traditional methods to diagnose the athlete and administer traditional medicine or muthi.

Similarly, as highlighted, Participant 007 stated that

The healer will use the knowledge of soothing muscles and possibly use the immune boosters and cannabis to prevent cramps.

The responses from the participants suggest that the traditional methods and the knowledge of soothing muscles will be used to diagnose the athlete, however, the participants did not explain in detail what those methods are. Despite the participants' failure to explain the methods, they were able to acknowledge that *muthi* might be used as a possible remedy for the athlete's pain, thus, the responses by the participants reflected PIV.

In an attempt to answer the question, two of the eight participants whose responses reflected IV are shared and this is what they had to say in response to the question: Participant 003 stated that

The traditional healer will use ditaola 'bones used to connect with the supernatural for diagnosis' to connect with ancestors for them to guide the healer on what to do or to help determine the cause of the pain in his legs……. The traditional healer will give the athlete herbs to apply on his legs and to drink.

Similarly, Participant 004 responded to the question by stating that

Firstly, the traditional healer will consult his\her ancestors through ditaola. The healer will interpret diataola based on what he\she observes and check if it is just a normal pain or witchcraft…. The healer will tell the athlete to go to a hospital if his pain is not caused by witchcraft, but if its witchcraft, he will give the athlete the traditional medicine to help heal his leg.

The responses by Participants 003 and 004 seem to suggest that the traditional healer will use *ditaola* as a means of supernatural source for guidance and observation for diagnosis. The two aspects suggested by the participants are at the very heart of IK. Furthermore, the participants suggested that the healer will provide traditional medicine such as herbs for the athlete to drink and apply to help remove the pain, thus, the responses reflect IV.

Question 8: Do you think the myths and the rituals play an important role in IKS? Explain your answer with examples if possible.

The responses from the majority (six participants) of the participants reflected IV, while only three of the participants' responses reflected PIV and three participants' responses reflected UV.

In an attempt to answer the question, two out of the three participants whose responses reflected UV stated the following: Participant 004

> *No, because they are not true, they are just assuming things about the cultures they know nothing about, for example, people claim that Zulu people do not get circumcised because of their own beliefs and values*.

On the other hand, Participant 008 responded to the question by simply saying *"no"* without any possible reason. The response from the two participants seem to suggest that the myths and the rituals play no role in IK, their reason is that the myths are not true, and the rituals may be important to one ethnic group, and they may be less important to another. However, the participants seem to lack knowledge of the idea that the myths can be used to preserve biodiversity or even help to protect the indigenous community. Hence, the responses by the participants reflected UV.

In an attempt to answer the same question, two out of the three participants whose responses reflected PIV stated the following: Participant 001

> *Yes, they can help shape the community, by making the children be better people*.

Similarly, Participant 002 responded by saying

> *Yes, myths guide the children on a way they should grow*.

While Participants 004 and 008 disagreed with the idea that the myths and the rituals play an important role in IK, Participants 001 and 002 agree that the myths and the rituals play an important role in IK. However, Participants 001 and 002 have not provided the reasons that reflect a full understanding of the role the myths and the rituals play in IK, thus their responses to the question reflected PIV.

Contrary to the responses provided by the previous participants, three of the six participants' responses reflected IV. They responded to the question by saying the following: Participant 003 stated

> *Yes, they do because myths play a huge role in preserving biodiversity in different cultures across the world*.

Similarly, Participant 007 responded by saying that

> *Yes, the myths have taught us to be more sustainable, for example, the myth that if you chop down a food tree without planting another tree there will be death in your family… we were also told that if we burn such trees for fire, their fumes will cause blindness, as such we were not allowed to use them for wood*.

On the other hand, Participant 009 responded to the same question by stating that

> *Yes, they do because during storytelling a, number of indigenous plantations are mentioned and also the medicinal qualities are indicated during narration of the story*.

The responses from Participants 003, 007 and 009 show that they all agree that the myths and the rituals play a significant role in IK. Their reasons range from the idea that the myths help to protect biodiversity and they help with sustainability to show how IK is embedded in the shared stories. An example of a myth that was shared by Participant 007 which serves as an important role in the prevention of deforestation, as such, was contrary to Participant 001 and 002 as the reasons shared by Participants 003, 007 and 009 reflect IV.

Question 9: Some think IK is infused with the social and the cultural values. Do you believe IK reflects the social and cultural values of a specific community? Do you believe IK can only be used in specific areas or do you believe it can be used in other areas or globally to solve problems?

The responses from the majority (seven participants) of the participants reflected IV, while only five of the participants' responses reflected PIV and no participant's response reflected UV.

In an attempt to answer the question, two out of the five participants whose responses reflected PIV shared the following: Participant 002 stated that

> *Yes, IK explain the values of a particular community where those cultural activities are taking place…. IK can be used in a specific area not global because every community have their way to use their own IK*.

On the other hand, Participant 008 answered the question by simply saying *"yes"* with no reason and agreed that IK can be used globally but further provided no reason and an example.

The responses from Participants 002 and 008 agree with the idea that IK reflected the social and cultural values, hence, it is used it is practised by a particular community or ethnic group. However, on whether IK can be used to solve the global problems, one participant agreed with the idea, but one provided no reason while the other disagreed with it and highlighted that IK is limited to a particular group thus it will fail to solve the global problems. Thus, the responses of the two participants reflected PIV.

On the other hand, two of the seven participants whose responses reflected IV said the following in an attempt to answer the question: Participant 005 stated that

> *Yes because what works in certain societies and cultures cannot work with others. Hence, each society has its knowledge about certain things…IK should be used globally, as long as ideas are shared to solve problems and people can are made aware of other people's knowledge so that they can know how to adapt the knowledge to solve the problems*.

Furthermore, Participant 009 responded to the same question by stating that

Yes, it does, because of the knowledge of seasonal changes, the San people, for example, may perform the rain dance to coincide with the onset of the rainy season… yes, IK can be used globally, for example, acupuncture was developed in the east, but it is used globally to relieve pain on some patients.

The responses by Participants 005 and 009 suggest that the participants agree with the notion that IK does reflect the social and the cultural values. Both the participants' reasons were the fact that IK and its cultural values were limited to a particular ethnic group or indigenous community, with Participant 009 giving an example about the rain dance. Furthermore, the participants agreed that IK can be used to solve the global problems, with both participants highlighting the need to adapt the IK of one ethnic group to the other. Hence, an example of acupuncture was provided, as such the responses that were shared by both participants reflected IV.

Question 10: Do you believe that the IK practitioners can or cannot change knowledge? Explain your answer with an example.

The responses from the majority (eight participants) of the participants reflected IV, while only one of the participants' responses reflected PIV and three participants' responses reflected UV.

In an attempt to answer the question, two of the three participants whose responses reflected UV answered the question by stating the following: Participant 006

The indigenous practitioners cannot change the IK because it is their forefathers' knowledge, and it is just passed to them as it is and cannot be researched. Similarly, Participant 004 responded by saying *They cannot change it because we all don't know the exact root of it or prove where it comes from*.

The responses from both participants seem to suggest that indigenous knowledge cannot change their knowledge as such IK is not tentative. The participants' reasons for their responses stem from the idea that IK is passed from one generation to the next, thus only the generation that is aware of the roots of such knowledge has the right to change it. Hence, the knowledge cannot be changed by the other traditional practitioners, as such, the responses and reasons provided by the two participants reflected UV.

On the other hand, four of the eight participants whose responses reflected IV responded by sharing the following: Participant 005

> *Yes, they can change it, because some of the problems which we face now were not there previously. Therefore, this will mean new ways of knowing must be practised hand in hand with the old one*.

On a similar note, Participant 008 stated that

> *They can change the knowledge so that they can adapt to knowledge and ideas and adapt to the evolving world*.

Furthermore, Participant 001 responded to the same question by stating that

> *They can change it because the use of 'lengana' to cure cough and breathing system was found to be dangerous to the liver if is taken excessively*.

Similarly, Participant 011 responded by saying

> *Yes can change it, 'Doses' how indigenously doses were administered differ which resulted in overdoses at some stage. Thus, it made people think that herbs are ineffective, but if we modify the dose it could be more effective*.

The responses shared by the four participants suggest that the participants agree with the idea that the traditional practitioners can change their knowledge with reasons ranging from the changing times to the dangers posed by the medicines if the doses are not changed. The participants argue that as times change, the problems differ as such they need adapted solutions. They also highlighted that the other medications can be dangerous if the doses are not modified, and all these require the traditional practitioners to change their knowledge. Hence, IK is tentative in nature, as such the responses by the participants reflected IV.

4.3.3 Juxtaposing the pre-intervention and post-intervention responses from the VNOIK

In Table 4.4 the data from the pre-intervention and the post-intervention questionnaires is compared to determine if the intervention had any influence on the participating Life Sciences teachers' perceptions on the NOIK. The trend emerging from both the pre-intervention and the post-intervention classification shows that the majority of the responses that were provided by the participants reflected informed views after the intervention. This is the trend that is visible from both the pre- and the post-intervention responses. The number of responses reflecting IV from the pre-intervention questionnaire is 52 (43.3%).

Table 4.4: Summary of overall coded pre-intervention and post-intervention VNOIK views of the participants from the three settings ((Author's own work)

The number of views reflected in the Views of Nature of Indigenous Knowledge questionnaire				
Views	**NC**	**UV**	**PIV**	**IV**
Number of pre-intervention responses	5 (4.2%)	26 (21.7%)	37 (30.8%)	52 (43.3%)
Number of post-intervention responses	0 (0%)	26 (21.7%)	22 (18.3%)	72 (60%)

[**KEY:** NC = no classification; UV = uninformed view; PIV = partially informed view; IV = informed view]

The number is 16 short of the sum of all three classifications (NC, UV and PIV). On the other hand, the second highest number of responses stems from the classification PIV (37 responses). The number of responses reflecting IV (52 or 43.3%) is 15 more compared to the number of participants whose responses reflect PIV (37 or 30.8%).

Secondly, the responses from the post-intervention reflect a noticeable change where the number of participants' responses reflecting IV (72 or 60%), which is three times more than those reflecting UV (26 or 21.7%), which has become the second highest. As such the IV increased from 43.3% to 60% post-intervention. This noticeable change is not only the result of the increased number of the participants' responses reflecting IV post-intervention, but it is also a decreased number of participants' responses reflecting

PIV (from 30.8% to 18.3%). Furthermore, the number of responses from NC decreased from 5 (4.2) to 0 (0%).

Thirdly, when comparing the pre-intervention and the post-intervention responses, the visible trend that was identified shows an improvement concerning the participants' views about the nature of indigenous knowledge. The number of participants' responses which were classified as NC dropped from five during the pre-intervention to zero post-intervention, which is a 100% improvement after an intervention has taken place. Similarly, the trend continued concerning the number of responses reflecting PIV. The number of participants' responses reflecting PIV during pre-intervention was 37 (30.8%) and dropped to 26 (21.7%) post-intervention, which is a significant drop of 24.3%.

Lastly, concerning the number of responses reflecting UV, there was no change when comparing pre-intervention and post-intervention. However, the trend became visible once more concerning the number of participants' responses reflecting IV. The number improved from 52 (43.3%) responses from the pre-intervention to 72 (60%) responses post-intervention, which is a significant improvement of 38.5% compared to the pre-intervention responses. On one end, the analysis from the juxtaposition reflects a picture of findings from a study carried out by Sebotsa (2020), where the Natural Sciences (NS) teachers developed more nuanced views IK after the intervention. As well as Malatji (2023), whose study focused on NS teachers views of NOIK and his study revealed that the teachers held IV. On the other hand, a study by Cronje (2015) found that the Life Sciences teachers held PIV, however, suggested that with a well-planned intervention such views can be improved.

The overall range for the overall scores of the pre-intervention versus post-intervention

$$\textbf{Pre} = \frac{1.7-0.7}{1} = \underline{\mathbf{1}} \text{ versus } \textbf{Post} = \frac{2-1.1}{1} = \mathbf{0\underline{.9}}$$

The above calculations reflect an improvement of the minimum score of 0.7 from the pre-intervention to 1.1 minimum scores from the post-intervention. Furthermore, the maximum score from the pre-intervention improved from 1.7 to 2.0 post-intervention.

The average overall score of the pre- versus post-intervention

$$\textbf{Pre} = \frac{13.6}{12} = \underline{\mathbf{1.1}} \text{ versus } \textbf{Post} = \frac{14.9}{12} = \mathbf{1.\underline{2}}$$

The sum of the overall score increased from 13.6 to 14.9 post-intervention and this improvement was the result of the increased number of participants' responses reflecting IV, and the decreased number of participants' responses reflecting PIV. Furthermore, there was a decreased number of participants whose responses could not be classified. This claim is justified by the idea that the number of participants' responses reflecting UV had not changed when comparing the pre- and post-intervention responses. In other words, the decreased number of participants' responses from PIV and NC can be attributed to the increased number of participants' responses reflecting IV. Lastly, it is noticeable that the average overall score has increased from 1.1 to 1.2, a 0.1 average overall score increase.

4.3.4 Presentation and analysis of pre-intervention data from the VNOS-D+

Table 4.5 presents the post-intervention VNOS-D+ responses of the participating Life Sciences teachers from the three settings. The participants' responses were coded, weighted and scored from the lowest score of 'No classification' (0) and 'Uninformed views' (0) to a high score of 'Informed views' (2).

Table 4.5: Summary of coded pre-intervention VNOS-D+ responses of participants from the three settings (Cronje, 2015)

Participants from the three settings											
Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Overall Score
001	IV	IV	IV	IV	UV	UV	IV	PIV	UV	IV	
Weighing	2	2	2	2	0	0	2	1	0	2	1.3
002	UV	IV	IV	PIV	PIV	PIV	UV	PIV	IV	IV	
Weighing	0	2	2	1	1	1	0	1	2	2	1.2
003	PIV	IV	IV	IV	IV	UV	UV	IV	IV	IV	
Weighing	1	2	2	2	2	0	0	2	2	2	1.5
004	IV	IV	UV	UV	UV	NC	NC	PIV	UV	PIV	
Weighing	2	2	0	0	0	0	0	1	0	1	0.6
005	IV	IV	IV	IV	PIV	UV	IV	IV	IV	IV	
Weighing	2	2	2	2	1	0	2	2	2	2	1.7
006	IV	IV	UV	IV	PIV	PIV	IV	UV	UV	IV	
Weighing	2	2	0	2	1	1	2	0	0	2	1.2
007	IV	UV	IV	PIV	IV	IV	UV	UV	IV	IV	
Weighing	2	0	2	1	2	2	0	0	2	2	1.3
008	IV	IV	IV	PIV	UV	UV	UV	UV	UV	IV	
Weighing	2	2	2	1	0	0	0	0	0	2	0.9
009	PIV	IV	IV	IV	UV	IV	IV	UV	UV	IV	
Weighing	1	2	2	2	0	2	2	0	0	2	1.3
010	UV	IV	PIV	PIV	IV	NC	IV	IV	UV	NC	
Weighing	0	2	1	1	2	0	2	2	0	0	1.0
011	UV	IV	PIV	IV	IV	PIV	NC	NC	UV	IV	
Weighing	0	2	1	2	2	1	0	0	0	2	1.0
012	UV	IV	IV	IV	IV	IV	IV	PIV	IV	IV	
Weighing	0	2	2	2	2	2	2	1	2	2	1.7
Total NC	0	0	0	0	0	2	2	1	0	1	6
Total UV	4	1	2	1	4	4	4	4	7	0	31
Total PIV	2	0	2	4	3	3	0	4	0	1	20
Total IV	6	11	8	7	5	3	6	3	5	10	64

[**KEY:** Q = Question; NC = No Classification; UV = Uninformed Views; PIV = Partially-Informed Views; IV = Informed Views]

From Table 4.5 it can be seen that the overall scores range from 0.6 to 1.7 out of the possible 2.0, thereby making the overall range for the overall score (0.6 + 1.7)/2 = 1.2, which suggested that most of the participants' responses reflected IV. This is evident from the total number of IVs compared to the total number of NC, UV and PIV. The participants' responses reflected 6 as the total number of NC out of the possible 120 which accounts for 5.0% of the total number of responses, while the other responses reflected 31 as the total number of UV, which accounts for 25.8% of the total number of responses. Furthermore, it can be seen from the table that the participants' responses reflected 20 total PIV which accounts for 16.7% of the total number of possible responses. Lastly, the participating teachers' total number of IVs is 64 out of the possible 120, which accounts for 53.3%, as such, the responses seem to suggest that the teachers have IV of the NOS as the deliberations on the teachers' responses are made below.

Question 1: What is Science?

The responses from the majority (six participants) of the participants reflected IV, while only two of the participants' responses reflected PIV and four of the participants' responses reflected UV.

In response to the question, two of the four participants whose responses reflected UV stated that: Participant 002

Science is the study of life.

On the other hand, Participant 012 responded to the question by saying

Science is the study of organisms using biotechnology.

The responses by the two participants limit what Science is and what Science does, in other words, there is more to Science than life and biotechnology. Science is a way of knowing and this includes the living and the non-living phenomena, thus the views reflected from the responses of these two participants are uninformed.

In an attempt to respond to the question, two of the six participants whose responses reflected IV responded to the question by stating the following: Participant 001

Science is the application of knowledge and understanding of natural and social world following different methods of doing things based on evidence.

Similarly, Participant 005 responded to the question by stating that

Science is a way of knowing and understanding the world.

The two participants agree that Science involves attempts to understand the natural phenomena using various methods based on evidence. The responses seemed to suggest that the two participants understand that Science is empirical in nature by depending on the evidence and it involves creativity and imagination, hence different methods are used. As such, the responses provided by the participants reflected IV.

Question 2: What makes Science (or a scientific discipline such as physics, biology, etc.) different from the other subjects/disciplines (art, history, philosophy, etc.)?

The responses from the majority (eleven participants) of the participants reflected IV, while there were no participants whose responses reflected PIV and one of the participants' responses reflected UV.

In response to the question, the participant whose response reflected UV stated the following: Participant 007

Science is more focused on understanding the world we live in.

The response by the participant seemed to be oblivious to the notion that Science studies the world and more, hence it is the study of other celestial bodies across the universe. Furthermore, the other subjects also study other aspects of the world we live in, however, Science is empirically based and practical, to say the least, thus the response by the participant reflected a UV.

In addition, three of the eleven participants whose responses reflected IV responded to the question by stating the following: Participant 001

Science is practical and based on evidence, in other words, in Life Sciences the focus is on living organisms and their environment. Similarly, Participant 006

> responded to the question by stating that *"Science discipline is different from other subjects in that it deals with proven facts that have gone numeral tests"*.

Furthermore, Participant 012 highlighted that Science

> *Can be taught practically where the outside world can be brought in the classroom situation*.

The responses from the participants seemed to suggest that Science is unique in such a way that it is practical, empirically based, studies natural phenomena (biotic and abiotic components) and involves experimentation. As such, the responses by the participants reflected IV.

Question 3: Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.

The responses from the majority (eight participants) of the participants reflected IV, while only two of the participants' responses reflected PIV and two of the participants' responses reflected UV.

In response to the question, one of the two participants whose responses reflected UV stated the following: Participant 006

> *No, it will never change, because it is how the system was created, for example. We have names given to certain objects, a generation before us knew them as they are and even the generation after us will know them as we currently do*.

The response by the participant seemed to contradict the idea that the scientific knowledge is durable, but it can change or be modified in light of new information. The stripping of Pluto from its planetary status was initially supported by geocentrism and later heliocentrism and it was found to be the correct aspect concerning the relationship between the sun and the other planets. These decisions by the scientists support the idea that Science is tentative in nature, hence, the response by the participant reflected a UV.

In an attempt to respond to the question, one of the two participants whose responses reflected PIV responded to the question by stating the following: Participant 011

Yes, it is more western orientated and gradually focuses more on indigenous knowledge.

The response from the participant seemed to agree with the idea that scientific knowledge may change, however, the reason seemed to focus more on the epistemological border crossing of IK and Science. Thus, the reason does not address the notion of Science being tentative in nature, but rather it speaks to the shared tenets between IK and Science. As such, the response by the participants reflected the views that are partially informed.

In addition, three of the eight participants whose responses reflected IV responded to the question by stating the following: Participant 005

Yes, if new evidence is available and has been tested and verified.

Similarly, Participants 008 and 012 shared similar responses

Yes, if new information emerges or is discovered, then knowledge may change, and *It can change in the future as new ideas are added or acquired* respectively.

The responses by the participants seemed to agree with the idea that scientific knowledge may change provided that there is new evidence, and new knowledge is discovered or new ideas regarding the phenomenon in question are acquired. Thus, the responses by the majority of the participants are of IV.

Question 4: How do the scientists know that dinosaurs existed? Explain your answer. How certain are scientists about the way dinosaurs looked? The scientists agree that about 65 million years ago the dinosaurs became extinct (all died away). However, the scientists disagree about what caused this to happen. Why do you think they disagree even though they all have the same information? If a scientist wants to persuade other scientists of their theory of dinosaur extinction, what do they have to do to convince them? Explain your answer.

The responses from the majority (seven participants) of the participants reflected IV, while only four of the participants’ responses reflected PIV and one of the participant's responses reflected UV.

In response to the question, one participant whose response reflected UV stated the following: Participant 004

> *By a phylogenetic tree, it helps them to identify to whom family it belongs to…… The physical appearance and their footprint…… No answer….. I will convince them to persuade it because they might come up with something different because still to date, scientists still disagree about the cause of dinosaur extinction*.

The response by the participant seemed to suggest that they think a phylogenetic tree provides a background of an organism. However, in the case of dinosaurs, the fossils are the first evidence that is needed, and carbon dating may help in determining the age and how the dinosaurs may have looked. In many cases, the scientists have different schools of thought, hence, their disagreements. As such, the response by the participants reflected UV.

In addition, in an attempt to respond to the question, one of the four participants whose responses reflected PIV responded to the question by stating the following: Participant 002

> *They found fossils; they discovered the fossils of dinosaurs….. They explain that it looks like a vertebrate animal because there was a presence of vertebrae column…… Because there is one who ever sees it. There is no proper evidence that dinosaurs exist, even though there are fossils……. They should allow them to learn about dinosaurs with proper evidence of dinosaurs fossils*.

The response from the participant seemed to suggest that they are aware of the significant role played by the fossils in identifying the dinosaurs. However, the rest of the response by the participant does not address the questions, but it cannot be ignored that the participant is aware of the role played by the fossils, hence, the response by the participant reflected a view that is partially informed.

On the other hand, one of the seven participants whose responses reflected IV responded to the question by stating the following: Participant 003

Fossils were discovered of creatures symbolising dinosaurs that showed to have lived on earth years ago…. They used fossils found which were their skeletons and used a phylogenetic tree to show what they might have looked like. Such are also used on unidentified human remains to see what they could have looked like… They do not have the same idea of which natural disaster could have eradicated them. The proof is not sufficient and none of them were there to say they saw what happened.

The responses from the participant suggested that the participant is familiar with what fossils are and how they have to help determine what the dinosaurs looked like. Furthermore, the participant shows understanding and the importance of carbon dating, phylogenetics and that scientists differ due to different schools of thought and such differences are the reflections of creativity and imagination used by the scientists. As such, the responses by the participants reflected views that are informed.

Question 5: To predict the weather, the weather persons collect different types of information. Often they produce computer models of different weather patterns. Do you think weather persons are certain (sure) about the computer models of the weather patterns? Why or why not?

The responses from the majority (five participants) of the participants reflected IV, while there were three participants whose responses reflected PIV and four of the participants' responses reflected UV.

In response to the question, two of the four participants whose response reflected UV stated the following: Participant 001

For the fact that they produce different weather patterns, this ensures their models are certain.

Similarly, Participant 008 responded to the same question by stating that

Yes, because they have been taught about it and they are experts.

The answers provided by the participants seem to suggest that the fact that the computer models used to study the weather patterns are capable of studying a variety of weather patterns, which means that people are certain about the weather patterns. Furthermore, the participants also think that the fact that the people who study weather patterns have studied and are experts in the field makes them certain about the weather patterns. The responses by the participants are failing to address the idea that the people studying weather patterns are not certain. As such they have to collect as much data as possible so that their predictions may not be too far off, hence the responses reflected UV.

In addition, in attempts to respond to the question, one of the three participants whose responses reflected PIV and one of the five participants whose responses reflected IV responded to the question by stating the following: Participant 006

> *No because weather is a natural phenomenon and it can change anytime, which will invalidate their predictions*.

On the other hand, Participant 003 whose response reflected IV stated that

> *No, weather predictions are not always accurate and can change due to a natural disaster or any natural factor*.

The responses from the participants seem to acknowledge that the people studying the weather are not certain about the weather patterns. However, Participant 006 sees the weather as a natural phenomenon as such it can change at any time. The participant does not provide reasons on what could cause such a change of weather and the response from this participant seem to suggest that every natural phenomenon can change anytime.

On the other hand, Participant 003 agrees that people who study weather are not certain, and the participant further acknowledges the changing weather. However, unlike Participant 006, Participant 003 explains that these changing weather patterns may be caused by the natural disasters or the natural factors. As such, the response by the first participant reflected a view that is partially informed, while the response by the latter reflected a view that is informed.

Question 6: The model of the inside of the earth shows that the earth is made up of layers called the crust, the upper mantle, the mantle, the outer core and the inner core. Does the model of the layers of the earth *exactly* represent how the inside of the earth looks? Explain your answer.

With regards to this question, the responses from the participants were spread across the categories where the responses from the majority (four participants) of the participants reflected UV. On the other hand, there were three participants whose responses reflected PIV with three participants whose responses reflected IV and two participants whose responses were NC.

In response to the question, two participants (004 and 010) did not respond to the question, thus their responses or lack thereof were categorised as no classification. Furthermore, two of the four participants whose responses reflected UV stated the following: Participant 001

> *Models represent everything real*.

Similarly, Participant 008 responded by stating that

> *No, nobody ever opened the earth to see what is inside.*

The responses from Participant 001 seems to suggest that the models are the exact representatives of how a phenomenon looks like. On the other hand, Participant 008 believes that the only reason why a model does not look the same as what it represents is that no one has entered the inside of the earth, therefore the responses reflected UV.

In an attempt to respond to the question, one of the three participants whose responses reflected PIV responded to the question by stating the following: Participant 006

> *No, the layers show the earth as being a round object and it is said to be rotating, so it does not represent how the inside is made as we do not wake up one day with our heads upside down*.

The participant's response seemed to suggest that the model of the earth is not the same as the real earth. However, the reason the participant reflects is the misconceptions of how the earth orbits and rotates around the sun, hence the response by the participant showed PIV.

On the other hand, one of the three participants whose responses reflected IV responded to the question by stating the following: Participant 009

> *A model does not represent exactly how the layers of the earth are arranged. It is an ideological perspective because there is no visual scientific evidence of the layers*.

The response by the participant acknowledges that a model does not look exactly like what it represents. The participant also explained the missing aspects around the model and highlighted that a model is an ideological structure that simplifies what would otherwise be complex, as such the response reflected IV.

Question 7: Scientists try to find answers to their questions by doing investigations/ experiments. Do you think that the scientists use their imaginations and creativity when they do these investigations/experiments? If **NO**, explain why. If **YES**, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

With regards to this question, the responses from the participants were spread across the categories where the responses from the majority (six participants) of the participants reflected IV. On the other hand, there were no participants whose responses reflected PIV, however, there were four participants whose responses reflected UV and two participants whose responses were NC.

In response to the question, two participants (004 and 011) did not respond to the question, thus, as highlighted from the previous question, their responses or lack thereof were categorised as no classification. Furthermore, two of the four participants whose responses reflected UV stated the following: Participant 003

> *No, if they did use their imagination and creativity, their findings would not be accurate and would be null. They conclude on their experiments from observations of what is happening*.

Similarly, Participant 008 responded by stating that

> *No, only facts and stick to the experiment. Using one's imagination will bring inaccurate results*.

The responses from the participants seemed to suggest that creativity and imagination have no place in Science because they will promote inaccuracies and null results and Participant 008 went as far as encouraging the reader to stick to the experiments. The participants are oblivious to the idea that creativity and imagination are responsible for the planning and analysis of results in Science, as such the responses from the participants reflected UV.

On the other hand, two of the six participants whose responses reflected IV responded to the question by stating the following: Participant 001

> *Yes, making scientific guesses in the experiments, in other words, hypothesising, they are using their imaginations. Creativity is used in planning an investigation so that they can obtain their reliable results*.

Similarly, Participant 005 responded to the question by stating that

> *Yes, during observations, experimentation, interpretation and analysis of data. Imagination and creativity are important aspects of Science as they allow one to generate scientific knowledge based on their observations and thinking throughout their investigations. One should be able to think about the causes and effects of variables and what can be done thereafter*.

The responses from these participants showed that they understand that creativity and imagination play a significant role in Science, because experimentation, hypothesising, observations and planning just to name a few need these two tenets. Therefore, the responses by the participants reflected views that are informed.

Question 8: Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

With regards to this question, the responses from the participants comprised of responses where the majority (four participants) of the participants reflected UVs and (four participants) PIV. On the other hand, there were three participants whose responses reflected IV, and one participant whose responses were NC.

In response to question, Participant 008 did not respond to the question, thus, as highlighted from the previous question, the response or the lack thereof was categorised as NC. Furthermore, two of the four participants whose responses reflected UV stated the following: Participant 006

> *A theory is not proven but a law is proven, as such a theory is a hypothesis*.

Similarly, Participant 007 responded by stating that

> *Scientific theory is a proven fact and scientific law is just stated with no proven fact*.

The participants' responses seemed to suggest that between these two aspects, one is proven, and the other is not. Furthermore, the participants have not been able to explain the differences between the two aspects and the important roles they play in Science. One participant (006) likens or synonymises scientific theory with a hypothesis. As such the responses provided by the participants reflected UV.

In an attempt to respond to the question, one of the three participants whose response reflected IV responded to the question by stating the following: Participant 010 responded to the question by stating that

Yes, theory explains how something happens and law explains what will happen.

Firstly, the participant acknowledges that there is a difference between the two scientific tenets and the way the participant described scientific theory showed that a series of statements are needed to explain how a phenomenon happens. Furthermore, the participant shows an understanding of what a scientific law is and the way the difference between the two has been established, it is clear that each plays a significant role in Science, thus the response from the participant reflected IV.

Question 9: After the scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.

The responses from the majority (seven participants) of the participants reflected UV, while there were no participants whose responses reflected PIV and five of the participants' responses reflected IV.

In response to the question, three of the seven participants whose response reflected UV stated the following: Participant 001

No, they are scientific facts that are not subject to change.

Similarly, Participants 009 and 010 responded to the same question by stating that

So far no, according to my limited knowledge. Evolutionary ideas have not changed, and the atomic model has not changed yet.

and Participant 010

No, what is only done is the modification of theories not changing the originality.

The responses from the participants seemed to contradict the idea that scientific knowledge is tentative. This is derived from their responses where they all start with "*no*" which disagrees with the scientific knowledge changing. The participants' argument stems from the understanding that the theories are facts and that the theory of evolution, and the model of an atom has not changed. The participants seemed to be oblivious to the fact that there once was Dalton's, Rutherford's and now Niels Bohr's model of an atom. Therefore, it is unfounded that the model of an atom has not changed, thus the responses by the participants reflected UV.

On the other hand, four of the five participants whose responses reflected IV responded to the question by stating the following: Participant 002

> *Yes, theory can change concerning time, for example, theory of evolution by Lamarck*.

Similarly, Participants 003, 004 and 012 responded to the question by stating that

> *Yes, new species are found and change the origins of others.*

Participant 004

> *Yes, they will change if there is new evidence.*

and participant 012

> *Theory can change as time goes on as new ideas and knowledge are added*.

The responses from the participants seemed to agree with the idea that scientific knowledge is tentative. This is derived from their responses where they all started with *"yes"* and they highlighted that the theories can only change provided that new species are discovered, which will usher in new knowledge. Participant (002) provided an example of two naturalists (Lamarck and Darwin) who postulated two different theories of evolution, where Lamarck's theory was later disproved by Darwin. As such, the response and the reasons provided by the participants reflected IV.

Question 10: Is there a relationship between Science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

With regards to this question, the responses from the participants were skewed towards one category where the responses from the majority (ten participants) of the participants reflected IV. On the other hand, there was one participant whose response reflected

PIVs, however, there were no participants whose responses reflected UV and one participant whose response was NC.

In response to the question, Participant 010 did not respond to the question, thus, as highlighted from the previous question, the response or the lack thereof was categorised as no classification. Furthermore, one participant whose response reflected PIV stated the following: Participant 004

> *Yes, Science can be manipulated, but cultural values cannot*.

The participant's response initially seemed to agree with the idea that there is a relationship between Science, society and cultural values, but the reasoning does not reflect the understanding of the relationship between the three aspects. As such, the response by the participant reflected PIV.

On the other hand, three of the ten participants whose responses reflected IV responded to the question by stating the following: Participant 001

> *Science being the act of doing, is influenced by the society and culture in which they find themselves and also influences their work*.

Similarly, Participants 006 and 008 responded to the question by stating that

> *Yes, there is a relation, Science is our daily life and it's now infused with our cultural values because we do scientifically practice our culture*.

Participant 008

> *Yes, cultural values determine society that determines Science. The cultural medicine that we use are used in culture helps to determine what society can use and leads to the type of medicine that would be used because we know they are capable*.

The responses from the participants seem to agree with the idea that there is a relationship between Science, society, and cultural values. This is derived from their responses where they all started with *“yes”* and they highlighted that Science exists in society and the cultural values influence how the scientists view investigated phenomena. Therefore, Science is culturally embedded, as such the responses provided by the participants reflect IV.

4.3.5 Presentation and analysis of the post-intervention data from the VNOS-D+

Table 4.6 presents the post-intervention VNOS-D+ responses of the participating Life Sciences teachers from the three settings. The participants' responses were coded, weighted, and scored from the lowest score of 'No classification and Uninformed views' (0) to a high score of 'Informed views' (2).

Table 4.6: Summary of coded post-intervention VNOS-D+ responses of the participants from the three settings (Cronje, 2015).

Participants from the three settings											
Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Overall Score
001	UV	IV	IV	PIV	UV	IV	IV	PIV	UV	IV	
Weighing	0	2	2	1	0	2	2	1	0	2	1.2
002	UV	IV	IV	PIV	IV	IV	UV	UV	IV	IV	
Weighing	0	2	2	1	2	2	0	0	2	2	1.3
003	IV	IV	IV	PIV	IV	IV	UV	UV	IV	IV	
Weighing	2	2	2	1	2	2	0	0	2	2	1.5
004	PIV	IV	IV	PIV	UV	UV	IV	PIV	UV	IV	
Weighing	1	2	2	1	0	0	2	1	0	2	1.1
005	IV	IV	IV	IV	IV	UV	IV	IV	IV	IV	
Weighing	2	2	2	2	2	0	2	2	2	2	1.8
006	IV	PIV	UV	PIV	IV	IV	IV	IV	IV	UV	
Weighing	2	1	0	1	2	2	2	2	2	0	1.4
007	IV	IV	IV	IV	IV	UV	UV	UV	IV	IV	
Weighing	2	2	2	2	2	0	0	0	2	2	1.4
008	PIV	IV	IV	PIV	IV	IV	IV	PIV	IV	IV	
Weighing	1	2	2	1	2	2	2	1	2	2	1.7
009	PIV	PIV	IV	IV	UV	IV	IV	IV	IV	IV	
Weighing	1	1	2	2	0	2	2	2	2	2	1.6
010	UV	PIV	IV	PIV	IV	UV	IV	PIV	UV	IV	
Weighing	0	1	2	1	2	0	2	1	0	2	1.1
011	UV	IV	IV	PIV	IV	IV	IV	PIV	UV	IV	
Weighing	0	2	2	1	2	2	2	1	0	2	1.4
012	UV	IV	IV	PIV	IV	IV	IV	IV	IV	IV	
Weighing	0	2	2	1	2	2	2	2	2	2	1.7
Total NC	0	0	0	0	0	0	0	0	0	0	0
Total UV	5	0	1	0	3	4	3	3	4	1	24
Total PIV	3	3	0	9	0	0	0	5	0	0	20
Total IV	4	9	11	3	9	8	9	4	8	11	76

[**KEY:** Q = Question; NC = No Classification; UV = Uninformed Views; PIV = Partially-Informed Views; IV = Informed Views]

From Table 4.3 it can be seen that the overall scores range from 1.1 to 1.8 out of the possible 2.0 thereby making the overall range for the overall score (1.1 + 1.8)/2 = 1.5. This suggests that most of the participants' responses reflected an improved number of IVs. This is evident from the total number of IVs compared to the total number of NC, UV and PIV. The participants' responses reflected 0 as the total number of NC out of the possible 120 which accounts for 0% of the total number of responses, while their other responses reflected 24 as the total number of UV, which accounts for 20.0% of the total number of responses. Furthermore, it can be seen from the table that the participants' responses reflected 20 as the total PIV which accounts for 16.7% of the total number of possible responses. Lastly, the participating teachers' total number of IVs is 76 out of the possible 120, which accounts for 63.3%, as such, the responses seem to suggest that the teachers have IV of the NOS as the deliberations on the teachers' responses are made below.

Question 1: What is Science?

The responses from the majority (five participants) of the participants reflected UV, while only three of the participants' responses reflected PIV and four of the participants' responses reflected IV.

In response to the question, two of the five participants whose responses reflected uninformed views stated that: Participant 001

> *Science is an act of doing things which must always be related to the subject, such as Life Sciences to make learners aware of the world around them.*

On the other hand, Participant 012 responded to the question by saying

> *Science is the study of organisms using biotechnology*.

The responses from the participants describe Science based on what is done in school and by so doing they limit what Science is capable of doing. The participants were not able to explain that Science is a way of knowing. The description of Science by the participants did not reflect a single tenet which serves as the pillar of Science, as such the views reflected in the responses are uninformed.

In an attempt to respond to the question, Participant 009 who one of the three participants is whose responses reflected PIV responded to the question by describing Science as

> *A domain where we study events that have taken place in our natural world in terms of the scientific methods*.

This response from the participant seems to acknowledge that Science uses scientific methods to study a phenomenon, however, the notion that Science only focuses on events that have taken place is disputable. There are events such as the weather, which predictions are made, thus such that the event is studied before it even takes, such as the response from the participant reflected views that are partially informed.

In addition, two (Participants 005 and 006) of the four participants whose responses reflected IV defined Science as

> *A way of knowing and understanding the universe* and *A systematic study of the universe and things that exist in it*, respectively.

What can be deciphered from the two responses is that Science is a way of knowing, and logical methods are used to study the universe and its inhabitants, as such the responses by the participants reflected IV.

Question 2: What makes Science (or a scientific discipline such as physics, biology, etc.) different from the other subjects/disciplines (art, history, philosophy, etc.)?

The responses from the majority (nine participants) of the participants reflected IV, while only three of the participants' responses reflected PIV and there was no participant whose response reflected UV.

In an attempt to respond to the question, one of the three participants whose responses reflected PIV responded to the question by stating the following: Participant 006

> *Scientific discipline is different from other subjects in that it deals with facts, which are proven while other subjects deal with philosophy and theory*.

This response seemed to acknowledge that Science is factual, and it seeks to prove certain phenomena. However, the participant appears to suggest that Science does not give attention to theory and does not have a philosophical aspect. As such, the response by the participants reflected views that are partially informed.

On the other hand, three of the nine participants whose responses reflected IV responded to the question by writing the following: Participant 003 *“In Science conclusions are made from proven experiments”*. Furthermore, Participants 004 and 005 shared similar responses

> *Science deals with data that have been collected, proven scientifically through hypothesis. It always has backing experiments to prove what is taught or written* and *Science requires evidence, generated through scientific methods.* respectively.

The responses acknowledge the idea that Science is dependent on experiments, as well as hypotheses and it uses empirically based using evidence that has been generated using scientific methods. Thus, the responses by the participants seemed to suggest that the participants are aware that the scientific tenets are responsible for making Science more different from the other subjects, as such the responses reflected IV.

Question 3: Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.

The responses from the majority (eleven participants) of the participants reflected IV. On the other hand, there were no participants whose responses reflected PIV well and there was one participant whose responses reflected UV.

In an attempt to respond to the question, one participant whose response reflected UV responded to the question by stating the following: Participant 006

No, it will not change because it is subject to several tests to prove its validity. For example, humans are believed to have evolved from monkeys and even today it is believed to be so.

The response from the participant did not take into consideration that initially the scientists use a geocentric model with regards to determining the celestial body that is at the centre of the universe until Galileo proposed the heliocentric model. Therefore, with such an event it is justifiable that scientific knowledge is subject to in light of new information, and this does not ignore the knowledge's durability. As such, the response by the participant reflected UV.

On the other hand, three of the 11 participants whose responses reflected IV responded to the question by writing the following: Participant 002

Yes, knowledge may change due to outcomes of every generation.

Furthermore, participants 003 and 007 shared similar responses

Yes, as the earth is ever evolving, new information is always surfacing and *Yes, as the world evolves we gather new knowledge that is likely to change the way we think.* Respectively.

What can be generated from the responses is that the participants acknowledge that Science may change in the future, provided new information or knowledge comes through. The participants also believe that as the universe grows, new phenomena are discovered, which will likely change the way people think or view things, which will allow for scientific knowledge to be tentative. As such, the responses by the participants reflected views that are informed.

Question 4: How do the scientists know that the dinosaurs existed? Explain your answer. How certain are the scientists about the way the dinosaurs looked? The scientists agree that about 65 million years ago the dinosaurs became extinct (all died). However, the scientists disagree about what caused this to happen. Why do you think they disagree even though they all have the same information? If a scientist wants to persuade the other scientists of their theory of dinosaur extinction, what do they have to do to convince them? Explain your answer.

The responses from the majority (nine participants) of the participants reflected PIV. On the other hand, there were no participants whose responses reflected UV and there were only three participants with responses reflecting IV.

In an attempt to respond to the question, two of the nine participants whose responses reflected PIV responded to the question by stating the following: Participant 003

> *They have evidence to prove their theory of dinosaurs' fossils…… They used carbon dating to form a physical structure on the fossils….. It does not show how they all died, and they were both not there……. They would have to bring proof, real-life evidence that shows what happened to them*.

On the other hand, Participant 004 responded to the question by stating that

> *Polygenetic tree, identifying their origin, where they are arisen from based on their physical appearance and ancestors……… By their physical appearance footprint and ancestors…… Because, based on the causes of extinction, they are not well convinced… I will tell them that according to me, I am not convinced by the way scientists concluded based on the cause of extinction*.

What is decoded from the participants' responses is that they are aware of the discovery of fossils, the use of carbon dating and the role of polygenetic trees in the study of dinosaurs. However, the participants' responses also suggest that the participants have misconceptions about what could have made the scientists disagree about the cause of the dinosaurs' extinction and how they would persuade other scientists. As such, the responses provided by the participants reflected the views that are partially informed.

On the other hand, three of the nine participants whose responses reflected IV responded to the question by writing the following: Participant 005

> *Through fossils, which provide evidence… By going through dinosaurs' fossils… Due to some missing information- gaps between what is known and not known…*

Provide them with the new evidence or information to fill the gap between what is known and what is unknown.

Furthermore, Participant 007 shared a similar response

The evidence of fossils is the evidence that exists… The bones and fossils that are found are used to complete the puzzle of what they looked like… The information is not sufficient to make concrete conclusions. That leaves a lot of loopholes for possibilities… Scientists have to do research and present their findings to the other scientists so that they can engage.

The responses from the participants suggested that the participants believe that the fossils can serve as tangible evidence, which is the idea of connecting different types of fossil bones to complete the puzzle. Furthermore, the participants also seemed to suggest that the scientists disagree due to a lack of having enough data and gaps that require them to use creativity and imagination. Thus, there are disagreements, and the need amongst the scientists to provide convincing evidence to persuade other scientists, as such, it is justifiable to deem the responses by the participants to be of IV.

Question 5: To predict the weather, the weather persons collect different types of information. Often they produce computer models of different weather patterns. Do you think the weather persons are certain (sure) about the computer models of the weather patterns? Why or why not?

The responses from the majority (nine participants) of the participants reflected IV. On the other hand, there were no participants whose responses reflected PIV and there were only three participants with responses reflecting UV.

In an attempt to respond to the question, two of the three participants whose response reflected UV responded to the question by stating the following: Participant 004

Yes, because they have studied the weather and tested their data scientifically until their hypothesis is proven and have done it several times.

On the other hand, Participant 009 responded to the same question by saying

Yes, if calculations are done properly, it will make the data in the computer model accurate.

The responses by the participants seemed to suggest that since the people who study weather are experts and calculations are made, therefore, that makes them certain about the weather. However, in actual sense, the people who study the weather patterns collect a lot of varying data as often as possible to help to make their predictions more reliable. As such, the responses by the participants reflected UV.

On the other hand, three of the eleven participants whose responses reflected IV responded to the question by writing the following: Participant 002

No, they are not sure since weather patterns change concerning time.

Furthermore, Participant 008 responded to the same question by stating that

They are not certain; it is a prediction depending on what happens.

What can be deciphered from the responses by the participants is that the people who study the weather patterns are not certain, this is due to the changing weather now and again, which makes it difficult to predict the weather patterns. However, due to the continuous collection of varying data weather prediction is possible, not always accurate, but doable. Thus, the responses by the participants reflected IV.

Question 6: The model of the inside of the earth shows that the earth is made up of layers called the crust, the upper mantle, the mantle, the outer core and the inner core. Does the model of the layers of the earth *exactly* represent how the inside of the earth looks? Explain your answer.

The responses from the majority (eight participants) of the participants reflected IV.
On the other hand, there were no participants whose responses reflected PIV and there were only four participants with responses reflecting UV.

In an attempt to respond to the question, two of the four participants whose response reflected UV responded to the question by stating the following: Participant 005

Yes, models are used to explain complex ideas in simpler ways. Therefore, as much as the earth is complex, scientists developed the model to explain and ease the understanding of the earth.

On the other hand, Participant 009 responded to the same question by saying

It depends on which point of view where this is looked at. Real will obvious versus scientific knowledge.

What can be deduced from the participants' responses is that they seemed to suggest that the scientific models look exactly like the phenomena they represent. Although such is not true, the participants' responses further acknowledge the main purpose of the models which is to simplify what appears to be complex. As such, the responses by the participants reflected UV, because they assume that the models do not look exactly like what they represent.

In addition, three of the 11 participants whose responses reflected IV responded to the question by writing the following: Participant 001

Models are the representation of real things, but it will never be exactly as the real thing. For example, a model representing the brain only shows three different parts of the brain and other parts are not shown.

The response by the participant seemed to suggest that the models are made to simplify what otherwise would look complex, the participant further provided an example of the parts of the brain. As such, the response provided by the participant reflected views that are informed.

Question 7: Scientists try to find answers to their questions by doing investigations/experiments. Do you think that the scientists use their imaginations and creativity when they do these investigations/experiments? If **NO**, explain why. If **YES**, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

The responses from the majority (nine participants) of the participants reflected IV. On the other hand, there were no participants whose responses reflected PIV and there were only three participants with responses reflecting UV.

In an attempt to respond to the question, two of the three participants whose response reflected UV responded to the question by stating the following: Participant 004

> *No, scientists use scientific explanation to explain Sciences which is having an investigation, which will lead to hypothesis*.

On the other hand, Participant 007 responded to the same question by saying

> *No, scientists only use and follow certain procedures, there is no room for imagination, and the results must be backed by concrete evidence*.

The participants seemed to suggest that in Science there is no place for creativity and imagination instead Science is more dependent on scientific explanations, and it has to follow certain procedures. However, Science uses creativity and imagination for planning and analysis and there is no universal method or procedure in Science, instead, the scientists use creativity and imagination. Therefore, the responses provided by the participants reflected UV.

On the other hand, three of the nine participants whose responses reflected IV responded to the question by writing the following: Participant 004

> *Yes, they use imagination and creativity for planning and interpretation of results*.

Similarly, participants 006 and 008 responded to the same question similarly

> *Yes, they use imagination in part of their planning. For example, model in which the* Deoxyribonucleic Acid *(DNA) is explained with letters whereas in our system we have no letters such as Adenine* and *Yes, they use their creativity and imagination for experimenting, analysing of data and observation*.

What can be generally deciphered from the responses of the participants is that creativity and imagination play a significant role in Science in terms of planning, interpreting results, experiments, analysis, and observations. An example by one of the participants (008), shows how creative and imaginative the scientists help make the explanation of nitrogenous bases more understandable. Thus, the responses and the examples that were provided by the participants concerning creativity and imagination in Science reflected the views that are informed.

Question 8: Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

The responses from the majority (five participants) of the participants reflected PIV.
On the other hand, there were four participants whose responses reflected IV and there were only three participants with responses reflecting UV.

In response to the question, all three participants whose responses reflected UV stated the following: Participant 002

> *Yes scientific theory explains information that can be supported by fact, law can also be tested, but theory can be rejected.*

On the other hand, Participant 003 responded to the question by saying

> *Law is what has been proven and theories are ideas that are still yet to be proven*.

There was also Participant 007 who responded to the very question by stating that

> *A theory is a proposed hypothesis with little evidence to back it up whereas the law is backed by evidence, hence it can't be changed*.

What can be deduced from the responses provided by the participants is that a scientific theory can be rejected, and a scientific law cannot, theory is still yet to be proven, meaning that theory is a law in the making, and it is just a hypothesis with little evidence. However, both scientific laws and theories are different, and one cannot be the other, both can be rejected, both can be tentative, and theory and hypothesis are two different aspects of Science. Therefore, the responses provided by the participants reflected UV.

In an attempt to respond to the question, one (participant 011) of the five participants whose responses reflected PIV responded to the question by agreeing with the idea that scientific laws and theories are different

> *Yes, scientific theory—not yet proven while laws could only be established after theory has been proven beyond reasonable doubt*.

The response by the participant highlights that there are differences between the two tenets and once the theory is proven beyond reasonable doubt, it graduates to become a scientific law. On the contrary, both tenets are different, they individually serve and promote distinctive scientific knowledge in the scientific community and one can never become the other. Therefore, while the participant acknowledges the existing distinction between the two tenets, the notion that one becomes the other reflected the views that are partially informed.

On the other hand, one (participant 012) of the four participants whose responses reflected IV responded to the question by stating that

> *Yes, theories describe how things happen, while laws describe what will happen in a given situation as demonstrated by mathematical equation*.

What can be deduced from the response is that the two tenets are different in such a way that one focuses on explaining and describing *how* phenomena take place, while the other focuses on *what* will happen by at times using mathematical equations. Thus, the response from the participant reflects an element of understanding the difference between the two tenets, as such, it held IV.

Question 9: After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.

The responses from the majority (eight participants) of the participants reflected IV. On the other hand, there were no participants whose responses reflected PIV and there were only four participants with responses reflecting UV.

In an attempt to respond to the question, two of the four participants whose response reflected UV responded to the question by stating the following: Participant 001

> *They will never change as they are not the same as facts and they are well supported*.

On the other hand, Participant 011 responded to the same question by saying *"No, none has ever come up"*. The responses provided by the two participants suggest that the scientific theories never change, this is because they are facts that are well-supported in the scientific community. However, on the contrary, the scientific theories like any other scientific knowledge are subject to change in light of new knowledge and evidence regarding phenomena. Furthermore, the tentative nature of scientific knowledge does not necessarily compromise the integrity and durability of scientific knowledge. Instead, it strengthens the scientific knowledge and makes it more reliable, as such, the responses provided show that the participants held UV.

On the other hand, three of the eight participants whose responses reflected IV responded to the question by writing the following: Participant 005

> *Yes, theory changes once there is new evidence, which has been tested and globally agreed by other scientists*.

Participants 007 and 012 responded to the same question similarly

> *Yes, when new evidence emerges it becomes easier to change theory. The out of Africa theory is recent and it is backed by evidence that was discovered recently* and *Theory can change as time goes on as new ideas are added.* Respectively.

What can be construed from the participants' responses is that the scientific laws can change provided, there is new evidence that has been tested or there are new ideas that have been widely accepted within the scientific community. In other words, scientific theories are tentative like all scientific knowledge, furthermore, for such knowledge to change, peer review, frequent testing, experiment, observations, and inferences should be at the centre towards validating. Therefore, the responses by the participants reflected that they hold IV concerning the question asked.

Question 10: Is there a relationship between Science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

The responses from the majority (eleven participants) of the participants reflected IV. On the other hand, there were no participants whose responses reflected PIV and there was only one participant with a response reflecting UV.

In an attempt to respond to the question, one participant whose response reflected uninformed views responded to the question by stating the following: Participant 006

> *No, there is no relationship as Science is there to suppress the cultural values of people using indigenous knowledge*.

What can be deciphered from the response provided by the participant is that there is no relationship between Science, society, and cultural values. The participant believes that Science has subdued other knowledge systems, particularly IK. The statement made by the participant holds an element of truth in it, particularly on the aspect of Science being dominant. However, it is on the contrary true that there is a relationship between Science, society, and cultural values because Science is by nature socially and culturally embedded. As such the response provided by the participant reflected UV.

On the other hand, four of the eleven participants whose responses reflected IV responded to the question by writing the following: Participant 004

> *Yes, in Science when they prove the hypothesis and is rejected or accepted, the society and cultural values are included when conducting research in Science*.

Similarly, Participant 009 responded to the same question in a similar manner

Yes, there is a link between Science, society, and cultural beliefs, for example, Egyptians used Science and mathematics to build pyramids as tombs for the dead.

The responses from the participants agree with the idea that there is a relationship between Science, society, and cultural values. One participant (004) believes that when scientific research is being carried out, IT is carried out within the confines of society and culture. On the other hand, the other (009) provided an example of how the Egyptians of the old used Science to build pyramids that served as a graveside for the Pharos. Hence, the responses by these participants show that they hold views that are informed.

In addition, Participant 005 responded to the question by saying

Yes, because Science allows us to understand our world, therefore Science does not occur alone. It is socially and culturally embedded. There won't be Science without society and culture.

On the other hand, Participant 007's response to the question was

Yes, because Science is everywhere, and it is part of our everyday life.

What can be deciphered from these pair of participants is that there is a relationship between Science, society, and cultural values, because Science provides an understanding of the world with its culture and society. Furthermore, Science is socially and culturally embedded. Therefore, the responses by the participants reflected IV.

4.3.6 Juxtaposing the pre-intervention and post-intervention responses from the VNOS-D+

In Table 4.7 the data from the pre-intervention and the post-intervention questionnaires is compared to determine the influence of the intervention on the participating Life Sciences teachers.

Table 4.7: Summary of overall coded pre-intervention and post-intervention VNOS-D+ views of the participants from the three settings (Author's own creation).

The number of views reflected in the Views of Nature of Science Questionnaire				
Views	**NC**	**UV**	**PIV**	**IV**
Number of pre-intervention responses	6 (5%)	31 (26%)	20 (16%)	64 (53%)
Number of post-intervention responses	0 (0 %)	24 (20%)	20 (17%)	76 (63%)

[KEY: NC = no classification; UV = uninformed views; PIV = partially informed views; IV = informed views]

The trend emerging from both the pre-intervention and the post-intervention classification shows that the majority of the responses provided by the participants reflected informed views. This is the trend that is visible from both the pre- and the post-intervention responses. The number of responses reflecting IV from the pre-intervention questionnaire is 64 (53%). The number is more than all the three classifications (NC, UV and PIV) combined. Although the second highest stems from the classification UV (31 or 26%), the number of responses reflecting IV (64 or 53%) is more than twice the number of responses reflecting UV (26%).

In addition, the responses from the post-intervention reflect a noticeable change where the number of participants' responses reflecting IV (76 or 63%) has become more than three times than those reflecting UV (24 or 20%). This noticeable change is not only the result of an increased number of participants' responses reflecting IV post-intervention, but also a decreased number of participants' responses reflecting UV and participants whose responses were NC.

When comparing the pre-intervention and post-intervention responses, the visible trend that was identified shows an improvement concerning the participants' views about the nature of Science. The number of participants' responses which were classified as NC dropped from 6 (5%) during the pre-intervention to zero post-intervention, a 100% improvement after an intervention has taken place. Similarly, the trend continued concerning the number of responses reflecting UV. The number of participants' responses reflecting UV during pre-intervention was 31 (26%) and it dropped to 24 (20%) post-intervention, which is a significant drop of 7.7%.

In addition, concerning the number of responses reflecting PIV, there was no change when comparing pre-intervention and post-intervention. However, the trend became visible once more concerning the number of participants' responses reflecting IV. The number improved from 64 (53%) responses from the pre-intervention to 76 (63.3%) responses post-intervention, which is a significant improvement of 18.8% compared to the pre-intervention responses. Similarly, the juxtaposition reflects the findings from the study carried out by Sebotsa (2020), where the NS teachers developed more nuanced views of NOS after the intervention. As well as Chuene and Singh (2024), whose study focused on Sciences teachers' views of NOS and their study found that the teachers held IV. However, a study by Cronje (2015) found that the Life Sciences teachers held PIV of NOS and suggested that with a well-planned intervention such views can be improved.

The overall range for the overall scores of the pre-intervention versus post-intervention

$$\textbf{Pre} = \frac{1.7-0.6}{1} = \underline{\textbf{1.1}} \text{ versus } \textbf{Post} = \frac{1.8-1.1}{1} = \textbf{0}\underline{\textbf{.7}}$$

The above calculations reflect an improvement of the minimum score of 0.6 from the pre-intervention to 1.1 minimum scores from the post-intervention. Furthermore, the maximum score from the pre-intervention improved from 1.7 to 1.8 post-intervention.

The average overall score of the pre- versus post-intervention

$$\textbf{Pre} = \frac{13.7}{12} = \underline{\textbf{1.1}} \text{ versus } \textbf{Post} = \frac{17.2}{12} = \underline{\textbf{1.4}}$$

The sum of the overall score increased from 1.1 to 1.4 post-intervention and this improvement was the result of an increased number of participants' responses reflecting IV, and a decreased number of participants' responses reflecting UV. Furthermore, there was a decreased number of participants whose responses could not be classified. This claim is justified by the idea that the number of participants' responses reflecting PIV had not changed when comparing the pre and post aspects. In other words, the decreased number of participants' responses from UV and NC can be attributed to the increased number of participants’ responses reflecting IV. Lastly, it is noticeable that the average overall score has increased from 1.1 to 1.4, which is a 0.3 average overall score increase.

4.3.7 Presentation and analysis of the pre-intervention and post-intervention data collected from POSTT LFSC

This section is an attempt to present the analysed data that was gathered from the Pedagogy of Science Teaching Test for Life Sciences (POSTT LFSC). The category of each answer from the multiple-choice questions that were drawn aligned with each category using the item page number and the response key from the four original tests.

The participants' responses were categorised using codes and deliberations were made concerning the participants' responses that were associated with the categories namely: Didactic Direct (DD); Active Direct (AD); Guided Inquiry (GI) and Open Inquiry (OI). I deliberated on the number of responses that are associated with each category from pre-intervention compared to the post-intervention responses where a percentage increase or decrease was determined between the data that was generated from the pre- and the post-intervention. Table 4.8 presents the categories and the description of each category.

Table 4.8: POSTT LFSC categories and their descriptions (Cobern et al., 2010).

Category	Description
Didactic Direct	This means that the participant's (Life Sciences teacher) response presents the concept or principle directly and it explains it. Furthermore, the participant illustrates with an example or demonstration and provides no learner activities, but takes learner questions and answers them or clarifies.
Active Direct	This means that the participant's response presents the Science concept or principle directly and explains it. Furthermore, the participant illustrates with an example or demonstration and takes learner questions and answers them or clarifies. Lastly, provides learner activity based on the presented Science, e.g., hands-on practical verification of a law.
Guided Inquiry	This means that the participants present the lesson where topics are approached by learner exploration of a phenomenon or idea, with the teacher guiding them toward the desired Science concept or principle arising from the activity. A teacher may explain further and give examples to consolidate. Questions are dealt with by discussion.
Open Inquiry	This means that the participant's classroom allows for the learners to be guided minimally and these learners are free to explore a phenomenon or idea as they wish and devise ways of doing so. The teacher facilitates but does not prescribe. The inquiry process is considered the most important thing. The learners present what they did and discovered.

4.3.8 Presentation and analysis of pre-intervention data from the POSTT LFSC

Table 4.9 presents the pre-intervention POSTT LFSC responses of the participating Life Sciences teachers from the three settings. The responses are based on the answers given on the 17 items (questions) of the POSTT LFSC. The 17 items are presented as scenarios regarding a topic in Life Sciences, discussing the most effective ways to teach it. Each scenario is followed by a multiple-choice question with four options, asking participants to select the one that best represents their teaching practice for the topic in question. The participants' responses were coded, weighted in percentages and scored from 'Didactic Direct' to 'Open Inquiry'. Please refer back to Table 3.5 in Chapter 3.

Table 4.9: Summary of coded pre-intervention participants' responses to the Pedagogy of Science Teaching Test (POSTT LFSC) from the three settings ((Author's own creation)

Participant	IN1	IN2	IN3	IN4	IN5	IN6	IN7	IN8	IN9	IN10	IN11	IN12	IN13	IN14	IN15	IN16	IN17	
001	AD	DD	GI	AD	DD	DD	OI	GI	AD	GI	GI	AD	GI	GI	AD	OI	GI	
002	AD	DD	OI	OI	AD	DD	OI	AD	OI	GI	AD	GI	GI	OI	AD	DD	GI	
003	GI	OI	DD	OI	AD	GI	AD	AD	OI	OI	DD	DD	AD	OI	GI	DD	GI	
004	GI	AD	OI	AD	GI	GI	DD	OI	DD	GI	DD	GI	GI	GI	AD	OI	GI	
005	DD	DD	AD	AD	GI	GI	GI	AD	DD	DD	AD	GI	GI	GI	GI	DD	AD	
006	DD	OI	GI	GI	DD	GI	OI	GI	GI	GI	AD	GI	AD	OI	AD	OI	AD	
007	DD	OI	DD	OI	OI	GI	DD	GI	DD	GI	AD	GI	OI	DD	GI	AD	OI	
008	OI	GI	DD	AD	GI	GI	OI	DD	DD	GI	GI	AD	OI	GI	GI	DD	OI	
009	DD	OI	GI	DD	GI	GI	AD	AD	GI	AD	DD	OI	GI	GI	AD	OI	OI	
010	OI	DD	GI	DD	GI	GI	OI	AD	DD	GI	DD	OI	GI	OI	GI	OI	OI	
011	AD	OI	GI	AD	AD	GI	OI	GI	DD	OI	OI	GI	GI	OI	AD	AD	AD	
012	DD	DD	DD	DD	OI	GI	OI	AD	AD	DD	OI	DD	GI	OI	GI	DD	OI	
Total DD	5	5	4	3	2	2	2	1	6	2	4	2	0	1	0	5	0	**44**
Total AD	3	1	1	5	3	0	2	6	2	1	4	2	2	0	6	2	3	**43**
Total GI	2	1	5	0	5	10	1	4	2	7	2	6	8	5	6	0	4	**68**
Total OI	2	5	2	4	2	0	7	1	2	2	2	2	2	6	0	5	5	**49**

[**KEY:** Didactic Direct = DD; Active Direct = AD; Grounded Inquiry = GI; Open Inquiry =OI; Item Number = IN]

It can be seen in Table 4.9 that on the one hand, the total number of DD is 44 out of the possible 204 which accounts for 21.6% of the responses provided by the participants. On the other hand, the total number of AD is 43 out of the possible 204, which accounts for 21.1% of the responses provided by the participants. Furthermore, the total number of GIs is 68 out of the possible 204 and this is the option with the highest number, which accounts for 33.3% of the responses provided by the participants. Lastly, the total number of OI is 49 out of the possible 204 and this is the option with the second highest number, which accounts for 24% of the responses provided by the participants.

Below is the presentation of the participating Life Sciences teachers' responses to the itemised multiple-choice questions in relation to each category. The presentation will begin with responses falling within didactic direct, followed by active direct, guided inquiry and conclude with open inquiry.

- **<u>Didactic Direct:</u>**

The number of items from the test with the majority of participants whose responses reflect the DD category are item numbers 1 and 9, with five and six participants respectively. On the other hand, on Item numbers 2; 11 and 16 have five, there are four and five participants whose responses reflect the DD category, which is a joined majority with the AD and the OI categories. Lastly, the rest of the participants' responses are spread across the other three categories.

- **<u>Active Direct:</u>**

The number of items from the test which has the majority of participants whose responses reflected the AD category are item numbers 4 and 8, with five and six participants respectively. On the other hand, on Item numbers 11 and 15 there are four and six participants whose responses reflect the AD category respectively, which is a joined majority with the DD and the GI categories respectively. Lastly, the rest of the participants' responses are spread across the other three categories.

- **<u>Guided Inquiry:</u>**

The number of items from the test which has the majority of participants whose responses reflect the GI category are item numbers 3; 5; 6; 10; 12 and 13, with five,

five, ten, seven, six and eight participants respectively. On the other hand, Item number 15 has six participants whose responses reflect the GI category, which is joined majority with the AD category. Lastly, the rest of the participants' responses are spread across the other three categories.

- **Open Inquiry:**

The number of items from the test which has the majority of participants whose responses reflect the OI category are item numbers 7, 14 and 17, with seven, six and five participants respectively. On the other hand, Item number 2 had five participants whose responses reflect the OI category, which is a joined majority with the DD category. Lastly, the rest of the participants' responses are spread across the other three categories.

Categories DD and AD have two item numbers with majority responses, while the OI category has three majority responses however, the category GI has six item numbers with majority responses, which is the highest number of majority item numbers across the categories. This trend of responses reflects what is evident from above, that the GI category dominates in terms of the overall numbers and percentage, followed by the OI category.

4.3.9 Presentation and analysis of post-intervention data from POSTT LFSC

Table 4.9 presents the post-intervention POSTT LFSC responses of the participating Life Sciences teachers from the three settings. The participants' responses were coded, weighted in percentages, and scored from 'Didactic Direct' to 'Open Inquiry'.

Table 4.10: Summary of coded post-intervention participants' responses to the Pedagogy of Science Teaching Test (POSTT LFSC) from the three settings (Author's own creation).

Participant	IN1	IN2	IN3	IN4	IN5	IN6	IN7	IN8	IN9	IN10	IN11	IN12	IN13	IN14	IN15	IN16	IN17	
001	GI	GI	GI	GI	OI	DD	AD	GI	DD	GI	GI	AD	GI	GI	GI	OI	OI	
002	GI	GI	OI	GI	AD	GI	GI	DD	AD	OI	OI	OI	GI	GI	AD	OI	DD	
003	OI	OI	DD	DD	GI	GI	OI	OI	GI	GI	DD	OI	AD	AD	GI	GI	AD	
004	GI	OI	GI	AD	AD	GI	AD	DD	DD	OI	AD	GI	GI	GI	AD	OI	GI	
005	GI	AD	GI	AD	GI	DD	GI	OI	AD	AD	AD	OI	OI	GI	GI	OI	OI	
006	OI	AD	GI	GI	DD	GI	OI	GI	DD	DD	AD	DD	DD	AD	AD	OI	OI	
007	AD	OI	DD	AD	OI	GI	DD	GI	DD	GI	DD	GI	OI	OI	OI	AD	OI	
008	OI	OI	DD	AD	GI	GI	OI	DD	DD	GI	GI	AD	OI	GI	GI	DD	OI	
009	DD	OI	AD	GI	GI	GI	OI	OI	OI	DD	AD	OI	GI	GI	AD	OI	AD	
010	OI	DD	GI	DD	GI	GI	OI	AD	DD	GI	DD	OI	GI	OI	GI	OI	OI	
011	AD	DD	OI	GI	DD	GI	OI	AD	DD	GI	AD	GI	DD	OI	GI	OI	GI	
012	DD	DD	DD	DD	DD	GI	OI	AD	AD	DD	OI	DD	GI	OI	GI	DD	OI	
Total DD	2	3	4	3	3	2	1	3	7	3	3	2	2	0	0	2	1	**41**
Total AD	2	2	1	4	2	0	2	3	3	1	5	2	1	2	4	1	2	**37**
Total GI	4	2	5	5	5	10	2	3	1	6	2	3	6	6	7	1	2	**70**
Total OI	4	5	2	0	2	0	7	3	1	2	2	5	3	4	1	8	7	**56**

[**KEY:** Didactic Direct = DD; Active Direct = AD; Grounded Inquiry = GI; Open Inquiry =OI; Item Number = IN]

It can be seen in Table 4.10 that on the one hand, the total number of DD is 41 out of the possible 204 which accounts for 20.1% of the responses that were provided by the participants. On the other hand, the total number of AD is 37 out of the possible 204, which accounts for 18.1% of the responses that were provided by the participants. Furthermore, the total number of GI is 70 out of the possible 204 and this is the option with the highest number, which accounts for 34.3% of the responses provided by the participants. Lastly, the total number of OI is 56 out of the possible 204 and this is the option with the second highest number, which accounts for 27.5% of the responses provided by the participants.

Below is the presentation of the participating Life Sciences teachers who responded to the itemised multiple-choice questions in relation to each category. The presentation will begin with the responses falling within the didactic direct sphere, followed by the active direct, the guided inquiry and it will conclude with open inquiry.

- **<u>Didactic Direct</u>**

The number of items from the test with the majority of the participants whose responses reflect the DD category is item number 9 with seven participants. On the other hand, item number 8 has three participants whose responses reflect the DD category, which is joined majority with the AD, the GI and the OI categories. Lastly, the rest of the participants' responses are spread across the other three categories.

- **<u>Active Direct</u>**

The number of items from the test with the majority of participants whose responses reflect the AD category is item number 11 with five participants. On the other hand, item number 8 had three participants whose responses reflect the AD category which is joined majority with the DD, the GI and the OI categories. Lastly, the rest of the participants' responses are spread across the other three categories.

- **<u>Guided Inquiry</u>**

The number of items from the test which has the majority of participants whose responses reflected the GI category were item numbers 3; 4; 5; 6; 10; 12; 13; 14 and 15, with five, five, five, ten, six, six and seven participants respectively. On the other hand, item number 1 has four participants whose responses reflect the GI category, which is joined majority with the OI category. Lastly, item number 8 has three participants whose responses reflect the GI category which is joined majority with the AD category. Lastly, item number 8 has three participants whose responses reflect the GI category which is joined majority with the DD, the AD and the OI categories, while the rest of the participants' responses were spread across the other three categories.

- **<u>Open Inquiry</u>**

The number of items from the test which has the majority of participants whose responses reflect the OI category are item numbers 2; 7; 12; 16 and 17, with five, five, seven, five, eight and seven participants respectively. On the other hand, item number 1 has four participants whose responses reflect the OI category, which is joined majority with the GI category. Lastly, six participants whose responses reflected the GI category, had joined majority with the AD category. Lastly, item number 8 has three participants whose responses reflected the OI category, which is joined majority with the DD, the AD and the GI categories, while the rest of the participants' responses are spread across the other three categories.

Categories DD and AD have one item number with majority responses, while the OI category has five item numbers with majority responses. However, category GI has eight item numbers with majority responses, which is the highest number of majority item numbers across the categories. This trend of responses reflects what is evident from the above, that GI dominates in terms of overall numbers and the percentage through both pre- and post-intervention, followed by the OI category.

4.3.10 Juxtaposing the pre-intervention and post-intervention responses from POSTT LFSC

Table 4.11 presents the juxtaposition of the pre-intervention and the post-intervention responses that are provided by the participating Life Sciences teachers.

Table 4.11: Summary of overall coded pre-intervention and post-intervention POSTT LFSC responses of the participants from the three settings (Author's own creation).

The number of responses reflected from the categories of the Pedagogy of Science Teaching Test (POSTT LFSC)				
Categories	**DD**	**AD**	**GI**	**OI**
Number of pre-intervention items associated with the category	44 (21.6 %)	43 (21.1 %)	68 (33.3%)	49 (24%)
Number of post-intervention items associated with the category	41 (20.1%)	37 (18.1%)	70 (34.3%)	56 (27.5 %)

[KEY: Didactic Direct = DD; Active Direct = AD; Grounded Inquiry = GI; Open Inquiry =OI]

The trend emerging from both the pre-intervention and the post-intervention categories shows that the majority of the responses provided by the participants were aligned with the GI category. This is the trend that is visible from both the pre- and the post-intervention responses. The number of responses reflecting the GI category from the pre-intervention questionnaire is 68 (33.3%). The number is 19 less than the sum of both the DD and the AD categories. On the other hand, the second highest number of responses stems from OI (49 responses or 24%). The number of responses reflecting the GI category (68 or 33.3%) is 19 more compared to the number of participants whose responses were aligned with the OI category (49 or 24%).

Secondly, the responses from the post-intervention reflect a noticeable change where the number of participants' responses reflect the GI category (70 or 34.3%), which is almost twice more than those responses that aligned with the AD category (37 or 18.1%). This noticeable change is not only the result of the increased number of participants' responses aligned with the GI and the OI categories post-intervention, but it is also a decreased number of participants' responses that are aligned with the DD category.

Furthermore, when comparing the pre-intervention and the post-intervention responses, the visible trend that was identified shows that there is a conceptual change concerning the participants' alignment about their pedagogical attentions. The number of participants' responses which are categorised as DD dropped from 44 during the pre-intervention to 41(20.1%) post-intervention, which is an almost 7% shift after an intervention has taken place. Similarly, the trend continued concerning the number of responses reflecting the AD category. The number of participants' responses aligning with the AD category during pre-intervention was 43 (21.1%) and it dropped to 37 (18.1) post-intervention, which is a significant drop of 13.9%.

Lastly, the trend continued once more concerning the number of participants' responses aligning with the GI category. The number improved from 68 (33.3%) responses from the pre-intervention to 70 (34.3%) responses post-intervention, which is a slight improvement of 2.9% compared to the pre-intervention responses. Similarly, the trend continued concerning the responses aligning with the OI category, the number increased from 49 (24%) to 56 (27.5%), which is a significant improvement of 14.2%. The juxtaposition of the analysis reflected a similar trend that from a similar study on Physical Sciences teachers based in township and suburban schools by Ramnarain and Schuster (2014). They noticed that while teachers at suburban schools display a GI orientation, with concepts being developed via a GI phase, those at township schools generally have a strong AD teaching orientation, involving direct exposition of the science followed by confirmatory practical work (Ramnarain & Schuster, 2014). However, another study on Physical Sciences pre-service teachers pedagogical orientation had different findings where pre-service teachers preferred the direct approach inclined to AD with a small group which preferred the OI (Sondlo & Ramnarain, 2018).

4.4 Presentation and analysis of the pre-intervention and post-intervention data from the SDLI

Due to the implications for expenses, the turnaround time, and the sample estimate precision, obtaining a representative sample size is still crucial for any research endeavours (Adam, 2020). Hence, Taro and Israel (1967) posit that the size of a sample in any study that uses primary data looks for the participants' responses through questionnaires. However, one of the keys "challenges that Science researchers face in research studies is the determination of an appropriate sample size which is representative of the population under study" (Adam, 2020, p.90). In an attempt to obviate such a challenge, a statistician named Yamane Taro developed a formula that could be used to determine the sample size from any given population (1967). The formula is presented below.

$$\mathbf{n} = \frac{N}{1 + N(e)^2}$$

Table 4.12 presents the meaning of each variable that was drawn from the formula as well as the parameters of the margins of error used in the presentation and analysis of the data below.

Table 4.12: Sample size formula keys (Author's own creation).

Keys	**Meaning**
n	Denotes the sample size
N	Denotes the population of the undertaken study
e	Denotes the margin error which is 0.10

As highlighted above, in the context of this study, the margin error that was used is 0.10 where the population under the study comprised of 42 Life Sciences teachers as highlighted in Chapter 3, and below is an illustration of how the sampling was done.

$$\mathbf{n} = \frac{N}{1 + N(e)^2}$$

$$\mathbf{n} = \frac{42}{1 + 42(0.10)^2}$$

$$\mathbf{n} = \frac{42}{1.42}$$

$$\mathbf{n} = 30$$

As highlighted from the formula above, the number of Life Sciences teachers who participated in this study is 38, where 12 teachers served as the experimental group, while 26 served as the control group. The presentation of data from both the pre- and the post-responses that was provided by both groups is below.

4.4.1 The pre-intervention and post-intervention presentation and analysis of data from the SDLI gathered from the control group

Table 4.13 represents the pre-intervention and the post-intervention data for the control group on the items in the SDLI where the minimum and maximum scores by the participants are presented. These scores were used to generate the mean scores and the standard deviation per item. It is worth noting that the control group was not involved in the intervention. As such '*pre- and post-intervention*' are used to denote the period between the administration of the first and the second SDLI to the control group.

Table 4.13: Descriptive Statistics of the control group (SPSS 26th version).

		PRE				POST			
Item number	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Item 1	26	3	5	4.12	.766	2	5	4.38	.852
Item 2	26	3	5	4.46	.647	4	5	4.54	.508
Item 3	26	3	5	4.38	.697	3	5	4.58	.578
Item 4	26	3	5	4.58	.703	3	5	4.50	.707
Item 5	26	2	5	4.38	.697	4	5	4.46	.508
Item 6	26	2	5	4.08	.744	2	5	4.38	.752
Item 7	26	2	5	4.08	.744	3	5	4.19	.567
Item 8	26	3	5	4.08	.484	3	5	3.88	.588
Item 9	26	3	5	4.12	.653	3	5	4.23	.587
Item 10	26	3	5	3.96	.662	3	5	4.08	.688
Item 11	26	1	5	3.69	1.050	1	5	3.92	.977
Item 12	26	1	5	3.81	1.059	3	5	4.08	.744
Item 13	26	3	5	4.00	.693	3	5	4.12	.653
Item 14	26	3	5	4.08	.628	3	5	4.31	.618
Item 15	26	3	5	4.12	.711	2	5	4.04	.774
Item 16	26	2	5	3.88	.711	2	5	4.00	.748
Item 17	26	2	5	4.27	.724	3	5	4.31	.679
Item 18	26	1	5	4.19	.895	3	5	4.46	.647
Item 19	26	2	5	4.19	.801	3	5	4.31	.618
Item 20	26	2	5	4.23	.765	1	5	4.08	.935
Valid N (listwise)									

Table 4.13 shows that the participants' responses pre-intervention had the lowest score of 1 on three occasions and this score is reflected in items 11, 12 and 18. However, the

post-intervention data reflected the participants' lowest score of 1 done only on two occasions (items 11 and 20). Furthermore, the participants' pre-intervention scores generated two high standard deviations on items 11 and 12 which suggests that it was on two occasions that these items reflected data that was spread out. On the other hand, it was 18 (18 items) occasions where the participants' responses reflected the standard deviation which suggested that the data was somewhat clustered around the mean score. The participants' post-intervention scores generated only one high standard deviation score (item 14), which means that most of the data was clustered around the mean score when compared to the pre-intervention responses. Lastly, the data that was drawn from the pre-intervention phase reflected the lowest and the highest mean of 3.69 (item 11) and 4.58 (item 4) respectively, as opposed to the post-intervention which had the lowest and the highest mean score of 3.88 (item 8) and 4.58 (item 3) respectively.

Table 4.14 represents the pre-intervention and the post-intervention T-Test and the paired sample test from the control group on the items in the SDLI where the item numbers from the pre-intervention are paired with the post-intervention. The paired samples are used to determine the mean between the pre-intervention and the post-intervention scores per item and the variation that exists within the items. Lastly, the table also presents the significance where one-sided p and two-sided p are presented.

Table 4.14: T-Test, Paired Samples Test (SPSS 26th version).

Item number		T	df	Significance	
				One-Sided p	Two-Sided p
Pair 1	Item 1 – Item 1	-1.494	25	.074	.148
Pair 2	Item 2 - Item 2	-.527	25	.301	.603
Pair 3	Item 3 - Item 3	-1.547	25	.067	.134
Pair 4	Item 4 - Item 4	.527	25	.301	.603
Pair 5	Item 5 - Item 5	-.570	25	.287	.574
Pair 6	Item 6 - Item 6	-2.309	25	.015	.029
Pair 7	Item 7 - Item 7	-.768	25	.225	.449
Pair 8	Item 8 - Item 8	1.547	25	.067	.134
Pair 9	Item 9 - Item 9	-1.140	25	.132	.265
Pair 10	Item 10 - Item 10	-.827	25	.208	.416
Pair 11	Item 11 - Item 11	-1.237	25	.114	.228
Pair 12	Item 12 - Item 12	-1.428	25	.083	.166
Pair 13	Item 13 - Item 13	-1.000	25	.163	.327
Pair 14	Item 14 - Item 14	-1.806	25	.042	.083
Pair 15	Item 15 - Item 15	.440	25	.332	.664
Pair 16	Item 16 - Item 16	-1.000	25	.163	.327
Pair 17	Item 17 - Item 17	-.238	25	.407	.814
Pair 18	Item 18 - Item 18	-1.766	25	.045	.090
Pair 19	Item 19 - Item 19	-.827	25	.208	.416
Pair 20	Item 20 - Item 20	1.280	25	.106	.212

Table 4.14 reflects the highest t-value of 1.280 with a one-sided p of 0.106 and a two-sided p of 0.212. This presentation is drawn from the paired sample item 7 reflecting the

large differences that exist between the two sets. However, the paired samples 1 and 11 reflected the lowest t-value of -2.309 with is a one-sided p of 0.015 and a two-sided p-value of 0.029 thereby reflecting the minimal difference that exists between the two sets.

Table 4.15 represents the summarised data of the pre-intervention and the post-intervention responses from the control group. The table reflects the categories heading the items, the pre-intervention and the post-intervention minimum and maximum scores, the mean scores, and the standard deviations as well as the generated p-values.

Table 4.15: Summarised data table for the control group (Author's own creation).

The scoring criteria for the questionnaire used to collect the summarised data below were as follows: 1= strongly disagree; 2= disagree; 3= neutral; 4= agree and; 5= Strongly Agree							
Category	***Motivation for learning***						
			Pre		***Post***		***T-test***
Item No.	***Items***	***Variables***	***(Min;Max)***	***Mean±SD***	***(Min;Max)***	***Mean±SD***	***P-value***
1	I know what I need to learn		(3;5)	4.12±0.37	(2;5)	4.38±0.85	0.148
2	Regardless of the results or effectiveness of my learning, I still like learning		(3;5)	4.46±0.64	(4;5)	4.54±0.50	0.603
3	I strongly hope to constantly improve and excel in my learning		(3;5)	4.38±0.69	(3;5)	4.58±0.57	0.134
4	My successes and failures inspire me to continue learning		(3;5)	4.58±0.70	(3;5)	4.50±0.70	0.603
5	I enjoy finding answers to questions		(2;5)	4.38±0.69	(4;5)	4.46±0.50	0.574
6	I will not give up learning because I face some difficulties		(2;5)	4.08±0.74	(2;5)	4.38±0.75	0.029
Category	***Planning and implementation***						
			Pre		***Post***		***T-test***
Item No.	***Items***	***Variables***	***(Min;Max)***	***Mean±SD***	***(Min;Max)***	***Mean±SD***	***P-value***
7	I can pro-actively establish my learning goals		(2;5)	4.08±0.74	(3;5)	4.19±0.56	0.449
8	I know what learning strategies are appropriate for me in reaching my learning goals		(3;5)	4.08±0.48	(3;5)	3.88±0.58	0.134
9	I set the priorities of my learning		(3;5)	4.12±0.65	(3;5)	4.23±0.58	0.265
10	Whether in the clinical practicum, classroom or on my own, I can follow my plan of learning		(3;5)	3.96±0.66	(3;5)	4.08±0.68	0.416
11	I am good at arranging and controlling my learning time		(1;5)	3.69±1.05	(1;5)	3.92±0.97	0.226
12	I know how to find resources for my learning		(1;5)	3.81±1.05	(3;5)	4.08±0.74	0.166
Category	***Self-monitoring***						
			Pre		***Post***		***T-test***
Item No.	***Items***	***Variables***	***(Min;Max)***	***Mean±SD***	***(Min;Max)***	***Mean±SD***	***P-value***
13	I can connect new knowledge with my personal experiences		(3;5)	4.00±0.69	(3;5)	4.12±0.65	0.327
14	I understand the strengths and weaknesses of my learning		(3;5)	4.08±0.62	(3;5)	4.31±0.61	0.083
15	I can monitor my learning progress		(3;5)	4.12±0.711	(2;5)	4.04±0.77	0.663
16	I can evaluate my own learning outcomes		(2;5)	3.88±0.711	(2;5)	4.00±0.74	0.327
Category	***Interpersonal communication***						
			Pre		***Post***		***T-test***
Item No.	***Items***	***Variables***	***(Min;Max)***	***Mean±SD***	***(Min;Max)***	***Mean±SD***	***P-value***
17	My interaction with the others helps me plan for further learning		(2;5)	4.27±0.72	(3;5)	4.31±0.67	0.814
18	I would like to learn the language and culture of those with whom I frequently interact with		(1;5)	4.19±0.89	(3;5)	4.46±0.64	0.090
19	I can express messages effectively in oral presentations		(2;5)	4.19±0.80	(3;5)	4.31±0.61	0.416
20	I can communicate messages effectively in writing		(2;5)	4.23±0.76	(1;5)	4.08±0.93	0.212

The Self-Directed Learning Instrument Categories

Motivation for learning

In this category, all of the six items that were responded to by the participants from the pre-intervention phase are comprised of the mean/average, which suggested that five items out of the six items have participants who 'agree (4)'. On the other hand, one item mean/average reflects 'strongly agree (5)'. Secondly, the responses captured from the post-intervention are comprised of the mean/average that suggests that the participants 'agree (4)' with three items and 'strongly agree (5)' with the other three items. However, the p-value (0.148, 0.603, 0.134, 0.603 and 0.574) of five out of the six items from this category outlined that there were no significant changes between the scores recorded from the pre-intervention versus the scores recorded from the post-intervention.

In other words, only item number 6 '*I will not give up learning because I face some difficulties*' from this category reflects a significant change between the responses recorded from the pre- and the post-intervention with a p-value of 0.029. Secondly, the mean/average seems to suggest that the responses from the item number in question had improved post-intervention (mean from pre-intervention was 4.08 and mean from post-intervention was 4.38).

Planning and implementation

This category is also comprised of six items and the responses that were recorded from the pre- and the post-intervention through the mean/average seemed to suggest that all of the participants 'agree (4)' with each item. However, the p-value (0.449, 0.134, 0.265, 0.226 and 0.166) of six out of the six items from this category outline that there were no significant changes between the scores that were recorded from the pre-intervention versus the scores that were recorded from the post-intervention.

Self-monitoring

This category is comprised of four items and the responses that were recorded from the pre- and post-intervention have an average/mean that can be interpreted as a score that suggested that the majority of the participants 'agree (4)'. Secondly, the p-value

(0.327, 0.663 and 0.327) of each item from the category seem to suggest that there was no significant change from the responses that were captured from the pre- and the post-intervention.

In other words, only item number 14 '*I understand the strengths and weakness of my learning*' from this category reflects a significant change between the responses that were recorded from the pre- and post-intervention with a p-value of 0.083. Secondly, the mean/average seems to suggest that the responses from the item number in question had improved post-intervention.

Interpersonal communication

This category is also comprised of four items and the responses recorded from the pre- and post-intervention have an average/mean that can be interpreted as a score that suggests that the majority of the participants 'agree (4)'. Secondly, the p-value (0.814, 0.416 and 0.212) of each item from the category seems to suggest that there was no significant change from the responses that were captured from both the pre- and the post-intervention.

In other words, only item number 18 '*I would like to learn the language and culture of those whom I frequently interact with*' from this category reflects a significant change between the responses that were recorded from the pre- and post-intervention with a p-value of 0.090. Secondly, the mean/average seems to suggest that the responses from the item number in question had improved post-intervention.

4.4.2 The pre-intervention and post-intervention presentation and analysis of data from the SDLI gathered from the experimental group

Table 4.16 represents the pre-intervention and the post-intervention data for the experimental group on the items in the SDLI where the minimum and maximum scores by the participants are presented. These scores were used to generate the mean scores and the standard deviation per item.

Table 4.16: Descriptive Statistics of the experiment group (SPSS 26th version).

		PRE				POST			
Item number	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Item 1	12	3	5	4.17	.835	4	5	4.42	.515
Item 2	12	3	5	4.50	.674	4	5	4.67	.492
Item 3	12	4	5	4.83	.389	3	5	4.50	.674
Item 4	12	3	5	4.42	.793	4	5	4.58	.515
Item 5	12	4	5	4.75	.452	4	5	4.58	.515
Item 6	12	4	5	4.67	.492	3	5	4.75	.622
Item 7	12	3	5	4.42	.793	3	5	4.00	.603
Item 8	12	3	5	4.08	.669	3	5	4.25	.622
Item 9	12	2	5	3.58	1.084	3	5	4.08	.669
Item 10	12	2	5	4.17	1.030	3	5	4.17	.718
Item 11	12	1	5	3.67	1.073	3	5	4.17	.835
Item 12	12	2	5	3.67	.985	3	5	4.17	.718
Item 13	12	3	5	4.50	.798	3	5	4.42	.793
Item 14	12	2	5	3.92	.900	2	5	3.92	1.084
Item 15	12	2	5	4.00	.853	3	5	4.42	.669
Item 16	12	3	5	4.08	.669	3	5	4.25	.622
Item 17	12	4	5	4.58	.515	4	5	4.75	.452
Item 18	12	4	5	4.67	.492	2	5	4.42	.900
Item 19	12	2	5	4.17	.937	2	5	4.17	.835
Item 20	12	4	5	4.33	.492	2	5	4.17	.937
Valid N (listwise)	12								

Table 4.16 shows that the 12 participants' responses pre-intervention had the lowest score of 1 on one occasion and this score is reflected in item 11. However, the post-intervention data reflected 2 as the lowest score and this was done on four occasions (items 14, 18, 19 and 20). Furthermore, the participants' pre-intervention scores

generated three high standard deviations on items 9, 10 and 11, which suggests that it was on three occasions that these items reflected the data that was spread out. On the other hand, it was 17 (17 items) occasions where the participants' responses reflected standard deviation which suggested that the data was somewhat clustered around the mean score. The participants' post-intervention scores generated only one high standard deviation score (item 14), which means that most of the data were clustered around the mean score when compared to the pre-intervention responses. Lastly, the data drawn from the pre-intervention phase reflected the lowest and highest mean of 3.58 (item 9) and 4.83 (item 3) respectively, as opposed to the post-intervention lowest and highest mean score of 3.92 (item 14) and 4.75 (item 6 and 17) respectively.

Table 4.17 represents the pre-intervention and the post-intervention T-Test, and it paired the sample test from the experimental group on the items in the SDLI where the item numbers from the pre-intervention are paired with the post-intervention. The paired samples are used to determine the mean between the pre-intervention and the post-intervention scores per item and the variation that exists within the items. Lastly, the table also presents the significance where one-sided p and two-sided p are presented.

Table 4.17: T-Test, Paired Samples Test (SPSS 26th version).

Item number		t	df	Significance	
				One-Sided p	Two-Sided p
Pair 1	Item 1 – Item 1	-1.915	11	.041	.082
Pair 2	Item 2 - Item 2	-1.000	11	.169	.339
Pair 3	Item 3 - Item 3	1.773	11	.052	.104
Pair 4	Item 4 - Item 4	-1.000	11	.169	.339
Pair 5	Item 5 - Item 5	.804	11	.219	.438
Pair 6	Item 6 - Item 6	-.561	11	.293	.586
Pair 7	Item 7 - Item 7	2.803	11	.009	.017
Pair 8	Item 8 - Item 8	-1.000	11	.169	.339
Pair 9	Item 9 - Item 9	-1.483	11	.083	.166
Pair 10	Item 10 - Item 10	.000	11	.500	1.000
Pair 11	Item 11 - Item 11	-1.915	11	.041	.082
Pair 12	Item 12 - Item 12	-1.732	11	.056	.111
Pair 13	Item 13 - Item 13	.561	11	.293	.586
Pair 14	Item 14 - Item 14	.000	11	.500	1.000
Pair 15	Item 15 - Item 15	-1.449	11	.088	.175
Pair 16	Item 16 - Item 16	-.804	11	.219	.438
Pair 17	Item 17 - Item 17	-1.000	11	.169	.339
Pair 18	Item 18 - Item 18	1.149	11	.137	.275
Pair 19	Item 19 - Item 19	.000	11	.500	1.000
Pair 20	Item 20 - Item 20	.692	11	.252	.504

Table 4.17 reflects the highest t-value of 2.803 with a one-sided p of 0.09 and two-sided p of 0.017. This presentation is drawn from the paired sample item 7 reflecting the large differences that exist between the two sets. However, the paired samples 1 and 11 reflected the lowest t-value of -1.915 with a one-sided p of 0.041 and a two-sided p-

value of 0.082 thereby reflecting the minimal difference that exists between the two sets.

Table 4.18 represents the summarised data of the pre-intervention and post-intervention responses from the experimental group. The table reflects the categories heading the items, the pre-intervention and the post-intervention minimum and maximum scores, the mean scores, and the standard deviations as well as the generated p-values.

Table 4.18: Summarised data table for the experiment group (Author's own creation).

The scoring criteria for the questionnaire used to collect the summarised data below were as follows: 1= strongly disagree; 2= disagree; 3= neutral; 4= agree and; 5= Strongly Agree

Category	***Motivation for learning***						
			Pre		***Post***		***T-test***
Item No.	***Items***	***Variables***	***(Min;Max)***	***Mean±SD***	***(Min;Max)***	***Mean±SD***	***P-value***
1	I know what I need to learn		(3;5)	4.17±0.83	(4;5)	4.42±0.51	0.082
2	Regardless of the results or the effectiveness of my learning, I still like learning		(3;5)	4.50±0.67	(4;5)	4.67±0.49	0.339
3	I strongly hope to constantly improve and excel in my learning		(4;5)	4.83±0.38	(3;5)	4.50±0.67	0.104
4	My successes and failures inspire me to continue learning		(3;5)	4.42±0.79	(4;5)	4.58±0.51	0.339
5	I enjoy finding answers to questions		(4;5)	4.75±0.45	(4;5)	4.58±0.51	0.438
6	I will not give up learning because I face some difficulties		(4;5)	4.67±0.49	(3;5)	4.75±0.62	0.586
Category	***Planning and implementation***						
			Pre		***Post***		***T-test***
Item No.	***Items***	***Variables***	***(Min;Max)***	***Mean±SD***	***(Min;Max)***	***Mean±SD***	***P-value***
7	I can pro-actively establish my learning goals		(3;5)	4.42±0.79	(3;5)	4.00±0.60	0.017
8	I know what learning strategies are appropriate for me in reaching my learning goals		(3;5)	4.08±0.66	(3;5)	4.25±0.62	0.339
9	I set the priorities of my learning		(2;5)	3.58±1.08	(3;5)	4.08±0.66	0.166
10	Whether in the clinical practicum, in the classroom or on my own, I can follow my plan of learning		(2;5)	4.17±1.03	(3;5)	4.17±0.71	1.000
11	I am good at arranging and controlling my learning time		(1;5)	3.67±1.07	(3;5)	4.17±0.83	0.082
12	I know how to find resources for my learning		(2;5)	3.67±0.98	(3;5)	4.17±0.71	0.111
Category	***Self-monitoring***						
			Pre		***Post***		***T-test***
Item No.	***Items***	***Variables***	***(Min;Max)***	***Mean±SD***	***(Min;Max)***	***Mean±SD***	***P-value***
13	I can connect new knowledge with my personal experiences		(3;5)	4.50±0.79	(3;5)	4.42±0.79	0.586
14	I understand the strengths and weaknesses of my learning		(2;5)	3.92±0.90	(2;5)	3.92±1.08	1.000
15	I can monitor my learning progress		(2;5)	4.00±0.85	(3;5)	4.42±0.66	0.175
16	I can evaluate my own learning outcomes		(3;5)	4.08±0.66	(3;5)	4.25±0.62	0.438
Category	***Interpersonal communication***						
			Pre		***Post***		***T-test***
Item No.	***Items***	***Variables***	***(Min;Max)***	***Mean±SD***	***(Min;Max)***	***Mean±SD***	***P-value***
17	My interaction with others helps me plan for further learning		(4;5)	4.58±0.51	(4;5)	4.75±0.45	0.339
18	I would like to learn the language and culture of those with whom I frequently interact with		(4;5)	4.67±0.49	(2;5)	4.42±0.90	0.275
19	I can express messages effectively in oral presentations		(2;5)	4.17±0.93	(2;5)	4.17±0.83	1.000
20	I can communicate messages effectively in writing		(4;5)	4.33±0.49	(2;5)	4.17±0.93	0.504

Interpreting the SDLI data from the experimental group

As highlighted that in the context of this study the margin error that was used is 0.10. Therefore, if the p-value is less than 0.05 or 0.1 it means that there was a significant difference between the pre-intervention versus the post-intervention responses from the participants.

The self-directed learning instrument categories

Motivation for learning

In this category all of the pre-intervention and the post-intervention six items responded to by the participants reflected a mean/average that suggested that all the participants' responses are more skewed from the option of 'agree (4)' to 'strongly agree (5)'. In other words, the data generated from the pre-intervention responses in this category, has only four items that suggested that the participants 'strongly agree (5)' with the items compared to five items from the post-intervention responses. However, the p-value (0.339, 0.104, 0.339, 0.438 and 0.586) of five out of the six items from this category outline that there were no significant changes between the scores that were recorded pre-intervention versus the scores that were recorded post-intervention.

In other words, only item number 1 '*I know what I need to learn*' from this category reflects a significant change between the responses recorded pre- and post-intervention with a p-value of 0.082. Secondly, the mean/average seemed to suggest that the responses from the item number in question had improved after the intervention had taken place.

Planning and implementation

This category is also comprised of six items and the responses recorded from the pre- and post-intervention through the mean/average seem to suggest that all of the participants 'agree (4)' with each item. However, the p-value (0.339, 0.166, 1.000 and 0.111) of four out of the six items from this category reflect no significant difference between the responses recorded from the pre-intervention when compared to the post-intervention.

In other words, item number 7 '*I can pro-actively establish my learning goals*' and item number 11 '*I am good at arranging and controlling my learning time*' have a p-value (0.017 and 0.082, respectively) that reflect that there were significant changes pre- and post-intervention. However, the mean/average values from both items seemed to suggest that one item reflected improvement and the other reflected a significant change in regression. In item number 11, the mean/average score pre-intervention is lower than that of post-intervention, which signifies a positive significant change. On the other hand, item number 7 has a mean/average from the pre-intervention that is higher than that of the post-intervention, which reflects a significant negative change (pre-intervention mean of 4.42 and post-intervention mean of 4.00).

Self-monitoring and Interpersonal communication

These categories are comprised of four items each and the responses recorded from the pre-, and the post-intervention have an average/mean that can be interpreted as a score that suggests that the majority of the participants 'agree (4)'. Secondly, the p-value (0.586, 1.000, 0.175 and 0.438; 0.339, 0.275, 1.000 and 0.504 respectively) of each item from both categories seemed to suggest that there was no significant change from the responses that were captured from both the pre- and the post-intervention.

4.4.3 The juxtaposition of the SDLI data collected from the experimental group and the control group

The pre and the post-intervention responses that were gathered from the experimental group had a mean/average that suggested that the majority of the participants 'strongly agreed' or their responses scored level 5 as most of the mean/averages were converted from 4.5 to 5. In contrast, the pre and the post-intervention control group's mean/average per item appeared to suggest that the participants agree, or their responses scored level 4. Secondly, the common occurrence between the two groups was the p-value from the majority of the items, which suggested that there were no significant changes between the pre-interventions and the post-intervention responses.

In addition, there were only three items from the experimental group with p-values that suggested that there were significant changes in the participants' responses between the pre- and the post-intervention contexts. The pre-intervention versus the post-intervention mean/averages of responses from two items with p-values that had significant change reflected an increase (growth) of mean/average, although minimal, still there was growth. The growth of the mean/average from both items signifies the positive influence of the intervention. However, as highlighted above that the p-value from item 7 '*I can pro-actively establish my learning goals*' showed that there was a significant change with a mean/average decrease from pre- to post-intervention. In other words, the mean/average captured from the pre-intervention response is higher than the mean/average captured from the post-intervention responses which means that the significant change was negative.

Furthermore, there were also three items from the control group with p-values that suggested that there were significant changes in the participants' responses between the pre- and the post-intervention. However, unlike the experiment group, the mean/average of each of the three items suggested that the change signified a positive influence from the intervention.

Mentz and De Beer (2021) show that the quantitative instruments such as the SDLI by Cheng et al. (2010) often do not measure the true impact of interventions on self-directed learning- especially in the case of short interventions and that qualitative data often provides a better description of reformed teaching and learning practices. A similar study on NS teachers by Sebotsa (2020) used SDLI to determine the teachers' SDL and found that indications of early self-directed learning, but these findings did not help them in improve their teaching methods or the growth of teacher agency in removing structural obstacles. For this reason, I also engaged the in-classroom observations.

4.5 Presentation and analysis of the classroom observations

The classroom observations comprised of six teachers with two teachers representing a setting. In other words, Participants 002 and 004 represented the rural setting; Participants 007 and 008 represented the semi-urban setting while Participants 009 and 011 represented the urban setting. Each participant was observed once in a post-intervention context using the adapted RTOP (Piburn et al., 2000). To present the data comprehensively, I start by providing a contextual background of each participant's classroom before presenting and analysing the data that was generated from the classroom observations using Table 4.19. I started with the participating teachers from the rural setting, followed by the teachers from the semi-urban setting and then concluded with the teachers from the urban setting. Later on, I presented the data in categories as per the RTOP that was used for the classroom observations, this allowed him to deliberate on each category comprehensively with remarks at the end to help make sense of the data that was deduced from the observations.

During the classroom observations, I observed six teachers, with two teachers representing each of the three settings. Each participant was observed once after the intervention using the adapted RTOP (Piburn et al., 2000). Firstly, I provided a contextual background of each participant's classroom within their setting (as shown in Table 4.19). After that, they deliberated on the RTOP categories.

Table 4.19: The contextual background of each classroom (Author's own work).

Participants from the rural setting	
Participant 002 and 004	The geographical location and the infrastructure of both schools showed that they are quintile 2 category schools. Their lessons took place in a Grade 12 classroom with approximately 55 and 60 learners respectively, where the majority were female learners. The topic for the day was Mutation and the Nervous system respectively. The teaching strategies that were used by both teachers involved question and answer as well as the whole class discussion with Participant 004 encouraging the learners to also work in pairs. The teachers did not use any teaching aid and there was no evidence of a lesson plan. The majority of the learners spoke the same language (Sepedi) and shared similar cultural beliefs. Each learner had a Life Sciences textbook.
Participants from the semi-urban setting	
Participant 007 and 008	The geographical location and infrastructure of the two schools showed that they are quintile 3 category schools. The lesson took place in a Grade 10 and Grade 11 classroom with approximately 80 and 50 learners respectively, where the majority were female learners. The topic for the day was Traditional Technology and Photosynthesis respectively. The teaching strategy that was used by the teachers involved question and answer as well as the whole class discussion, while 008's lesson encouraged the learners to lead the lesson. The teachers did not use any teaching aid and there was no evidence of lesson plans. Their classrooms were comprised of multi-tribal learners, with some of the learners coming from Zimbabwe, clearly with different cultural backgrounds. Each learner had a Life Sciences textbook.
Participants from the urban setting	
Participant 009	The geographical location and infrastructure of the school reflected that it is a quintile 5 category school. The lesson took place in a Grade 11 classroom with 36 learners where gender was equally balanced. The topic for the day was Photosynthesis and the teaching strategy used by the teacher involved question and answer as well as group work that encouraged a whole-class discussion. The teacher brought only the green leaves as a teaching aid and there was no evidence of a lesson plan. The classroom is comprised of multi-tribal and multi-racial learners, with some of the learners coming from Zimbabwe, clearly with different cultural backgrounds and some of the learners were of Somali descent, Indian descent and coloureds. Each learner had a Life Sciences textbook.
Participant 011	The geographical location and infrastructure of the school reflected that it is a quintile 5 category school. The lesson took place in a Grade 12 classroom with approximately 35 learners where gender was equally balanced. The topic for the day was the Brain and the teaching strategy that was used is a more teacher-centred question and answer approach by the teacher and it involved a question-and-answer session. The teacher did not have any teaching aid and there was no evidence of a lesson plan. The classroom is comprised of multi-tribal and multi-racial learners, with some of the learners coming from Zimbabwe, clearly with different cultural backgrounds and some of the learners were of Somali descent. Each learner had a Life Sciences textbook.

During my observations, I had the chance to reflect on the lessons using the RTOP instrument, which has four categories. In the next section, I describe these categories.

4.5.1 Category 1: Lesson plan and implementation

This category focused on the teaching strategies, the learners' prior knowledge, and their preconceptions as well as determining if the lesson was designed to engage the learners as members of the learning community (Piburn et al., 2000). Furthermore, the category sought to determine if the lesson allowed for the learner's exploration than the formal presentation or whether the teacher encouraged the learners to look for other modes of investigation (Piburn et al., 2000). Lastly, to determine if the focus and the direction of the lesson were inspired and dependent on ideas established by the learners Table 4.20 represents the scores that were obtained by the participants during their classroom pedagogy.

Table 4.20: Lesson plan and implementation (Piburn et al., 2000).

Category	**Lesson plan and implementation**					
Participant	Item 1	Item 2	Item 3	Item 4	Item 5	Average
002 (Rural)	3	4	3	3	3	3.2
004 (Rural)	2	3	3	2	3	2.6
007 (Semi-urban)	3	3	3	3	3	3
008 (Semi-urban)	3	3	3	4	2	3
009 (Urban)	4	3	3	4	3	3.4
011 (Urban)	3	1	2	0	0	1.2

[**KEY:** 0 = never occurred; 4 = very descriptive; Item 1 = prior knowledge; Item 2 = learner engagement; Item 3 = learner exploration; Item 4 = valuing of alternative modes of investigation; Item 5 = learner-centred lesson]

From Table 4.20, it can be seen that the Participants' (002 and 004) average was 3.2 and 2.6 out of the possible perfect 4, while Participants (007 and 008) produced an average score of 3. Furthermore, Participants (009 and 011) produced average scores of 3.4 and 1.2, respectively. The two aspects that stood out from the data above were that only one participant (011 from the urban setting) out of the six participants had the lowest average score (1.2) which suggested that his lesson was poorly presented. On the other hand, Participant 009 from the same setting obtained an average score (3.4) that suggested that his lesson was well presented than any other participants (002, 004, 007 and 008 from rural and semi-urban, respectively) whose lesson was well presented. In other words, the average scores (1.2 and 3.4) reflected that the participants (009 and 011) were from the same setting, but they approached their lessons differently.

The average scores of Participants 002 and 004 in Table 4.20 were 3.2 and 2.6, respectively, out of a perfect score of 4. Participants 007 and 008 had an average score of 3, whereas Participants 009 and 011 received 3.4 and 1.2, respectively. It is worth noting that Participant 011 from an urban area earned the lowest average score, indicating that the lesson was inadequately presented. However, when compared to Participants 002, 004, 007, and 008 from the rural and semi-urban settings, Participant 009 from the same setting got the highest average score, implying a well-presented lesson. In conclusion, the average scores of 1.2 and 3.4 suggest that Participants 009 and 011 from the same context addressed their lectures in different ways.

- **Rural setting**

Participant 002: The teacher did not use a baseline assessment to determine the learners' prior knowledge, instead he began the lesson by asking the learners what mutation is and what they understand by the term mutation. One learner defined mutation as *"The rearrangement of larger parts of genes or chromosomes that results in a variant form that may be transferred to the generations".* Although the lesson appeared to allow the learners to engage as members of the community, the learners' exploration did not precede the formal presentation. The direction of the lesson was determined by the learners' ideas, and this was evident when the other learner asked the teacher about harmful mutation, *"Sir, because some of the COVID-19 vaccines are through mRNA aren't they going to temper with our DNA?"* Hence, the lesson encouraged the learners to seek alternative modes of investigations.

Participant 004: The teacher applied a short baseline assessment by discussing with the learners what transpired the previous day. She asked the learners what they understood by neuron and also requested the learners to provide the types of neurons. She asked this question to determine the learners' prior knowledge. She further encouraged the learners to work in pairs as they attempt to answer the question. This allowed the learners to engage as members of the learning community, while the learners were encouraged to discuss with each other, the learner exploration was preceded by a formal presentation from the teacher. Lastly, the focus and the direction of the lesson were determined by the learners, and this was evident when some learners were not able to distinguish the difference between unipolar, bipolar and multipolar neurons. During class, the teacher started with a quick evaluation of the learners' previous knowledge. She asked them to define what a neuron is and name different types of neurons. This was to understand how much they knew before diving into the lesson. The learners were then encouraged to work together in pairs to answer the question. This not only promoted teamwork and communication among the learners but also gave them the chance to explore and discover alongside one another. The teacher also gave a formal presentation before the discussion. However, the lesson's direction and focus were largely influenced by the learners' interests and queries. It became apparent that some learners struggled to differentiate between unipolar, bipolar, and multipolar neurons.

- **Semi-urban setting**

Participant 007: The teacher did not ask any baseline questions to the learners, instead she asked the learners about what they understood about traditional technology. The first thing the learners did was to immediately go to the last pages of their textbook to try and find the definition of traditional technology. The learners did not find the answer, as such the teacher proceeded to ask them about what homemade medicines they use when they have the flu or when they are sick. In this context, the learners' exploration preceded the formal presentation as the learners were encouraged to share their home remedies. One learner shared, *You mix lemon with garlic, ginger, honey, and warm water*. The other learner said, *If I have a blocked nose, I boil water, add plenty of mint and inhale the steam*, by so saying, it was evident that the learners were responsible for the direction and the focus of the lesson. The integration of IK from the learners was evident as they claimed to have used different herbs to heal their ailments.

Participant 008: The teacher attempted to determine the learners' prior knowledge by asking the learners to define photosynthesis and one learner said, *Photosynthesis is the process whereby plants manufacture their food.* However, the teacher was more interested in the learners' ability to present the definition in a formula format and a couple of learners went to the chalkboard to try and presented but they failed. The lesson allowed for the learners' exploration, and it focused on the learners' alternative modes as they continued to try and write the formula in words before using symbols.

- **Urban setting**

Participant 009: The teacher started the lesson by employing a baseline assessment to try and determine the learners'' prior knowledge by asking them to define photosynthesis. The learners briefly discussed the question, and each group was able to highlight that photosynthesis *is the process whereby green plants manufacture their food*. The other learners were able to add that only the plants that are "autotrophs" are only capable of carrying out such a process. The lesson allowed the learners to engage as members of the learning community. Although a formal presentation preceded learner exploration the lesson was learner-centred where the learners were grouped, and they were encouraged to discuss before they could provide answers to the questions. This was evident when the teacher came to class with green leaves to help highlight the internal and external factors of photosynthesis. It was impressive how this group of learners could easily ignore any distractions and remain focused on the topic at hand.

Participant 011: The teacher did not apply a baseline assessment to determine the learners' prior knowledge, instead he asked the learners to provide components of the human brain. The learners were textbook reliant as such once the question was asked, the learners quickly consulted the textbooks. The lesson was more teacher-centred and a formal presentation discouraged learner exploration and the focus, and the direction of the lesson were determined by the teacher.

4.5.1.1 Conclusion drawn from Category 1 (Lesson Plan and Implementation)

The descriptions above revealed that the teachers approached their teaching differently irrespective of their setting. This was evident when some of the teachers began their lessons with a baseline assessment, while the other teachers focused on the content they were supposed to teach on that day. All of the teachers' lessons were learner-centred except for Participant 011 whose lesson was more teacher-centred. Although the teachers from the rural and the urban settings (Participants 002; 004 and 009, respectively) allowed the focus and the direction of their lessons to be determined by the learners where they served as facilitators, the formal presentation preceded learner exploration. On the other hand, in Participant 011's classroom, the lesson was never about the learners rather it was more teacher centred. Hence, out of the six participants, it was only Participant 011 whose lesson appeared to have been passive where the learners failed to engage or even participate.

It is evident that the teachers had varying approaches to teaching and learning regardless of the setting. Some teachers began their lessons with a baseline assessment, while the others focused on teaching the content. All of the teachers had learner-centric lessons except for Participant 011 whose lesson was more teacher-centric. The teachers from the rural and the urban settings (Participants 002, 004, and 009, respectively) allowed the learners to determine the focus and direction of the lessons, with the teachers acting as facilitators. However, in Participant 011's classroom, the lesson was solely about the teacher, and the learners did not engage or participate. Thus, out of the six participants, only participant 011 had a passive lesson.

4.5.2 Category 2: Content: Propositional

This category sought to determine if fundamental concepts were used and if there reflected coherent conceptual understanding as well as whether the teacher had a concrete grasp of the content knowledge (Piburn et al., 2000). Furthermore, the category sought to determine if the elements of abstraction were promoted whenever it was deemed necessary, and whether the lesson was contextualised and integrated with real-world phenomena (Piburn et al., 2000). Lastly, Table 4.21 represents the scores that were obtained by the participants during their classroom pedagogy.

Table 4.21: Content (propositional knowledge) (Piburn et al., 2000).

Category	**Content** (*Propositional*)					
Participant	Item 6	Item 7	Item 8	Item 9	Item 10	Average
002 (Rural)	4	3	3	3	3	3.2
004 (Rural)	3	3	4	2	3	3
007 (Semi-urban)	3	3	3	2	3	2.8
008 (Semi-urban)	3	3	4	1	3	2.8
009 (Urban)	3	3	4	3	4	3.4
011 (Urban)	4	2	4	0	2	2.8

[**KEY:** 0 = never occurred; 4 = very descriptive; Item 6 = involving fundamental concepts; Item 7 = promotion of conceptual understanding; Item 8 = grasping subject matter; Item 9 = encouraging elements of abstraction; Item 10 = contextualisation]

From Table 4.21, it can be seen that the participants' (002 and 004) had average scores of 3 and 3.2 out of the possible perfect 4, while both participants (007 and 008) produced an average score of 2.8. Furthermore, the participants (009 and 011) produced average scores of 3.4 and 2.8, respectively. The two aspects that stood out of the data above were that only one participant (009 from the urban setting) obtained the highest average score (3.4) again, which suggested a well-reflected propositional content knowledge in the classroom. On the other hand, unlike in the lesson implementation, all the participants' average scores (3.2, 3, 2.8, 2.8 3.4 and 2.8 respectively) suggested that their content knowledge was well presented in the classroom. In other words, all the participants from the three settings (rural, semi-urban and urban) reflected high propositional content knowledge.

In Table 4.21, Participants 002 and 004 had average scores of 3 and 3.2 out of a perfect score of 4, while Participants 007 and 008 had an average score of 2.8. Additionally, Participants 009 and 011 had average scores of 3.4 and 2.8, respectively.

It is worth noting that only one participant (009 from the urban setting) achieved the highest average score (3.4), thereby indicating a strong understanding of the lesson content. However, unlike in lesson implementation, all the participants (with average scores of 3.2, 3, 2.8, 2.8, 3.4, and 2.8, respectively) demonstrated a high level of propositional content knowledge in the classroom, regardless of their setting (rural, semi-urban and urban).

- **Rural setting**

Participant 002: The lesson involved fundamental concepts such as harmless and harmful mutations, examples of disorders, diseases as well as the gene mutations. The teacher reflected good content knowledge and he was also able to contextualise the lesson by using COVID-19 as an example as he was teaching the topic of mutation. However, at times it seemed like the learners were challenging him as he deferred some of the questions to the coming lesson or he would say the question was unrelated to the topic. Furthermore, there were no elements of abstraction, but the connections with real-world phenomena were explored and valued when the learners raised the misconceptions that were held by their community regarding COVID-19.

Participant 004: The teacher was able to use concepts, such as the types of neurons axons, stimuli and how to identify unipolar, bipolar, and multipolar neurons and transmitters, which were pertinent to the topic. The teacher went as far as talking about the axons, the transmitters, and the impulses because she was teaching about the nervous system. She did not use the chalkboard to teach, rather she preferred engaging with the learners. Her content knowledge was evident as she encouraged the learners to use multiple books for study and references. This allowed the learners to learn from each other and ask questions freely, which promoted a coherent conceptual understanding and reflected the teacher's solid grasp of the subject’s content knowledge that was relevant to the class. There was an element of abstraction and a connection to real-world phenomena where the teacher spoke about how fast impulses are and how a message travels around a human body.

- **Semi-urban setting**

Participant 007: The teacher involved a fundamental concept when she mentioned that the majority of the herbs or traditional medicines work holistically and one of the learners complained about the period it takes to heal using homemade medicine. This was when the lesson was seen to promote a conceptual understanding and the teacher showed content knowledge by requesting the learners to share the concoctions. However, a debate began when the teacher asked how traditional medicines were tested, which led to the learners talking about ancestors thus, the learners' personal beliefs took centre stage. The teacher continued to facilitate the lesson, which reflected that the lesson connected with the real-world phenomena, particularly in the eyes of the learners.

Participant 008: The lesson involved fundamental concepts especially when the teacher asked the learner about the components of photosynthesis after the learners struggled to present the formula on the chalkboard. This also reflected the teacher's grasp of the subject matter content. Thus, one learner said, "*Carbon dioxide is important for the process of photosynthesis*" and the other learners proceeded by stating *"Light from the sun, chlorophyll and others*". The lesson had an element of abstraction when the teacher asked the learners about where photosynthesis was taking place, and it took some time before one learner answered by saying "chloroplast" and this improved the learners' confidence. This was evident when the teacher asked a question, but also miss presented the information related to the question and the learners were quick to rectify the teacher.

- **Urban setting**

Participant 009: The lesson involved the fundamental concepts of photosynthesis, and it appeared as if the learners had a good understanding of the concepts. The lesson promoted conceptual understanding as the teacher spoke about the surface area of the aloe and the role played by the surface area in preserving water. This reflected the solid grasp of the subject matter by the teacher. Although some learners appeared to be unfamiliar with aloe, some learners who grew up in a rural area before they moved to an urban area were able to describe the plant to the confused learners. The element of abstraction and the connection of the real-world phenomena was reflected when the teacher told the learners about the hydrophytes, the mesophytes and the xerophytes (plants) as well as the role played by the surface area of their leaves during photosynthesis.

Participant 011: The lesson involved the fundamental concepts of the subject, and this was evident when the teacher asked the learners to explain the concepts such as the medulla, the cerebellum, the cerebrum, and the other components. The teacher did reflect a solid grasp of the subject matter content that was related to the lesson. However, there was no evidence of conceptual understanding from the learners because every time the teacher asked questions, the learners resorted to their textbooks. Furthermore, the elements of abstraction were question-based and there was no connection with the real-world phenomena. This was because the learners appeared passive throughout the majority of the lesson. It seemed as if the teacher was not using the relevant teaching method. Most learners consulted their textbooks more than anything.

4.5.2.1 Conclusion drawn from category 2 (Content: Propositional knowledge)

The description above revealed that five teachers out of the possible six attempted learner-centredness in their classroom and this yielded good results as the learners appeared to be comfortable when they determined the direction of the lesson. Although the teachers were able to bring context to their lessons, it was only Participants 007 and 009 who were able to integrate IK into their lessons. This was evident when Participant 007's classrooms discussed the traditional medicines they used for their ailments. Furthermore, Participant 009 brought into his class leaves and allowed the learners to discuss aloe in the classroom. Therefore, even with their concrete content knowledge, it can be said that five participants had successful lessons, but only two were able to integrate IK into their lessons, while only Participant 011's lesson left a lot to be desired. Although the lessons were learner-centred where the teachers mostly used classroom discussions as teaching method, the learners were not afforded the opportunity to be hands-on. Hence, approaches such as Problem-Based learning that allow for laboratory-work and teaching methods such as Jigsaw and De Bono's six thinking hats, which allow for critical engagement were not used.

4.5.3 Category 3: Content: procedural knowledge

This category sought to determine if the learners were able to use various ways to represent phenomena and if they were allowed to make predictions, hypothesise, and test their hypotheses (Piburn et al., 2000). Furthermore, this was used to determine if the learners were engaged in thought-provoking activities that required a critical assessment and if the learners were reflective about their learning as well as if intellectual rigour and challenging of ideas were valued (Piburn et al., 2000). Lastly, Table 4.22 represents the scores obtained by the participants during their classroom pedagogy.

Table 4.22: Content (Procedural knowledge) (Piburn et al., 2000).

Category	**Content** (*Procedural knowledge*)					
Participant	Item 11	Item 12	Item 13	Item 14	Item 15	Average
002 (Rural)	1	2	3	3	2	2.2
004 (Rural)	1	2	3	3	3	2.4
007 (Semi-urban)	1	1	3	3	3	2.2
008 (Semi-urban)	3	3	3	4	2	3
009 (Urban)	3	3	3	4	3	3.2
011 (Urban)	0	0	2	3	1	1.2

[**KEY: 0** = never occurred; 4 = very descriptive; Item 11 = using varied models; Item 12 = learning making predictions; Item 13 = learners are actively engaged; Item 14 = learners were reflective; Item 15 = valuing intellectual rigour]

From Table 4.22, it can be seen that the participants (002 and 004) had averages of 2.2 and 2.4 out of the possible perfect 4, while Participants 007 and 008 produced an average score of 2.2 and 3. Furthermore, Participants 009 and 011 produced average scores of 3.2 and 1.2, respectively. The two aspects that stood out of the data above were that only one participant (011 from the urban setting) out of the six participants had the lowest average score (1.2) which suggested that his procedural content knowledge left a lot to be desired. On the other hand, Participant 009 from the same setting obtained an average score (3.2) that suggested that his procedural content knowledge was well reflected than any other participants (002, 004, 007 and 008 from rural and semi-urban, respectively). In other words, the average scores (1.2 and 3.2) reflected that the participants (009 and 011) from the same setting had contradictory levels of procedural content knowledge.

In Table 4.22, two participants (002 and 004) scored an average of 2.2 and 2.4 out of a perfect score of 4, while Participants 007 and 008 had an average score of 2.2 and 3. Additionally, Participants 009 and 011 obtained average scores of 3.2 and 1.2, respectively. The data reveals that only Participant 011, who was from an urban setting, had the lowest average score (1.2), thereby indicating poor procedural content knowledge. However, Participant 009, also from the same setting, obtained an average score of 3.2, which suggested better procedural content knowledge than any other participant (002, 004, 007, and 008 from rural and semi-urban areas). In summary, the average scores of 1.2 and 3.2 show that the participants (009 and 011) from the same setting had conflicting levels of procedural content knowledge.

- **Rural setting**

Participant 002: The learners had their textbooks, as such most of the drawings the teacher made on the board were taken from the textbooks. The learners predicted and informally estimated that a sudden change in chromosome 21 would impact the traits of the offspring. Furthermore, the learners were engaged in thought-provoking discussions, and this was evident when they brought up the issue of COVID-19 and the misconceptions around it, particularly by the surrounding community. The learners were reflective about their learning, and this was evident when some learners did not know which pair of chromosomes determined the character of the offspring. Lastly, the challenge of ideas was valued as some learners questioned the integrity of some pharmaceutical companies about the safety of vaccines.

Participant 004: A group of learners reflect a good level of knowledge regarding the different types of neurons such as the connector neurons, the multipolar neurons as well as the bipolar sensory neurons. The learners had difficulty distinguishing between the unipolar, the bipolar, and the multipolar neurons. The learners proposed that the positioning of the nucleus in the neurons was the differentiating factor between the different neurons. The learners eventually got the opportunity to reflect on their level of understanding of the concepts, but the understanding left more questions than answers. The teacher intervened by allowing the other groups of learners to explain how they can identify the different types of neurons by asking them to discuss the characteristics of types of neurons and this encouraged confused learners to reflect on their learning.

- **Semi-urban setting**

Participant 007: The learner did not use a variety of means to represent phenomena, instead the lesson was centred on the engagement among the learners and the teacher. Furthermore, the learners never had an opportunity to test their predictions or hypotheses and the learners were engaged in thought-provoking sessions that involved critical thinking among the learners. This was evident when the learners debated about how the herbs are not to be trusted since they have not been laboratory tested. However, one learner asked this question, *"If home remedies are not to be tested, then my question is how our grandparents were surviving using these herbs before these modern medicines were invented if we say they cannot be trusted?"* The debate among the learners continued.

Participant 008: The learners were involved in graphs, and they were allowed to make predictions, and this was evident when the learners were given activities on a printed page. The activity required the learners to plot graphs about the rate of photosynthesis and the absence of light. The learners were required to identify data that would be suitable to plot on the x-axis and on the y-axis which was thought-provoking to some of the learners and the activity allowed some of the learners to reflect on their learning.

This was evident when some learners confused the plot of the y-axis and the x-axis data, but it was eventually clarified, and the teacher continued facilitating.

- **Urban setting**

Participant 009: The teacher provided each learner with a green leaf because the topic that was being taught was photosynthesis. The teacher used the structure of the leaf to engage the learners about the factors affecting photosynthesis. The factors that were discussed were both internal and external. Although the learners were given textbooks during the activity, their focus appeared to be more on attempting to answer the questions and referring to the textbook thereafter. The activity was thought-provoking, and it allowed the learners to make predictions and hypothesise where those that struggled were able to reflect on their learning through the help of the other learners.

Participant 011: The learners did not have the opportunity to a variety of material to represent phenomena, nor were they able to make predictions, because they resorted to note-taking and listening to the teacher as he was teaching. Furthermore, due to the teacher-centred approach that was used by the teacher, the learners could not engage in a thought provocative activity or even be reflective about their learning.

4.5.3.1 Conclusion drawn from category 3 (Content: Procedural knowledge)

The description above revealed that although some learners struggled to understand some concepts, the teachers were able to use the other learners in the classroom to alleviate the learners' misconceptions. This was evident in Participant's 004 classroom when the learners could not identify the different types of neurons. Furthermore, the majority of the teachers succeeded in helping the learners to discuss, and to bring context to their learning and it allowed for reflection in their learning. However, in Participant 011's classroom, the learners were not able to reflect on their learning, because the lesson was more teacher-centred and the learners relied heavily on their textbooks.

The aforementioned description indicated that certain learners faced difficulties comprehending specific concepts, but the teachers managed to employ the other learners in the classroom to alleviate these misunderstandings. This was evident in the classroom of Participant 004 when the learners struggled to differentiate between the different types of neurons. Furthermore, the majority of the teachers successfully aided and scaffolded the learners in discussing and contextualising their learning, while also facilitating reflection. However, in the classroom of Participant 011, the learners were unable to reflect on their learning due to the lesson being heavily teacher-centred and relying heavily on textbooks.

4.5.4 Category 4: Classroom Culture: Communicative indicators

This category focused on the learners' communication of their ideas among each other's through various media and determine if the teacher was able to pose questions that trigger different ways of thinking from the learners (Piburn et al., 2000). Furthermore, the category intended to determine if there was an interaction specifically among the learners and if the learners' questions determined the direction of the lesson with respect towards the other learners (Piburn et al., 2000). Lastly, Table 4.23 represents the scores that were obtained by the participants during their classroom pedagogy.

Table 4.23: Classroom culture (Communicative indicators) (Piburn et al., 2000).

Category	**Classroom culture** (*Communicative indicators*)					
Participant	Item 16	Item 17	Item 18	Item 19	Item 20	Average
002 (Rural)	3	3	2	4	4	3.2
004 (Rural)	2	3	3	3	3	2.8
007 (Semi-urban)	3	2	2	3	2	2.4
008 (Semi-urban)	3	4	3	3	3	3.2
009 (Urban)	3	4	4	3	3	3.4
011 (Urban)	0	1	0	0	0	0.2

[**KEY:** 0 = never occurred; 4 = very descriptive; Item 16 = communication of ideas; Item 17 = triggering divergent thinking modes; Item 18 = learner to learner interaction; Item 19 = learner centred lesson; Item 20 = climate of respect to opinions]

From Table 4.23, it can be seen that the Participants (002 and 004) had an average of 3.2 and 2.8 out of the possible perfect 4, while Participants (007 and 008) produced an average score of 2.4 and 3.2. Furthermore, Participants (009 and 011) produced average scores of 3.4 and 0.2, respectively. The two aspects that stood out of the data above were that only one participant (011 from the urban setting) out of the six participants had the lowest average score (0.2) which suggested his classroom culture in terms of communication left a lot to be desired in class. On the other hand, Participant 009 from the same setting obtained an average score (3.2) that suggested that his influence on classroom culture was well reflected than any other participants (002, 004, 007 and 008 from rural and semi-urban, respectively). In other words, the average scores (1.2 and 3.2) reflected that the participants (009 and 011) from the same setting had a contradictory influence on classroom culture in terms of communication in their respective classrooms.

- **Rural setting**

Participant 002: The classroom culture was an interactive culture which allowed for an effective classroom discourse between the learners and the teacher, and the learners were allowed to take the teacher back when they felt like they were lost. Furthermore, the lesson was more learner-centred and learning-oriented. The proportion of learner talk was not high, especially the learner-to-learner, this was because the teacher was viewed as someone who provides direction for the lesson, and he used the learners' questions to guide the lesson.

Participant 004: The learners were given the latitude to discuss the ideas behind the concept that was discussed, although most of the learners reflected a few misconceptions regarding the topic. The misconceptions (how to identify the unipolar, bipolar, and multipolar neurons) that were held by the learners were visible to the teacher to address. The classroom culture allowed learners to make mistakes and the teacher, or the other learners were able to assist some of the learners. The teacher did address the misconceptions of the learners, by involving the other learners to provide characteristics of the neurons.

- **Semi-urban setting**

Participant 007: The classroom culture was one that allows for engaging discourse between the learners and the teacher. The teacher continued to encourage engagement amongst the learners. This was reflected when the learners shared their different beliefs and they appeared to have a high conviction about their beliefs. The teacher's questions triggered divergent modes of thinking and the high proportion of learner engagement was reflected. This was evident when the teacher allowed the learners to share their beliefs regarding medicines and most learners connected the traditional medicines to spirituality and beliefs as some learners argued that medicines are wisdom from the ancestors.

Participant 008: The classroom culture was learner-centred and there seemed to be a common respect amongst the learners and the teacher provided a safe space for the learners to express thoughts. The teacher asked the learners questions that seemed to be challenging to the learners and in an attempt to answer the questions, the learners worked together as the teacher facilitated. The teacher attempted to contextualise the lesson by using the surrounding environment to contextualise her questions. The learners' engagement determined the focus and the direction of the lesson, and the teacher continued to facilitate the lesson which encouraged respect among the learners.

- **Urban setting**

Participant 009: The classroom culture was learning-centred, where the learners seemed to be helping one another. The learners had varying socio-environmental backgrounds as such, it seemed like they had realised that they needed each other. This was seen when the teacher spoke about the xerophytes and the other learners had to get help from the others who were familiar with such plants. Lastly, the teacher gave an activity that required the learners to submit individually, but the learners worked together so that they may be able to individually make a comprehensive submission.

Participant 011: The questions that arose from the session were when the teacher asked the learners if they understood and the learners said that they understood, but the learners referred a lot to the textbooks. Therefore, the classroom culture was more teacher-centred and the teacher could not seem to be able to connect with the learners.

4.5.4.1 Conclusion drawn from category 4 (Classroom Culture: communicative indicators)

The description above showed that although the teachers used different teaching methods, five of them (Participants 002, 004, 007, 008 and 009, respectively) encouraged active learner participation. Some encouraged the learners to work in groups, but write activities individually (Participant 009), some encouraged the learners to work in pairs (Participant 004) and the others encouraged classroom discussion (Participants 002 and 007). Furthermore, some encouraged the learners to go and share their answers in front of the whole class (Participant 8). It can be said that a learner-centred lesson encourages the teacher to ask thought-provoking questions with learners fully participating but not hands-on, while the lesson that was drawn from Participant 011, where the learners remained passive.

4.5.5 Category 5: Classroom culture: Learner/teacher relationship

This category sought to determine if the teacher encouraged and valued active participation, the generation of conjectures, the discoveries of alternate solutions and the various ways of interpreting evidence by the learners (Piburn et al., 2000). Furthermore, the category focused on the teacher's ability to be patient with the learners and if he acted as a resourceful person who supported and enhanced the learners' investigations (Piburn et al., 2000). Lastly, the category sought to determine if the teacher was able to play the role of a listener and Table 4.24 represents the scores that were obtained by the participants during their classroom pedagogy.

Table 4.24: Classroom culture (Learner/ Teacher relationship) (Piburn et al., 2000).

Category	**Classroom culture** (*Learner/ Teacher relationship*)					
Participant	Item 21	Item 22	Item 23	Item 24	Item 25	Average
002 (Rural)	4	4	4	4	4	4
004 (Rural)	3	3	3	3	3	3
007 (Semi-urban)	3	2	3	3	3	2.8
008 (Semi-urban)	2	2	3	4	3	2.8
009 (Urban)	3	3	3	4	4	3.4
011 (Urban)	2	1	2	2	0	1.4

[**KEY:** 0 = never occurred; 4 = very descriptive; Item 21 = active participation; Item 22 = encouraging learners to generate conjecture; Item 23 = teacher is patient with learners; Item 24 = resourceful teacher; Item 25 = teacher acted as a listener]

From Table 4.24, it can be seen that the participants (002 and 004) had an average of 4 and 3, while both Participants 007 and 008 produced an average score of 2.8. Furthermore, Participants 009 and 011 produced average scores of 3.4 and 1.4, respectively. The three aspects that stood out of the data above were that only one participant (011 from the urban setting) out of the six participants had the lowest average score (1.4) that suggested that his classroom culture in terms of learner and teacher communication left a lot to be desired in class. On the other hand, for the first time, Participant 002 obtained a perfectly average score (4) that suggested that his influence on classroom culture in terms of learner and teacher communication was well reflected than in any other participants (004, 007 and 009). Lastly, Participant 009 for the first time scored the second highest with Participant 011 consistently scoring the lowest average.

- **Rural setting**

Participant 002: The learners participated by answering the questions when the teacher asked. Furthermore, the learners appeared to be comfortable around the teacher and they were able to ask questions. At times some of the learners would remind the teacher where and when they thought he missed something. The teacher was not as patient, particularly when they asked him questions that he was not sure how to answer, hence he was not as resourceful as a teacher ought to be.

Participant 004: The teacher allowed for the learner discussion and the learners were able to ask the teacher some questions when they were struggling with a few concepts. The teacher encouraged the learners to go to the board to share their ideas. This reflected the teacher's patience with the learners and her ability to identify the misconceptions emanating from the learners and take initiative by involving other learners. Hence, she was resourceful and supportive of the learners as a good listener.

- **Semi-urban setting**

Participant 007: The teacher provided the learners with opportunities to provide answers using their context due to the nature of the topic discussed in the classroom. The teacher asked questions where the learners were given a chance to discuss amongst themselves and provided answers that were more of a group answer than an individual group. Therefore, the teacher-learner relationship was more in the best interest of the learners. Hence, patience and resourcefulness were evident from the teacher as she continued to facilitate the lesson.

Participant 008: The teacher and the learners reflected a mutual relationship where the teacher provided the learners with a safe space and environment to participate and raise their concerns. The teacher allowed the learners to make mistakes on the board and allowed the others to help to rectify the learners and conclude by providing a meaningful context to alleviate some of the learners' misconceptions. This reflected patience and resourcefulness from the teacher.

- **Urban setting**

Participant 009: The teacher allowed for an environment where there was active learner participation and he also tried to provide context which would be helpful to almost the entire class. The learners were afforded opportunities to ask questions where and when necessary. The relationship appeared to be more swayed by the learners' interests.

Participant 011: The learners rarely attempted to engage the teacher or talk amongst themselves except when the teacher was giving instruction, such as asking the learners to refer to their textbooks. In most cases, the learners would refer to their textbooks to confirm the teacher's explanation. The relationship was rather more swayed to the teacher's interest.

4.5.5.1 Conclusion drawn from category 5 (Classroom Culture: learner/teacher relationship)

The description above reflected the teachers who were patient with their learners and those were also resourceful, and they allowed the learners to engage with each other with respect. Some learners shared the recipes of their home remedies, while the others described what aloe is and what it looks like compared to other plants. The others shared about the distrust the community have towards vaccines. Hence, the relationship between the participants and their learners reflected mutual respect. Although Participant 011's classroom appeared to be the only class that did not achieve the objective, this can be attributed to the learning method that was more teacher-centred used by the participant.

4.5.6 Overall conclusion about the classroom observations

The classroom observations of the participants revealed that the participants approached their lessons differently as others used baseline assessment and others just introduced their topics. There were five classrooms whose learners engaged successfully because of the teaching methods that were used by the participants. Furthermore, the observation revealed that although six teachers appeared to have a good grasp of the content knowledge it was only five participants who successfully delivered their lessons because of the teaching method they used. The data also revealed that the participants used a learner-centred approach without being hands-on or using teaching aids to address both cognitive and psychomotor domains and they were successful in achieving their lesson outcomes. It was only Participant 007 from the semi-urban and Participant 009 from the urban settings who were able to integrate IK in their lessons. Lastly, Participant 011 appeared to have failed to achieve the lesson objectives because of the teaching method that was used where the learners were passive and textbook reliant.

It was observed that the participants approached their lectures in various ways. Some used baseline assessments, while others just introduced their themes. Five of the classrooms examined employed excellent teaching strategies, resulting in engaged learners. Despite the fact that six teachers displayed high material understanding, only five participants delivered their lectures successfully owing to their effective teaching strategies. Participants that adopted a learner-centred approach met their lesson objectives, however only Participants 007 from a semi-urban context and Participant 009 from an urban setting incorporated IK into their teaching. Unfortunately, owing to a teaching technique that produced passive and textbook-dependent learners, Participant 011 failed to meet their lesson objectives.

4.6 Presentation and analysis of data collected from the semi-structured interviews

After the observations of each teacher as described above, semi-structured interviews were carried out with the same six teachers. Each teacher was asked five questions, and these questions were prompted by what transpired in the classroom. In other words, the interviews sought to determine if the participating teachers were aware of their classroom surroundings and if they were reflective about their classroom pedagogy. Each question that was asked is followed by the participating teachers' responses and the responses are presented based on the participants' setting. This means that the first two responses are from Participants 002 and 004 from the rural and then semi-urban settings (007 and 008) and followed by Participants 009 and 011's responses from the urban setting. Furthermore, after the responses to each question, I present a brief analysis of the participating teachers' responses. Lastly, after the interviews, I provided an overall analysis of the responses. The participants' actual words as they answer the questions are written in verbatim on the left and summarised using In-vivo coding on the right with the keys such as 'Participant 002' which means **P^{002}**.

4.6.1 Question 1: In your view of the lesson, would you say the overall lesson was a success? Why?

Table 4.25: The participating teachers' responses (Author's own creation).

Actual Words	Codes
Participant 002: *"The lesson was not as good as I wanted it to be. I wish I had some teaching aids like a chart and* Deoxyribonucleic Acid *(DNA) model so that more learning and understanding from the learners can occur".*	**P^{002}**LESSON NEEDED "TEACHING AIDS"
Participant 004: *"Yes it was, even though, I didn't reach the point of asking questions, because normally I reserve the last 15 minutes of the lesson to ask questions and eventually give the learners classwork or homework. The last 15 minutes of the lesson are very helpful in such a way that it helps me to address misconceptions reflected by the learners. In a nutshell".*	**P^{004}**THE NEED FOR MORE TIME
Participant 007: *"I don't think it was a successful lesson, because of the constant disturbances from the learners who constantly faint in the classroom. This makes it difficult to trace your position as the teacher and gauge the learners' position. This interrupts my style of delivery when I have to attend to the learner who fainted. I think even the learners know deep down that we are going to be interrupted, thus there is no proper learning taking place".*	**P^{007}**CONSTANT CLASSROOM DISTURBANCE
Participant 008: "*Today is a blessing in disguise that the printing machine didn't work because in most cases I am the one on the chalkboard trying to explain. However, today due to the printer not working I was able to give the learners a platform, this allowed the learners to be able to learn the content better. In other lessons, I would feel like talking alone, but today's participation was top-notch*".	**P^{008}**VISIBLE LEARNER PARTICIPATION
Participant 009: "*I am happy with the way it went, whether it was a success I will first have to look at the feedback of the classwork. However, the learners' responses from the introduction and how they remembered what we did in the previous lesson, to me that was a reflection that the lesson might be a success*".	**P^{009}**LEARNER PARTICIPATION CONSTRIBUTED TO THE SUCCESS OF THE LESSON
Participant 011: *"So far I am unable to gauge the success of the lesson because I did more of the introductory part of the topic that I wanted to teach. Secondly, we must understand that I have grouped the two grade 12s. In other words, my lesson today was more focused on the concepts of the topic than anything else".*	**P^{011}**UNABLE TO REFLECT

4.6.1.1 A brief analysis of the participating teachers' responses per setting

- **Rural setting**

The two participants (**P^{002}** and **P^{004}**) from this setting reflected slight dissatisfaction with how their lessons penned out. The **P^{002}** wondered how the lesson would have been had he used teaching aids, while **P^{004}** wished for more time so that she may reinforce the concepts she was teaching. The dissatisfaction from both teachers reflects poor planning and poor time management from both teachers because neither of the teachers had any evidence that they had lesson plans with them.

- **Semi-urban setting**

The two participants (**P^{007}** and **P^{008}**) from this setting reflected rather two contradictory reflections. The **P^{007}**'s classroom was mired and marred with disturbances, as such after each disturbance, the teacher had to retrace her steps, and reflected dissatisfaction with how her lesson turned out. On the other hand, **P^{008}** was happy with how her lesson turned out. Her satisfaction stems from the manner in which learner participation took centre stage during her lesson, especially the visible participation emanating from the male learners.

- **Urban setting**

The two participants (**P^{009}** and **P^{011}**) from the urban setting reflected two distinct responses where one was able to reflect on how his lesson turned out while the other could not reflect. This was evident when **P^{009}** was happy with how the learners participated, which he believed was the reason he felt his lesson was successful. On the other hand, **P^{011}** claimed that it was difficult for him to determine the success or the lesson or the lack thereof, because the learners have not yet submitted the activity he gave them. The teacher's inability to reflect on the lesson is rather a poor teaching identity.

4.6.2 Question 2: Are you satisfied with the way you introduced your lesson? Why?

Table 4.26: The participating teachers' responses ((Author's own creation).

Actual Words	**Codes**
Participant 002: *"I am happy with the way I introduced the lesson. Every day when I go to the class, the first thing I do is, ask the learners question regarding the previous lesson. This helps me to gauge the learners' level of knowledge and also know where they are concerning the topic at hand".*	**P⁰⁰²**FREQUENT APPLICATION OF BASELINE ASSESSMENT
Participant 004: "Yes, I am happy with the way I introduced the lesson".	**P⁰⁰⁴**SENSE OF SATISFACTION
Participant 007: *"I am not satisfied with the introduction of the lesson altogether, because of reasons shared from the previous question".*	**P⁰⁰⁷**SENSE OF DISATISFACTION DUE TO CLASSROOM DISRUPTIONS
Participant 008: *"I think I am [satisfied] because today I felt that I had a very fruitful lesson. The learners participated and the way they participated reflected another element of understanding from their side. Remember, I am repeating this topic with this class, now it shows me that I might have not done justice to these learners the first time I introduced this topic".*	**P⁰⁰⁸**SENSE OF SATISFACTION DUE TO LEARNER PARTICIPATION
Participant 009: *"Yes, I am very satisfied. You could see that the learners were more interested in helping each other than being textbook oriented".*	**P⁰⁰⁹**SENSE OF SATISFACTION DUE TO LEARNER-TO-LEARNER INTERACTION
Participant 011: *"Yes, I am satisfied with how I presented the lesson because the learners responded well, and I was able to cover the scope that I intended to cover today".*	**P⁰¹¹**SENSE OF SATISFACTION BECAUSE SCOPE FOR THE DAY WAS COVERED

4.6.2.1 A brief analysis of the participating teachers' responses per setting

- **Rural setting**

The two participants (**P⁰⁰²** and **P⁰⁰⁴**) were both satisfied with how they introduced their lessons. Participant 002 thought his frequent application of baseline assessment helped him to gauge the learners' content knowledge position, which played a significant role in engaging the learners. Although Participant 004 was pleased with her lesson, she chose to provide no reason for her claim.

- **Semi-urban setting**

The two participants (P^{007} and P^{008}) reflected contradictory sentiments with regards to how they introduced their lessons. P^{007} highlighted that due to these continuous disturbances, she felt that once the lesson is interrupted the whole lesson is ruined. On the other hand, P[008] felt that the lesson was fruitful and how she introduced the lesson contributed to the success of the lesson.

- **Urban setting**

The two participants (**P[009]** and **P[011]**) reflected a sense of satisfaction with regards to how they introduced their lessons, and their satisfaction was individually based on different reasons. **P[009]** was pleased with how he introduced the lesson, because that led to significant evidence of learner-to-learner interaction and participation. On the other hand, **P[011]** was happy with how he introduced the lesson, because he was able to complete what he intended to teach for that day.

4.6.3 Question 3: Are you satisfied with your interaction with the learners? Why?

Table 4.27: The participating teachers' responses (Author's own creation).

Actual Words	Codes
Participant 002: *"Yes, I am happy with learner interaction, but as a teacher it is important to always be prepared because the types of questions these learners ask are very tricky. That is why you saw that some questions I brushed aside so that I do not embarrass myself".*	**P⁰⁰²**SENSE OF SATISFACTION WITH LEARNERS' INTERACTION, BUT LACK OF CONFIDENT WITH CONTENT KNOWLEDGE
Participant 004: *"Yes, because in most cases I would ask a question and say to the learners, talk to your friend and what I mostly do is move around and ask these learners individually if they understand. By doing this, I can give each learner the attention required, unlike standing in from of the class where I might not be able to tell if the learners understand or not".*	**P⁰⁰⁴**SENSE OF SATISFACTION WITH LEARNER-TO-LEARNER INTERACTION
Participant 007: *"Yes I am satisfied with learner interaction, but it is worth noting that this is very dependent on the type of topic being taught. There are certain topics where the learners' drawback, like today's topic, most learners were excited and wanted to participate. In other words, the learners' ability to participate and interact in a particular topic is dependent on the learners' ability to relate to it (Contextualisation)".*	**P⁰⁰⁷**SENSE OF SATIFACTION WITH LEARNER-TO-LEARNER INTERACTION, BUT INTERACTION IS TOPIC DEPENDENT
Participant 008: *"Today I have never been this happy, about the way the learners interacted, especially the boys. They participated in such a way that I never thought they would, particularly since they normally keep very quiet in the classroom as if they depend on ESKOM".*	**P⁰⁰⁸**HAPPY WITH LEARNER INTERACTION, ESPECIALLY MALE LEARNERS
Participant 009: *"Yes, I asked about the dark phase of photosynthesis, and they were answering. This was done to assess them using baseline assessment so that I may know where they are and where I can start, and you saw that they were answering".*	**P⁰⁰⁹**HAPPY WITH LEARNER INTERACTION AND ANSWERS THEY PROVIDE
Participant 011: *"In my opinion, learner interaction is determined by us teachers and today I am not happy with the level of engagement in my classroom, but I know that this happened because there was a visitor in my class. You can see that they were shy, do you remember when I was talking about corpus callosum from grade 11? There was a learner who quoted it, but at the same time hid himself so that he is not seen".*	**P⁰¹¹**NOT HAPPY WITH LEARNER INTERACTION

4.6.3.1 A brief analysis of the participating teachers' responses

- **Rural setting**

The two participants (**P⁰⁰²** and **P⁰⁰⁴**) reflected that they were satisfied with how they interacted with their learners. Although **P⁰⁰²** was satisfied with his interaction with the learners, he was worried about his ability to provide the learners with correct answers, because he had doubts with his content knowledge. Hence, he frequently brushed aside or ignored the learners' questions at times. As for **P⁰⁰⁴**, she was happy with how the learners interacted and she claimed to have encouraged it through her teaching method as she frequently encouraged the learners to talk among themselves.

- **Semi-urban setting**

The two participants (**P**^{007} and **P**^{008}) reflected a sense of satisfaction with regards to how the learners interacted in their classroom. However, despite her satisfaction with learner interaction in her class, P^{007} claimed that learner interaction and participation is often reliant on the topic taught. Such a claim seems to suggest that a teacher plays no role on how the lesson turns out and as such the claim may be untrue. On the other hand, **P**^{008}, was even more pleased that her male learners played a significant role for learner interaction during her lesson.

- **Urban setting**

The two participants (**P**^{009} and **P**^{011}) from the urban setting reflect contradictory sentiments with regard to learner interaction. **P**^{009} was not only happy with learner interaction, but he also expressed his excitement about how his learners were able to provide quality answers. On the other hand, **P**^{011} was not pleased with the lack of learner interaction in his class, to some extent he insinuated that the presence of the researcher may have contributed to this lack of interaction and participation.

4.6.4 Question 4: Would you say you used a relevant teaching method for this class? Why?

Table 4.28: The participating teachers' responses (Author's own creation).

Actual Words	Codes
Participant 002: *"What I can say is, every teaching method has got a positive and a negative impact depending on the topic you are teaching on that day. Normally, every day after teaching the learners, the learners will after study sit in groups to discuss what I have taught them, so in this way I think my teaching method is good because it encourages the learners to work together".*	**P^{002}**UNDECISIVE ABOUT WHETHER THE TEACHING METHOD WAS RELEVANT FOR THE LESSON
Participant 004: *"Yes, I think I am using a relevant teaching method. I do not like standing in front of the learners. I enjoy walking around the desks because I get to interact with the learners and make them feel safe enough to ask questions when they do not understand. I know them and I hold them very close to my heart as such for me to tell if they understand, I have to talk to them on a level that appears personal so that they can open up".*	**P^{004}**CONFIDENT ABOUT THE TEACHING METHOD AND ITS IMPACT ON THE LEARNERS
Participant 007: *"No, I think maybe I should have used a different teaching method or even brought in a teaching aid to help make learning more meaningful to the learners".*	**P^{007}**UNHAPPY WITH THE TEACHING METHOD, NEEDED A TEACHING AID
Participant 008: *"Due to the printing machine failing to print the question papers. I had to use improvisation as a teaching method, and it worked for me. I had to think about the question from the top of my head as such a learner was very good".*	**P^{008}**HAPPY WITH THE TEACHING METHOD
Participant 009: *"That one is going to be difficult to answer, remember, first there has to be an introduction, and then I asked questions. COVID-19 prevented us from allowing learners to work as groups as such it is difficult to tell of the position which we are supposed to be in concerning teaching methods. I would have preferred to group them and give them a leaf in groups and request them to discuss".*	**P^{009}**NOT HAPPY WITH TEACHING METHOD
Participant 011: *"I am happy with the method because we are still on the introductory part of the topic and again some of these teaching methods are very much dependent on the classroom situation, such as the type of learners as well as the size of the class".*	**P^{011}** HAPPY WITH THE TEACHING METHOD "DEPENDENCE ON CLASSROOM SITUATION"

4.6.4.1 A brief analysis of the participating teachers' responses per setting

- **Rural setting**

The two participants (**P^{002}** and **P^{004}**) reflected contrasting responses when asked about if they thought they used the relevant teaching method. **P^{002}** was unable to provide a definite response, where he cautioned that any teaching method has its strength and weaknesses. However, **P^{004}** reflected satisfaction with the teaching method and the impact it had on the learners. The participant claimed that her teaching method allowed her to afford each learner the time they may need for clarity.

- **Semi-urban setting**

The two participants (**P^{007}** and **P^{008}**) also highlighted contrasting responses with regards to the teaching method. **P^{007}** was unhappy with the teaching method she used and also felt that she could have used aids to help the learners to make meaning as they learn. However, **P^{008}** was pleased with her teaching method because it encouraged more learner participant.

- **Urban setting**

The two participants (**P^{009}** and **P^{011}**) also highlighted contrasting responses with regards to the teaching method. **P^{009}** was not pleased with his teaching method and more importantly highlighted that although the learners worked in pairs, he would have liked it if they had worked in groups, but due to the COVID-19 rules there was nothing he could do. On the other hand, **P^{011}** was rather happy with his choice of teaching method, highlighted that the type of teaching method is dependent on the classroom situation including the type of learners and the size of the class.

4.6.5 Question 5: If there were some things you could change about your lesson, what would it be and why?

Table 4.29: The participating teachers' responses (Author's own creation).

Actual Words	Codes
Participant 002: *"Yes, there is something that I wish I could change, particularly, the types of equipment when teaching a topic like this, you wish you could at least bring along a projector, but will waste my time, especially every time I go to the class you first have to chase the other teacher out".*	**P^{002}**WISHED TO HAVE HAD TEACHING AIDS
Participant 004: *"Nothing, except for time. It [needed more to conclude the lesson] is never enough".*	**P^{004}**"NEEDED MORE TIME TO CONCLUDE THE LESSON"
Participant 007: *"Eish, a lot, a lot, I wish I could have brought in a teaching aid, the issue of a teaching aid could have drastically improved my lesson".*	**P^{007}**WISHED TO HAVE HAD TEACHING AIDS
Participant 008: "*No, I would not change anything for this lesson, this is because you could see the learners' curiosity, and I mean the break siren had gone off, but the learners did not want to go out because they too enjoyed the lesson".*	**P^{008}**SENSE OF SATISFACTION
Participant 009: *"I wish I could have changed the lesson so that I could supplement my explanations by adding the aspects of xerophytes, mesophytes and hydrophytes. I wish I could have brought in the specimen of aloe in the classroom just for learners to compare".*	**P^{009}**SENSE OF DISATISFACTION
Participant 011: *"I think I have a lot of things that I think I have to change. I think my teaching method does not cater for the needs of all the learners because as you teach you can see that some learners are in the dark. However, these learners are in the dark, I will help them tomorrow morning alone, because during the normal period due, to overcrowding which limits movement in the classroom, I am unable to help them".*	**P^{0011}**CONFLICTED ABOUT THE TEACHING METHOD AND WISH TO HAVE DONE MORE FOR THE LEARNERS

4.6.5.1 A brief analysis of the participating teachers' responses

- **Rural setting**

The two participants (**P^{002}** and **P^{004}**) from the rural setting have both highlighted that they were not entirely satisfied with some of the aspects of their lessons. **P^{002}** felt that his lesson would have been better had he used some teaching aids. On the other hand, **P^{004}** was pleased with her lesson, but wished to have had more time so that she may reinforce her lesson. The outstanding commonality between the two teachers is poor planning and poor time management.

- **Semi-urban setting**

The two participants (**P^{007}** and **P^{008}**) reflected contrasting responses regarding what they wish to have changed in their lessons. **P^{007}** wished to have brought teaching aids to assist learners with their learning. On the other hand, **P^{008}** was satisfied with how the lesson turned out and she stated that she would not want to change anything, as a result exposing P^{007}'s poor planning.

- **Urban setting**

The two participants (**P^{009}** and **P^{011}**) reflected similar sentiments about what they wished to have changed with regards to their lessons. **P^{009}** was not pleased with his lesson because he felt that he could have provided better and more relevant examples in his lesson. On the other hand, **P^{011}** was more conflicted about the teaching method because of what it offered to his learners during the lesson. The teacher was more concerned about the learners and what they may failed to learn during the lesson.

4.6.6 The overall analysis of data gathered from semi-structured interviews

It is worth noting that all the six participants who were interviewed, each had a minimum of three years teaching experience, as such it was expected that reflection would not be something new to them. However, this was not case as the interviews revealed that the six teachers' classrooms reflected poor planning and poor time management. This was evident from all the participants as none of them produced lesson plans and the responses by **P^{002}** (rural setting) and **P^{007}** (semi-urban setting) who wished to have brought teaching aids into their classrooms. Furthermore, **P^{009}** (urban setting) wished to have had better examples for his lesson to make learning more meaningful, while **P^{004}** (rural setting) wished to have had more time for her lesson.

In addition, the analysis also revealed the participants' abilities towards reflection. This was evident from the responses by **P^{002}** (rural setting) and **P^{011}** (urban setting) who could not determine if the used teaching method was relevant to the topic and determine if the lesson was a good lesson, respectively. Both participants claimed that the success of a teaching method is determined by the type of topic that is being taught. **P^{011}** (urban) claimed that he was happy with the lesson because he was able to cover the scope for the day. This is a classic example of a teacher whose classroom practice is driven by the desire sole purpose is to cover the syllabus or an annual teaching plan where teaching for meaningful learning is not the focal point.

In conclusion, although the participants' responses reflected that they do provide the learners with remedial classes and are considerate of how they wished to have the learners in groups so that they may learn better. It is sufficient to say the intervention had not improved their classroom pedagogy and SDL, because the interviews revealed that they have poor reflective abilities, planning and time management abilities.

4.7 Emerging themes from the holistic analysis and the six teachers from three settings

In this section, I present the themes (deliberations on these themes are presented in the next chapter) that emerged from analysing the data that was drawn from the teachers' compared responses of the VNOIK, the VNOS-D+, the POSTT LFSC and the SDLI post-intervention to decipher the influence of the intervention or the lack thereof. Furthermore, I present the themes that emerged from the six teachers who were observed in their classrooms using the RTOP and later on engaged in semi-structured interviews after the observations. This is an attempt to determine if the intervention influenced their pedagogy and their ability to self-reflect on their practices. The section starts by presenting the holistic themes that emerged and then it presents the emerging themes from the six teachers thereafter.

4.7.1 Emerging themes from the holistic analysis

- The intervention helped the participating teachers by improving their perceptions of the nature of indigenous knowledge.
- The intervention helped the participating teachers by improving their perceptions of the nature of Science.
- The intervention helped the participating teachers by shifting their pedagogical orientation mainly from didactic direct to either guided inquiry or open inquiry.
- There is evidence of a lack of significance or tangible change in the participants' self-directed learning post-intervention
- There was no submission of portfolios by the participating teachers.

4.7.2 Emerging themes from the participating teachers from the three settings

- The intervention helped the participating teachers from all settings by improving their perceptions of the NOIK. However, there were nuances with regards to the teachers' integration of NOIK in their classrooms, hence only two teachers, each from the semi-urban and urban settings were able to integrate NOIK in their classroom.

- The intervention helped the participating teachers from all settings by improving their perceptions of the NOS. However, there were nuances with regard to the teachers integrating the NOS in their classrooms
- There is evidence of poor preparation, poor time management (lack of agency) and poor reflective abilities
- There is no evidence of lesson preparation amongst the participants who were observed in their classrooms post-intervention.

4.8 The second stage of data analysis: Using the CHAT as a lens to zoom into the themes

In this section, the aim was to analyse the data and the findings using the third-generation Cultural Historical Activity Theory (CHAT). Lastly, I look at the data using the interpersonal plane, where they compare three sub-activity systems featuring the Life Sciences teachers from the rural, the semi-urban, and the urban settings. To analyse the findings, I use filters generated from each plane. Filters are defined smaller subsets of a collected set of data selected for viewing or analysis and these filters are generally used to improve data quality (De Cheveigne & Nelken, 2019; Facer, 2018). To start the analysis, I used the CHAT on a personal, institutional and interpersonal planes where four filters, one filter and one filter where generated and used, respectively.

4.8.1 Using the personal plane of CHAT as a lens

The personal plane of CHAT is utilised to observe Activity system A, which represents the Life Sciences teachers' actions during the intervention and Activity system B represents their classroom practice after the intervention (B) (See Figure 4.1). By using the third generation CHAT on a personal plane, I compare the actions of a Life Sciences teacher as the subject and what they should have achieved during the intervention, by juxtaposing the two activity systems.

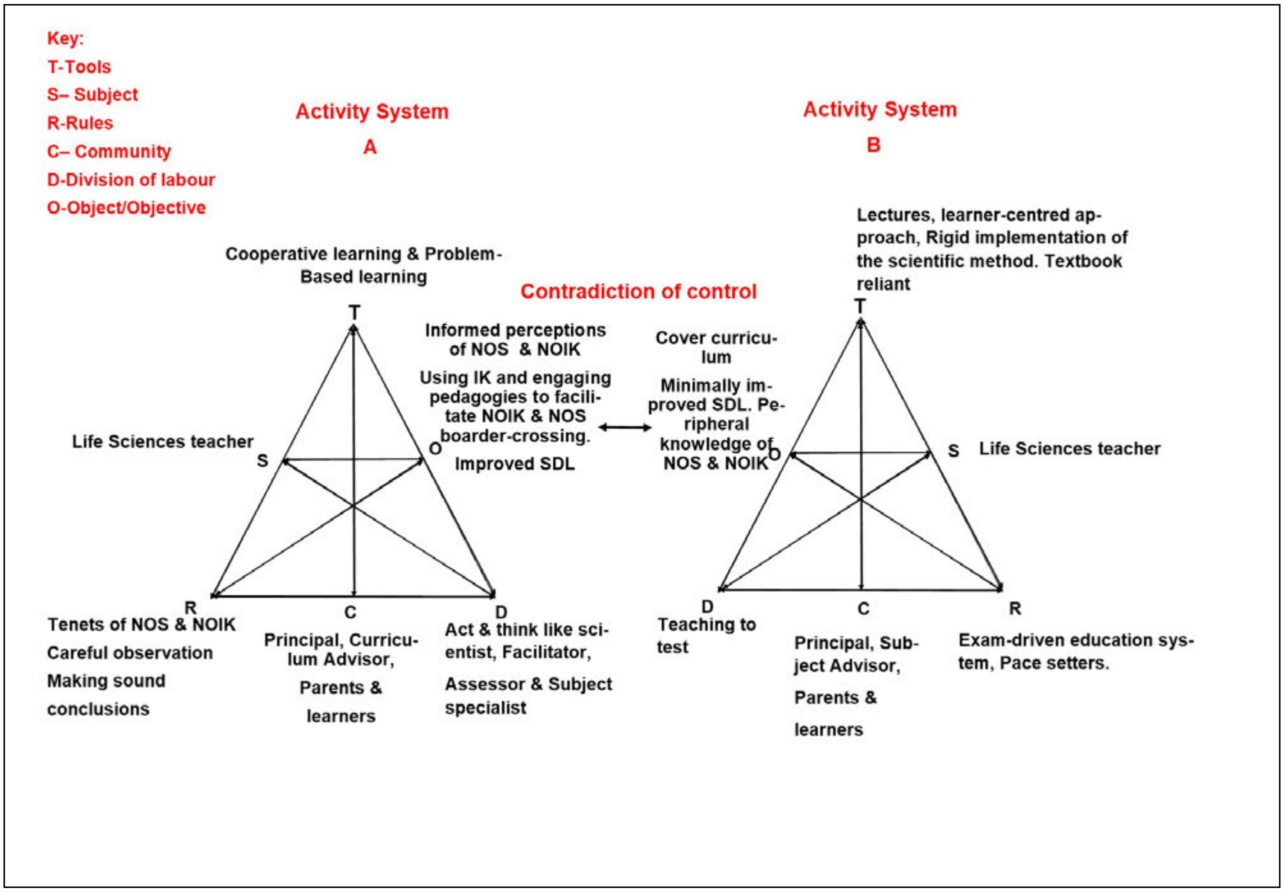

Figure 4.1: Third-generation CHAT reflecting the personal level

The four filters of analysis

- *Improved perceptions of the nature of indigenous knowledge, yet there is minimal ability to integrate it in the post-intervention classroom.*

During the intervention (Activity System A in Figure 4.1), I utilised various tools including laboratory work, problem-based learning, as well as CL, and focused on the process of fermentation, and the Kirby-Bauer technique. De Beer and Mentz (2017) have shown that CL can be a valuable tool for the Life Sciences teachers to integrate IK into their classrooms. Therefore, the goal was to equip the teachers with the necessary skills to effectively integrate IK in their teaching. The first tension emanated from when the teachers were expected to follow the prescribed pacesetter to cover the curriculum (AS B in Figure 4.1). The lessons were learner-centred, but tools such as laboratory work were not used because they are often viewed as ineffective in covering all the necessary content before Grade 12 learners write their trial exams. This was noted by Participants 002, 004 and 008. Some teachers also find that the omission of PBL such as laboratory work are more effective for teaching to the test, rather than for meaningful learning. Although the participating teachers are familiar with the active teaching-learning strategies that allow learners to be hands-on encourage learners to use cognitive and psychomotor domains such as Jigsaw, De Bono's six thinking hats, PBL and Puppetry. This is because they believe that these methods may take longer and may not be as efficient in terms of finishing the curriculum on time when compared to the learner-centred approaches such as classroom discussions that disregard aspects such as laboratory work that encourage learners to be hands-on through the use of learning aids.

These differences emanating from the tools of both the intervention (A in Figure 4.1) and the classroom (B in Figure 4.1) activity systems are seen as a contradiction of control as described by McNeil (2013), which is the result of the tensions arising from the elements of both the activity systems. Another tension emanates from the rules, where the intervention intended for the teacher to teach under the guidance of the tenets of the NOIK, where careful observations and sound conclusions are made. However, in his/her classroom post-intervention, participant 011 was seen as presenting a more exam-driven teaching that is guided by the pressure to complete the syllabus as guided by the pace-setter. According to Warford (2011), these newly trained teachers who intend to preach newly acquired methods learned in their training would see themselves reverting to more mundane teaching methods.

There is a tension between the object (Activity System A in Figure 4.1) and the division of labour (Activity System B in Figure 4.1) where the intended objective is for the teacher to use IK and engaging pedagogies to facilitate the NOIK and the NOS border-crossing. Particularly, that the Life Sciences CAPS document advocates for the integration of IK (South Africa (SA), 2011). However, the teacher seemed to be encouraged by the notion of teaching to test, thereby suggesting a disregard of Bloom's taxonomy which advocates for the development of cognitive and psychomotor domains.

- *Improved perceptions of the nature of Science post-intervention, yet there is a lack of integration in the classroom.*

There is a tension between the rules (Activity System A in Figure 4.1) and the object (Activity System B in Figure 4.1) where the rules intended for the teachers to be guided by the tenets of the NOS, as a careful observer and they make sound conclusions. However, the rules from Activity system B reflect an exam-driven education system that is guided by the demand to complete the syllabus as per the pacesetter. Thus, due to such demand the teachers are not able to operate within the confines of the tenets of the NOS. Furthermore, the teachers are not able to make observations and make sound conclusions, because although learner-centred, the teaching strategies they used are more exams driven than making sound conclusions.

Another tension arises from the division of labour in both Activity system A and Activity system B (Figure 4.1), where Activity system A intended for the teacher to act and think like a scientist. This emanated from the SLP at the ACDB where the teachers were graced with the pleasure of engaging in general sampling and laboratory protocol (the tenets of the natural sciences). However, Activity system B shows that the majority of the teachers have more preference for teaching to test due to the pressure of limited time to prepare for tests. Due to lack of time, the teachers are not able to capacitate the learners with the proper skills, and they are unable to think critically as subscribed by the policy document (SA, 2011).

- *Nuanced Improvement of classroom pedagogy post-intervention*

The tension emanates from the object in Activity system A and the object in Activity system B (Figure 4.1). The object intended for the teachers with an improved pedagogical emphasis is to use IK and engaging pedagogies to facilitate the NOIK and the NOS border-crossing. Where the teachers can connect with the indigenous learners and meet their pedagogical needs by integrating IK where the lessons are presented in a context that makes learning meaningful to the learners. However, the object from Activity system B reflects teachers with peripheral knowledge of the NOS and the NOIK, whose pedagogical strengths are learner-centred inclined. However, they disregard aspects related to learner-centred lesson such as allowing for the lessons to be hands-on and the use of teaching/learning aids that encourage the consideration of cognitive and psychomotor domains Thus, the teacher is unable to cater for and bring context into his/her pedagogy presented to the indigenous learner.

- *Evidence of present self-directed learning, yet there is minimal evidence of improved pedagogy.*

The tension emanating from this theme is drawn from the object from both activity systems in Figure 4.1 where the intervention intended to produce a teacher who would use IK and engaging pedagogies to facilitate the NOIK and the NOS border-crossing. Furthermore, it reflects improved self-directed learning. These aspects would improve the teacher's classroom pedagogy where there is the integration of IK in the Life Sciences classroom. However, the teachers are seen disregarding the informed perceptions of the NOIK and the NOS and resorting to covering the curriculum. Where the teachers reflect peripheral knowledge of the NOS and the NOIK, it reflects the minimal improvement of classroom pedagogy. As such, there seems to be many factors that contribute to a ‘contradiction of control’, the construct of McNeil (2013) referring to a misalignment in the objects of two activity systems. Despite the positive outcomes of the intervention (e.g., teachers having more nuanced views of the NOS and NOIK), there seems to be a “washout effect” in the post-intervention classroom, as a result of systemic tensions.

4.8.2 Using the institutional plane of the CHAT as a lens

According to Mentz and De Beer (2019), an activity system on an institutional plane can represent an entity or entities and in the context of the study, these entities are the two knowledge systems. Using the third-generation CHAT, I compared the NOS as a subject in Activity System C and the NOIK as a subject in Activity System D, where I juxtaposed the two activity systems (Figure 4.2).

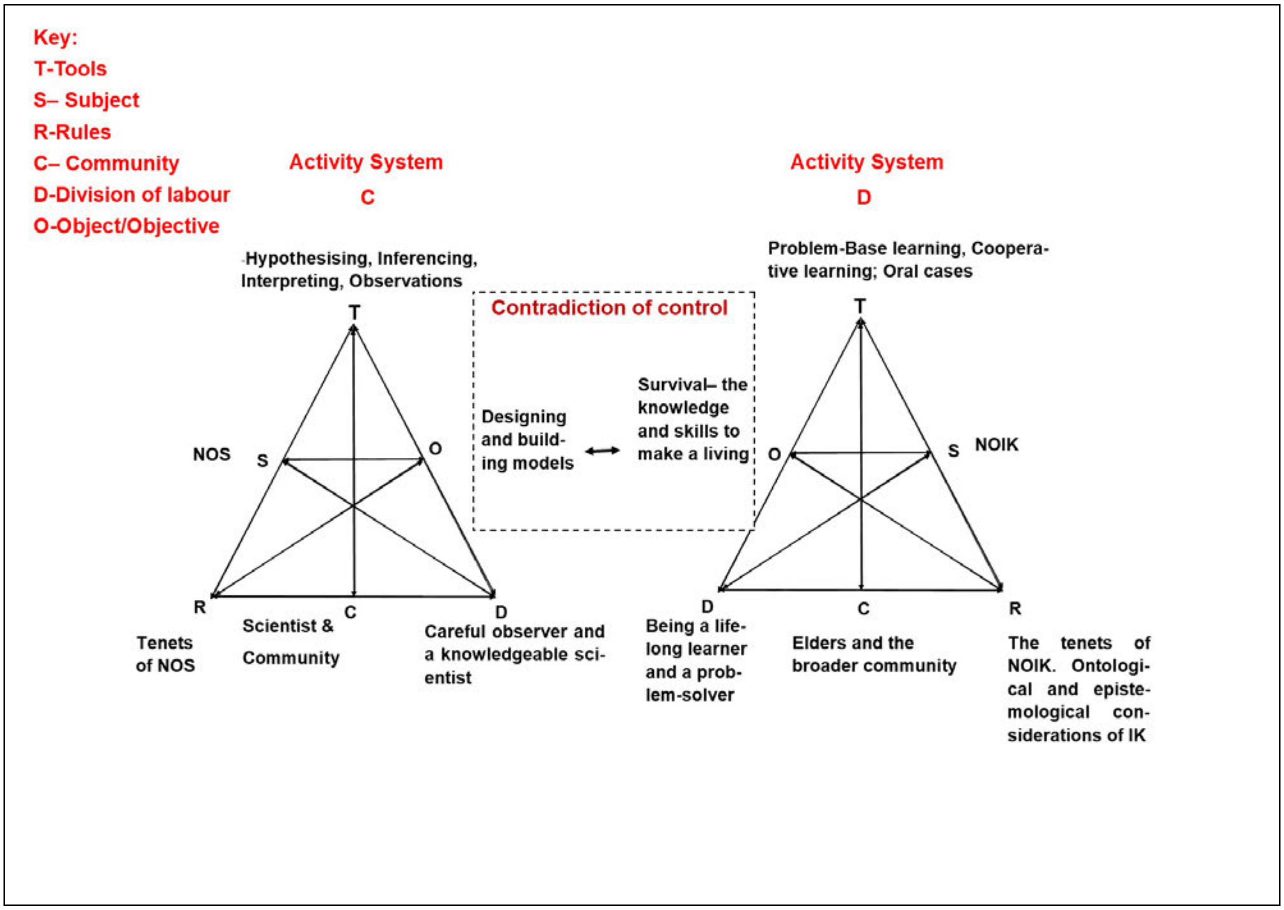

Figure 4.2: Third-generation CHAT reflecting the institutional level

The one filter of analysis

- *The shared tenets between the NOS and the NOS*

The institutional plane reflects shared tenets of both the knowledge systems and the other tenets that are somewhat contradictory. The NOS is empirically based while the NOIK is empirically based and metaphysical, a tenet (the metaphysical) that does not form part of the tenets of the NOS. The NOS is reductionist inclined, while the NOIK is holistic in nature. Thus, during the development of the programs that the participants engaged in during the intervention, I needed to develop the programmes that will reflect shared tenets between the two knowledge systems. Furthermore, allow for the different tenets between the two knowledge systems to be appreciated. Hence, De Bono's six thinking hats and puppetry were used during the SLP to discuss issues that were pertinent to the indigenous community, as well as the teachers being taken to the ACDB to address the NOS aspects of the intervention.

The institutional use of CHAT showed that there are shared tenets of natural Sciences and IK that hold affordances for enhancing SDL. Such analysis shows that epistemological border-crossing could be done in a way that honours the tenets of the two epistemologies, and it could result in minimal ‘contradiction of control’ (McNeil, 2013).

4.8.3 Using the interpersonal plane of CHAT as a lens

When using the CHAT in an interpersonal context, there are multiple "subjects" involved, such as the dynamic between a teacher's teaching and a student's learning (Mentz & De Beer 2019). The interpersonal plane of the CHAT in this study focuses on the settings of multiple subjects from different settings as the Life Sciences teachers from the rural setting Activity System E); the semi-urban setting (Activity System F) and the urban Activity System G) and is represented in Figure 4.3.

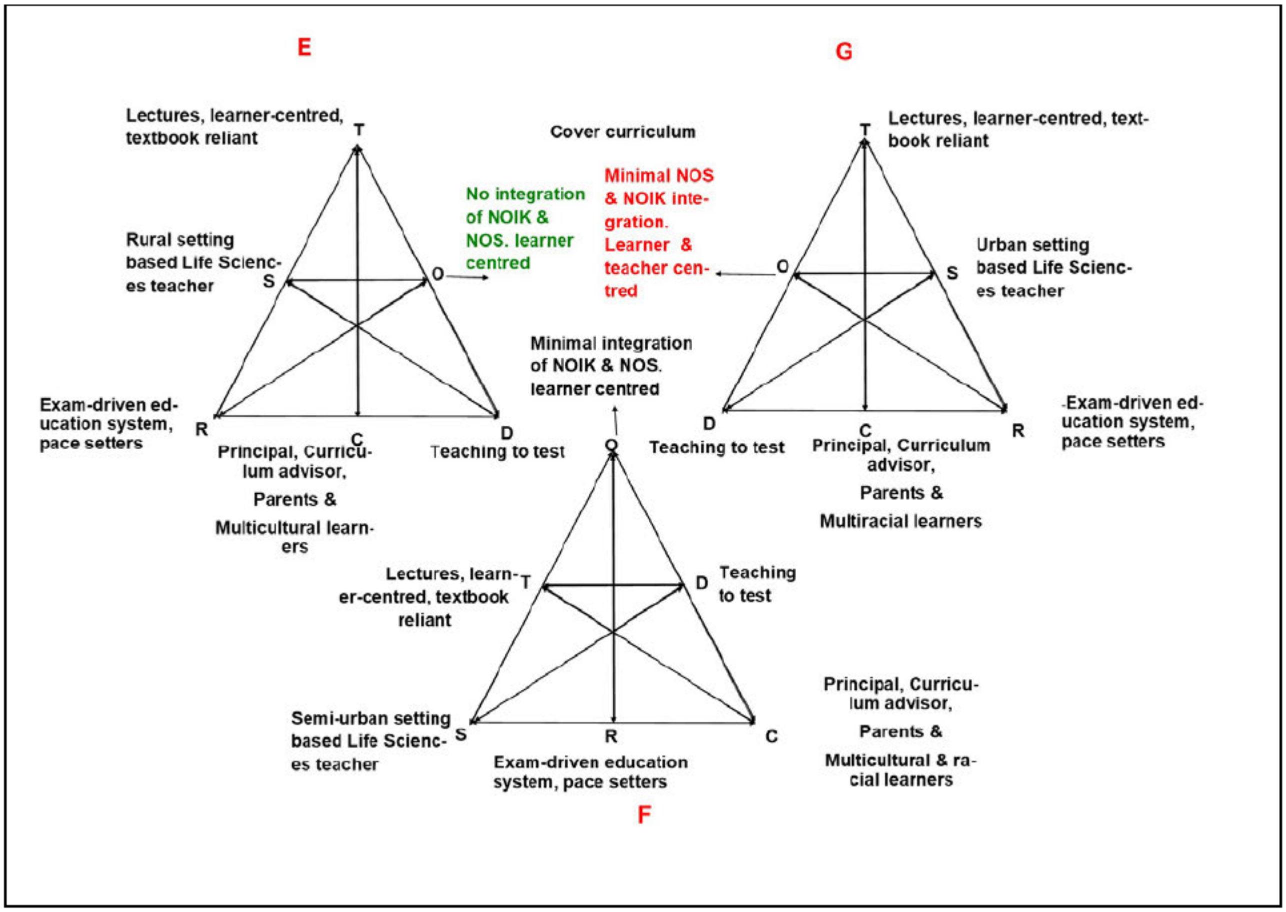

Figure 4.3: Third-generation CHAT reflecting the interpersonal level

The one filter of analysis

- *Improved perceptions of the NOIK of all the teachers from the three settings. However, it was only Participants 007 and 009 from the semi-urban and the urban settings that reflected the ability and the skills to contextualise and integrate IK in the classroom.*

The tension from the three activity systems emanates from the community in Activity systems E and in Activity systems F and G (Figure 4.3). The community is represented by multicultural and multi-tribal learners. However, only the teachers from Activity system E (rural setting) revealed that they are not adequately trained to contextualise the learners for diverse learners (multicultural and multi-tribal). In other words, the object of the three activity systems is where the teachers from the rural setting were not able to integrate NOS or NOIK in their classrooms. On the other hand, the teachers from the semi-urban and the urban settings were able to mainly integrate the NOIK and the NOS. The assumption was that due to the multiracial nature of the Activity systems F and G, the teachers would struggle to cater for the learners from the different racial backgrounds. However, despite receiving the same training as the teachers from the rural settings, the teachers from the semi-urban and the urban settings reflected the ability and skills to contextualise and integrate the NOIK and the NOS more than the teachers from the rural settings.

4.9 Conclusion

This chapter presented and analysed the data that was gathered from two open-ended questionnaires (VNOIK and VNOS), a questionnaire (POSTT LFSC) that determines the participants' pedagogical foci, a closed-ended questionnaire (SDLI), and the classroom observations (using RTOP) as well as the semi-structured interviews. The first four instruments were used and completed on a pre-intervention and post-intervention basis. In other words, the data that was presented and analysed from the four instruments was gathered from 12 Life Sciences teachers. On the other hand, the classroom observations and the semi-structured interviews were only conducted post-intervention with only six Life teachers (two from each setting). In other words, Participant 002 and Participant 004 represented the rural setting; Participant 007 and Participant 008 represented the semi-urban setting while Participant 009 and Participant 011 represented the urban setting.

This chapter examined the data that was collected from multiple sources, including the open-ended questionnaires (VNOIK and VNOS), a pedagogical focus survey (POSTT), a closed-ended questionnaire (SDLI), classroom observations (using RTOP), and semi-structured interviews. The first four instruments were completed by 12 Life Sciences teachers before and after the intervention. The classroom observations and interviews, on the other hand, were only conducted after the intervention with six Life teachers (two from each setting). Specifically, Participants 002 and 004 represented the rural setting, Participants 007 and 008 represented the semi-urban setting, and Participants 009 and 011 represented the urban setting.

CHAPTER 5: MAJOR FINDINGS, LIMITATIONS, CONTRIBUTIONS OF THE STUDY, RECOMMENDATIONS AND CONCLUSIONS

5.1 Introduction

In this chapter I deliberate on how the data analysis in Chapter 4 was used to answer the primary and the secondary objectives and to determine if the aims of this study were achieved. Furthermore, I deliberated on the major findings, the limitations, the contributions, the recommendations, and the conclusion.

5.2 Revisiting the research aim and research questions

This study set out to determine if the intended primary aim and primary research questions were achieved and answered, respectively. Due to the complexity of this study, both the primary aim and the research question were broken down to secondary aims and the secondary research questions, respectively. In this section I addresses the primary research questions and deliberates on the emerging holistic themes. Lastly, the secondary research questions are addressed, followed by the deliberations on the emerging themes from the participating teachers from the three settings and determine if the primary aim had been achieved.

5.2.1 Primary research question and holistic emerging themes

What is the influence of an intervention on the Life Sciences teachers' perceptions of the nature of Science, indigenous knowledge and the implications for their pedagogy and self-directed learning? From the collected data, there is clear evidence that the intervention benefited the teachers who participated. Particularly with regards to their views of the NOIK, as well as the NOS, because their perceptions improved post-intervention (see Table 4.4 and Table 4.7). Furthermore, the majority of the teachers' pedagogical orientation seemed to have shifted away from didactic direct and active direct to either guided inquiry or open inquiry (see Table 4.11). However, the self-directed learning instrument revealed no noticeable change of the participants' SDL pre- and post-intervention (see Table 4.16). Furthermore, the classroom observations revealed no sign of the teachers' ability to integrate either the NOIK or the NOS during the classroom practice from one setting (rural), while the other settings revealed nuanced findings from the classroom observations (semi-urban and urban). Lastly, the semi-structured interviews revealed that the observed teachers were characterised by poor planning, poor time management and the lack of mindfulness to the reflection post-lesson presentation.

- **Emerging themes from the holistic analysis**

a) *The intervention helped the participating teachers by improving their perceptions of the NOIK.*

The intervention helped the teachers by improving their perceptions of the NOIK and this was evident from the teachers' overall scores pre-intervention compared to their post-intervention responses. The teachers were able to provide informed responses that improved from 64 to 72, which is an increase by 20 or an improvement of 16.7% (see Table 4.4 for reference).

b) *The intervention helped the participating teachers by improving their perceptions of the NOS.*

The intervention helped the teachers by improving their perceptions of the NOS and this was evident from the teachers overall scores pre-intervention compared to their post-intervention responses. The teachers were able to provide informed responses that improved from 64 to 76, which is an increase by 12 or an improvement of 10% (see Table 4.7 for reference).

c) *The intervention helped the participating teachers by shifting their pedagogical orientation mainly from DD to either GI or OI.*

The intervention helped the teachers by improving their pedagogical orientation and this was evident from the teachers' response of the POSTT LFSC pre-intervention compared to their post-intervention responses. The teachers' responses were 68 GI and 49% OI pre-intervention, and they improved to 70 GI and 56 OI post-intervention, which was an improvement of two and seven respectively or 1% and 3.5% respectively (see Table 4.11 for reference).

d) There is evidence of a lack of significance or tangible change in the participants' SDL post-intervention.

The experimental group's responses from the SDL instrument post-intervention reflected no significant change when they compared to the pre-intervention responses. In other words, the majority (17 items) of the items responses had p-values that were more than 0.10, while only items 1, 7 and 11 had p-values of 0.082, 0.017 and 0.082 respectively. Furthermore, the control group's responses also reflected the majority of the items' responses with p-values more than 0.10 in 17 items, while only three items had p-values less than 0.10. The item numbers were 6, 14 and 18 with p-values of 0.029, 0.083 and 0.090 (see Table 4.16) respectively, which means that the intervention had no visible influence on the participants' SDL, because the visible change is reflected on the minority of the items.

e) There was no submission of portfolios by the participating teachers.

During the first two-day intervention that took place at the Landmark Protea Hotel in Polokwane, the participating teachers were requested to prepare portfolios to submit them a month after the intervention. The portfolios were intended for the teachers to track their own pedagogical development. There was no single teacher who was able to submit his/her portfolio and in respect to the participants' ethical rights no teacher was coerced or forced to submit the portfolio.

5.2.2 Secondary research questions and emerging themes from the participating teachers from the three settings

This section focuses on the research findings drawn from the secondary research questions as well as deliberations on themes that emerged.

Secondary research question 1: How do the Life Sciences teachers teaching in the urban, in semi-urban and in the rural based schools perceive the NOS, and how do these perceptions influence their pedagogy before and after the intervention?

- ***The findings from the responses of teachers based in the rural setting***

The two teachers from the rural settings (Participants 002 and 004) reflected informed and uniformed views with overall scores of 1.2 and 0.6 respectively pre-intervention. The teachers' responses post-intervention had improved with an overall score of 1.3 and 1.1 respectively. As such the teachers reflected informed views post-intervention.

The two teachers' pedagogical orientation seemed to be centred on GI pre-intervention and remained at GI with an improved numerical superiority post-intervention. However, the classroom observations revealed that none of the teachers were able to integrate the NOS and the semi-structured interviews revealed that the teachers had a poor time management and poor planning.

- ***The findings from the responses of the teachers based in the semi-urban setting***

The responses from the two teachers based in the semi-urban setting (Participants 007 and 008) reflected informed views and uninformed views with an overall score of 1.3 and 0.9, respectively pre-intervention. The teachers' responses post-intervention reflected improved views as their overall scores moved to 1.4 and 1.7 respectively, which improved the teachers' views.

The two teachers' responses from the POSTT LFSC reflected that their pedagogical orientation was centred on GI pre-intervention. The teachers' responses reflected a shift in their pedagogical orientation where the majority of their responses was centred on the OI. However, the classroom observations revealed rather nuanced findings where Participant 007 was able to integrate the NOS in her classroom, while Participant 008 was unable to integrate the NOS in her classroom. Hence, the nuanced findings and the semi-structured interviews revealed that the teachers had poor time management and poor planning, because the participant suggested that she wish she had enough more time with some teaching aids.

- ***The findings from the responses of the teachers based in the urban setting***

The responses of the two teachers from the urban setting (Participants 009 and 011) both reflected informed and partially informed perceptions with overall scores of 1.3 and 1.0 respectively pre-intervention. The teachers' responses post-intervention reflected improved perceptions with overall scores of 1.6 and 1.4 respectively. Thus, the teachers' responses post-intervention reflected informed perceptions.

The teachers' responses from the POSTT LFSC suggested that their pedagogical orientation pre-intervention was centred on both the AD and the GI. On the other hand, their responses post-intervention revealed that their pedagogical orientation is centred on OI and GI thereby reflecting a shift on pedagogical orientation and numerical superiority. However, the classroom observations revealed rather nuanced findings where Participant 009 was able to integrate the NOS in her classroom, while Participant 011 was unable to integrate the NOS in her classroom. Hence, the nuanced findings and the semi-structured interviews revealed that the teachers had poor time management and poor planning.

Secondary research question 2: How do the Life Sciences teachers teaching in the urban, in semi-urban and in the rural based schools perceive the NOIK, and how do these perceptions influence their pedagogy before and after the intervention?

- ***The findings from the responses of the teachers based in the rural setting***

The responses of the two teachers from the rural setting reflected informed and uniformed perceptions with the overall score of 1.2 and 0.7 respectively pre-intervention. The teachers' responses post-intervention reflected improved perceptions where the overall scores were both 1.1. Thus, reflecting informed perceptions from the teachers post-intervention.

The two teachers' pedagogical orientation seemed to be centred on the GI pre-intervention and remained at the GI with an improved numerical superiority post-intervention. However, the classroom observations revealed that none of the two teachers were able to integrate the NOIK and the semi-structured interviews revealed that the teachers had poor time management and poor planning.

- ***The findings from the responses of the teachers based in the semi-urban setting***

The responses of the two teachers from the semi urban setting reflected informed perceptions with the overall score of 1.3 and 1.5 respectively pre-intervention. Despite their informed perceptions pre-intervention, the teachers' responses post-intervention continued to improve with overall scores of 1.5 and 1.6, respectively. Thus, reflecting informed perceptions post-intervention.

The two teachers' responses from the POSTT LFSC reflected that their pedagogical orientation was centred on the GI pre-intervention. The teachers' responses reflected a shift in their pedagogical orientation where the majority of the six teachers' responses was centred on the OI. However, the classroom observations revealed rather nuanced findings where Participant 007 was able to integrate the NOIK into her classroom, while Participant 008 was unable to integrate the NOIK in her classroom. Hence, the nuanced findings and the semi-structured interviews revealed that the teachers had poor time management and poor planning.

- ***The findings from the responses of the teachers based in the urban setting***

The responses of the two teachers from the urban setting reflected informed and partially informed perceptions with overall scores of 1.5 and 1.0, respectively pre-intervention. The teachers' perceptions improved further post-intervention with the overall scores at 1.6 and 2.0 respectively. Meaning, despite the teachers' informed perceptions pre-intervention, the intervention seemed to have an influence on their perceptions of the NOIK. The teachers' responses from the POSTT LFSC suggested that their pedagogical orientation pre-intervention was centred on both the AD and the GI. On the other hand, their responses post-intervention revealed that their pedagogical orientation is centred on the OI and the thereby GI reflecting a shift on pedagogical orientation and numerical superiority. However, the classroom observations revealed rather nuanced findings where Participant 009 was able to integrate the NOIK in her classroom, while Participant 011 was unable to integrate the NOIK in her classroom. Hence, the nuanced findings and the semi-structured interviews revealed that the teachers had poor time management and poor planning.

Secondary research question 3: What transfer of new knowledge and skills occur in the classroom, after the intervention?

There was no evidence of transfer of the new knowledge, or the skill presented by the teachers who participated in the classroom observations. Despite Participants 007 and 009's ability to integrate the NOIK and the NOS by simply using the learners' contexts and allowing the learners to lead the lessons, the teachers continued to use the classroom discussions as their teaching methods. There was no single teacher who attempted to use some of the teaching methods/strategies that were learned during the intervention.

Secondary research question 4: How did the Life Sciences teachers' perceptions of their own self-directed learning change, during their participation in this research?

The collected data from the participating teachers who served as the experiment group reflected that there was no significant change of the collected data post-intervention when compared to the data that was collected pre-intervention. Therefore, the intervention had no influence on the teachers' SDL.

- **<u>Emerging themes from the participating teachers from the three settings</u>**

a) *The intervention helped the participating teachers from all settings by improving their perceptions of the NOIK. However, there were nuances with regards to the teachers' integration of NOIK in their classrooms, hence only two teachers, each from the semi-urban and urban settings were able to integrate NOIK in their classroom.*

The intervention helped the participating teachers from all the settings by improving their perceptions of the NOIK and this was evident when their responses pre-intervention was compared to their post-intervention responses. The teachers' responses reflecting informed perceptions accounted for 60% of the responses which is an improvement from the 43.3% of the pre-intervention responses.

b) *The intervention helped the participating teachers from all the settings by improving their perceptions of the NOS. However, there were nuances with* *regard to the teachers integrating the NOS in their classrooms*

The intervention helped the participating teachers from all the settings by improving their perceptions of the NOS and this was evident when their responses pre-intervention was compared to their post-intervention responses. The teachers' responses reflecting informed perceptions accounted for 63% of the responses which is an improvement from the 53% pre-intervention responses.

c) *There was evidence of poor preparation, poor time management (lack of agency) and poor reflective abilities*

The teachers who participated in the classroom observations reflected a lack of urgency and poor reflective abilities after the classroom observations during the semi-structured interviews. This was evident when Participants 002, 008 and 009 highlighted that in retrospect they should have brought teaching aids to their classrooms and used more contextual examples to help learners understand better. Furthermore, Participant 004 complained about the time spent in her class where she felt she needed more time in her classroom.

d) *There is no evidence of lesson preparation amongst the participants who were observed in their classrooms post-intervention.*

The teachers who participated in classroom observation did not prepare their lessons when they went to their respective classrooms. This was evident when not a single teacher was reflecting on their classroom practice during the semi-structured interviews.

5.3 Limitations of the study

In this section, I deliberate on the limitations of the study, which include, the sample group; the teachers' failure to submit portfolios; the teachers' failure to prepare lessons; the duration of the intervention and my limited time.

a) The sample group was small in such a way that the initial targeted number of participants was 15 teachers who were to form the experiment group and 27 teachers who would form a control group. However, the experiment group ended up been comprised of only 12 teachers, while the control group was 26. Some of the teachers withdrew from the study due to COVID-19 regulations, particularly the trip to ACDB where out of the 12 only six teachers managed to attend.

b) None of the teachers was able to submit the portfolio as initially requested. This made it difficult for me to gather data, but it could have been useful in determining the teachers' level of development post-intervention.

c) None of the teachers who were observed was able to provide a lesson plan, which made it difficult to gauge the teachers' level of preparation and their content knowledge particularly with regards to lesson preparation.

d) The intervention was made up of two short learning programs with each lasting for only two days. The majority of the teachers complained about how short each SLP was. As such, the SLPs that take more days to participate in would help the participants to have more to learn on the required material without feeling pressurised.

5.4 Contribution of this study

This study made contributions on three levels, namely; an epistemological contribution, research contribution and the methodological contributions. These contributions are elaborated below.

5.4.1 Epistemological contribution

This research ventured into epistemological border-crossing where IK was integrated into the Life Sciences and the Life Sciences teachers' understanding and classroom practices contributed towards the border-crossing which was part of the findings. Furthermore, based on the findings of this study, recommendations for future research studies were made and deliberated upon in Chapter 5 of this research study.

5.4.2 Research contribution

The study used the CHAT as the research lens on three levels (planes), namely; personal, institutional and interpersonal levels. The personal level juxtaposed two interdependent activity systems of the Life Sciences teacher during the intervention and after the intervention had occurred, which was part of the findings. Furthermore, based on the findings of this study, the recommendations for future research studies were made and deliberated in Chapter 5 of this research study.

The institutional level also juxtaposed the two interdependent activity systems that are represented by the two knowledge systems which are namely; the NOIK and the NOS that had to be considered for the activities that were prepared for the intervention. In other words, in this instance, the subject was presented by the knowledge systems not a person, hence, Mentz and De Beer (2019) suggest that the institutional level place focuses on the phenomenon that serves as the subject in the system, as such the 'subject' is not represented by a person but by "an entity or a construct" (p.59). Furthermore, based on the findings of this study, the recommendations for future research studies were made and deliberated upon in Chapter 5 of this research study. The use of CHAT on institutional level makes it clear that epistemological border-crossing in the classroom hold many affordances.

Lastly, the interpersonal level as a major contribution was used to juxtapose three interdependent activity systems of the Life Sciences teachers teaching Life Sciences in three settings namely; the rural, the semi-urban and the urban settings. The three activity systems reflected three different classrooms from three geographical, contextual and cultural environments, which contributed to the teachers' classroom practices, which also contributed to the findings of this research. Hence, based on the findings of this study the recommendations for future research studies were made and deliberated upon in Chapter 5 of this research study.

5.4.3 Practical contribution

The intervention in the form of the short learning programme was intended to empower the participating Life Sciences teachers in this study by developing their pedagogical content knowledge. The intervention further sensitised the Life Sciences teachers' towards self-directed learning. This study might have indirectly contributed to the learners' self-directedness, as the teachers created the opportunities using different teaching-learning strategies, to enhance the learners' SDL skills.

5.4.4 Methodological contribution

Another major contribution of this research study was the expansion of the analysis of the current VNOIK rubric by adding an additional category to Cronje's et al.'s (2015) three categories. This addition is elaborated on in Chapters 3 and 4 which initially categorised the participants' views into either uninformed views (U), partially-informed views (P) or informed views (I) (Cronje 2015; Cronje et al., 2015; Sebotsa, 2020). In a form of contribution, an addition of another category of the participants' views called No Classification (NC). The category is only applicable when the participants' response reflects 'no response; they state that they do not know, or the response does not address the prompt'. Hence, based on the findings of this study, the recommendations for future research studies were made and deliberated upon herein.

5.5 Recommendations

The findings from this study revealed several recommendations pertaining to the influence of an intervention on the Life Sciences teachers' perceptions on the NOS, the NOIK and the implications for their pedagogy and SDL. These recommendations include addressing systemic pressures, the need for more participants, stronger focus on the administration of the SDLI and the consideration to increase the duration of the SLPs and the deliberations are made below.

5.5.1 Addressing systemic pressures by engaging in Change Laboratories

The 'contradiction of control' often stems from systemic factors that lead to the so-called 'washout effect' of educational goals in the post-intervention classroom. Change Laboratories (CLs) hold many affordances during the design of effective Teacher Professional Development Programmes (TPDP). This is a result of certain CLs broadening their mandate to include societal concerns that are especially urgent on the continent, like climate change solutions and sustainable practices (Winberg et al., 2023). According to Mentz and De Beer (2019) CLs afford for a space and time where all stakeholders involved can engage in expansive learning and attempt to reach consensus and understanding. The CLs can allow for expansive learning that is rooted in social constructivism which allow the stakeholders to present their views, jointly redefine them and rethink their own views, by so doing putting expansive learning to practice (Mentz & De Beer, 2019). In order to achieve effective cooperation, it is important to consider the elements of cooperative learning where there is positive interdependence. Effective CLs involves structuring learning activities that encourage interaction and promote individual accountability, as well as developing interpersonal skills and facilitating group processing among stakeholders (Johnson & Johnson, 2018). As well as the elimination of control of power in expansive learning which suggest that CLs must be inclusive where each stakeholder must voice their views without fear and considering of the use of 4^{th} generation CHAT (Mentz & De Beer, 2019).

5.5.2 The need for a bigger pool of participants during SLPs to benefit more participants

It is advised that the future studies focus on gathering data from a bigger pool of participants. This is because this study revealed that the intervention had improved the participating teachers' perceptions of the NOS and the NOIK. In other words, the improved perception could be beneficial to the other Life Sciences teachers. As such, the bigger the pool of participants, the greater number of teachers who can benefit from the intervention.

5.5.3 Self-Directed Learning Instrument, and a stronger focus on SDL during Teacher Development Programmes (TDPs) interventions

For the participating teachers to honestly complete the SDLI, they need to fully understand what the self-rating instrument requires of them. In my opinion, most of the participating teachers only got to fully understand what items of the self-rating instrument required post-intervention. Thus, it is advised that the participating teachers be provided with a short workshop on the SDLI, so that when they complete the form pre-intervention they can rate themselves honestly, because the danger can be that they answer what they think I may want to hear.

5.5.4 Increased and establishing conducive communities of practice to support TDPs

During the SLPs, most participants complained about the short duration of the SLPs. The teachers requested more time for these SLPs so that they can learn more, as they felt that at times some aspects of the SLPs needed more time. As such, if more time is given to these SLPs the training can be more centred on the teachers learning pace. TDPs should "focus on teaching strategies associated with specific curriculum content supports teacher learning within their classroom context" (Darling-Hammond et al., 2017, p. 2). Therefore, it is advised that instead of having a two-day training, there should be a consideration of having more time for the SLPs. Also, blended-learning approaches could be followed, where teachers could also engage online in learning- and reflective tasks.

The findings of this study seem to suggest that the participating teachers would normally go back to their normal way of teaching. As such it is advised that there be refresher SLPs on the integration of IK for the teachers until there is evidence of conceptual change amongst the teachers. In this way, the teachers' classroom pedagogy can visibly improve.

All of the participating teachers who failed to submit the portfolios as requested and those who participated in the classroom observation never provided lesson plans and there was no evidence of lesson preparation. To have SLPs that can fully cater for the pedagogical need of the participating teachers, it is advised that there is time that is dedicated to guide the participating teachers on how to develop the portfolios. Lastly, it is advised that there be a time that is dedicated to guide the teachers on how to prepare lesson plans.

5.6 Conclusion

At the beginning of this research, through the use of secondary aims and secondary research questions I sought to address the primary research question which focused on the Life Science teachers, the NOS, the NOIK, their classroom pedagogies and SDL. In an attempt to answer the primary research question, I prepared an intervention for the participants which was divided into two short learning programmes and other than finding an appropriate response to the question, there were other discoveries that were made.

Through this research, I was able to use the Cultural Historical Activity Theory on an interpersonal plane thereby juxtaposing three activities and adding another aspect named ‘no classification’ or NC on the rubric that was used for the VNOIK among other things. Despite this historical endeavour, the research was able to achieve the findings that yielded a conclusion.

These conclusions highlight the positive influence from the intervention on the teachers' perceptions and pedagogies, but they also shed light on the areas that may need further attention, such as SDL and the practical integration of the NOS and the NOIK into classroom teaching. Furthermore, the study's limitations and recommendations provide cherished insights for future research and for the Life Sciences interventions.

5.7 My reflection as a researcher

Reflecting on my journey as a researcher, PhD candidate, Life Sciences teacher, and native citizen has been paramount to my academic development. Delving into specialised areas such as SDL, PCK, CHAT, and IK posed initial challenges due to the novelty of these concepts and navigating collaborative relationships with supervisors. Engaging in extensive literature review became imperative to grasp these concepts comprehensively.

Exploring PCK, I delved into various models, ultimately gravitating towards PCK for Science teaching, which resonated deeply with my understanding after thorough reading. My exploration of CHAT across different generations, including interpretations by scholars such as Leontiev and Engestrom, profoundly shaped my academic perspective. Recognising the pivotal role of integrating IK in the Life Sciences classroom, particularly evident during the SLPs, underscored its significance in professional growth for Life Sciences teachers.

The methodology section of any research holds significance, and venturing into unexplored territories presented a steep learning curve. Transitioning from a predominantly qualitative research approach to embracing mixed methods, understanding its designs, and aligning with appropriate paradigms marked a significant learning journey. Moreover, grappling with social constructivism and eventually contextualising Zone of Proximal Teacher Development (ZPTD) provided a sense of fulfilment in synthesising theoretical frameworks into practical application.

In conclusion, this academic expedition has fostered multifaceted personal and professional growth, emphasising that the essence lies in the journey rather than the destination.

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APPENDICES

APPENDIX A: ETHICAL CLEARANCE CERTIFICATE

NWU®
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27 October 2020

Dear Prof Petersen

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the North-West University Education, Management and Economic Sciences, Law. Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-NWU-EMELTEN-REC) on 26 October 2020, the NWU-EMELTEN-REC hereby approves your study as indicated below. This implies that the NWU-EMELTEN-REC grants its permission that, provided the general and specific conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: The influence of an intervention on Life Sciences teachers' perceptions of the nature of Science, indigenous knowledge and implications for their pedagogy and self-directed learning

Principal Investigator/Study Supervisor/Researcher: Prof Neal Petersen

Student: Mr Karabo Chuene

Ethics number:

N	W	U	-	0	1	1	1	5	-	2	0	-	A	2
Institution				Study Number						Year			Status	

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Single study
Commencement date: 23.09.2020
Expiry date: 22.09.2021

Risk: **Medium**

Approval of the study is provided for a year, after which continuation of the study is dependent on the receipt and review of a six-monthly monitoring report and the concomitant issuing of a letter of continuation.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The principal investigator/study supervisor/researcher must report in the prescribed format to the NWU-EMELTEN-REC:*
  - *six-monthly on the monitoring of the study, whereby a letter of continuation will be provided annually, and upon completion of the study; and*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the principal investigator/study supervisor/researcher must apply for approval of these amendments at the NWU-EMELTEN-REC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*

9.1.5.4.2 Ethics Approval Letter of Study 1

- *Annually a number of studies may be randomly selected for active monitoring.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility, the NWU-EMELTEN-REC reserves the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the study are revealed or suspected;*
    - *it becomes apparent that any relevant information was withheld from the NWU-EMELTEN-REC or that information has been false or misrepresented;*
    - *submission of the six-monthly monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and/or*
    - *new institutional rules, national legislation or international conventions deem it necessary.*
- *NWU-EMELTEN-REC can be contacted for further information via Ethics-EMELTEN-apply@nwu.ac.za or 018 299 4707*

Specific conditions:

1. The commencement and execution of the study are subject to COVID-19 restrictions and regulations and strict adherence to the prevailing COVID-19 research procedures and protocols.

The NWU-EMELTEN-REC would like to remain at your service and wishes you well with your study.

Please do not hesitate to contact the NWU-EMELTEN-REC for any further enquiries or requests for assistance.

Yours sincerely,

L.W. Meyer

Prof Lukas Meyer
Chairperson NWU-EMELTEN-REC

Current details:(23239522) G:\My Drive\9. Research and Postgraduate Education\9.1.5.4 Templates\9.1.5.4.2_NWU-HREC_EAL.docm
20 August 2019

File Reference: 9.1.5.4.2

APPENDIX B: LANGUAGE EDITOR'S LETTER

LoveToEdit

You Write. We Edit. You Love it.

09 October 2023

TO WHOM IT MAY CONCERN

RE: CONFIRMATION OF LANGUAGE EDITING SERVICES: K. J. CHUENE

I confirm that I have done language editing for K. J. Chuene's PhD thesis titled:

THE INFLUENCE OF AN INTERVENTION ON LIFE SCIENCES TEACHERS' PERCEPTIONS OF THE NATURE OF SCIENCE, INDIGENOUS KNOWLEDGE AND IMPLICATIONS FOR THEIR PEDAGOGY AND SELF-DIRECTED LEARNING

The thesis now conforms to the North West University's editing standards.

Yours sincerely

Moyo

Lynn N. Sibanda Moyo

Tel: 011 050 0376

Mobile: 071 989 0983

Email: lynn@lovetoedit.co.za

Member of the Professional Editors Guild

Professional EDITORS Guild

Address: 16 Countesses Ave, Randburg, South Africa, 2194 | **Telephone:** +27 11 050 0376 | **Email:** info@lovetoedit.co.za
Website: www.lovetoedit.co.za | **Registration Number:** 2016/ 425723/ 07

APPENDIX C: TURNITIN REPORT

33695520:Karabo_Chuene_(33695520)_Thesis_2023_Novem...

ORIGINALITY REPORT

14%	9%	4%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to North West University Student Paper	5%
2	Submitted to University of Limpopo Student Paper	1%
3	repository.nwu.ac.za Internet Source	1%
4	ujcontent.uj.ac.za Internet Source	1%
5	hdl.handle.net Internet Source	1%
6	books.aosis.co.za Internet Source	1%
7	dspace.nwu.ac.za Internet Source	1%
8	jewlscholar.mtsu.edu Internet Source	<1%
9	researchspace.ukzn.ac.za Internet Source	<1%

APPENDIX D: STATISTICIAN'S LETTER

University of Limpopo
Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3982, Fax: (015) 268 2306, Email: peter.mphekgwana@ul.ac.za

To: To whom it may concern

From: Mr MP Mphekgwana
Biostatistician
Date: 11 October 2023

Letter of Confirmation

Dear Sir/Madam

I hereby confirm that I have assisted Karabo Justice Chuene (33695520) with quantitative data analysis for the study titled "*The influence of an intervention on Life Sciences teachers' perceptions of the nature of Science, indigenous knowledge and implications for their pedagogy and self-directed learning*" aimed to investigate the influence of an intervention on Life Sciences teachers', teaching in urban, semi-urban and rural settings, perceptions of the NOS and NOIK, and the influence thereof on their pedagogy and SDL.

Hope you find everything in order.

Kind Regards,

Mphekgwana MP

Mr Peter Mphekgwana, University Biostatistician

Finding solutions for Africa

APPENDIX E: PERMISSION TO USE VNOIK QUESTIONNAIRE

Unknown

From:	Josef De Beer <Josef.DeBeer@nwu.ac.za>
Sent:	21 May 2020 07:54 AM
To:	KARABO CHUENE
Cc:	Neal Petersen
Subject:	Re: Request for permission to use VNOIK

Dear Mr Chuene

Thank you for your e-mail.

The VNOIK instrument was developed by one of my PhD students, when I was still employed by University of Johannesburg. Annelize Cronje and I published the instrument in the *African Journal of Research in Mathematics, Science and Technology Education*. Unfortunately Dr. Annelize Cronje (the first author) passed away two years ago. You have my permission to use this instrument.

Best wishes with this exciting research journey!

Kind regards

Josef

Josef de Beer FRSB
Navorsingsprofessor
Skool vir Natuurwetenskappe en Tegnologie vir Onderwys
Fakulteit Opvoedkunde
Tel: 018 285-2626
Faks: 018 2994238

NWU®

Josef de Beer
FRSB
Research Professor
School for Natural Sciences and Tecnology for Education
Faculty of Education
Tel: 018 285-2626
Fax: 018 2994238

>>> KARABO CHUENE <chuenekj@gmail.com> 5/13/2020 9:08 AM >>>
Good morning

My name is Karabo Justice Chuene and I am a PhD candidate at North West University Potchefstroom campus.
I am a lecturer by profession at University of Limpopo under Department of Maths. Science and Technology (school of education)
As a PhD candidate one of the ethics requirements is to have permission from the author of any data collecting instruments one may use
I therefore humbly request your permission to use VNOIK to collect data for my study.

Should this request be granted it will make my study more relevant appropriate.

Warm regards
Karabo Chuene

1

Quick Notes Page 16

APPENDIX F: PERMISSION TO USE VNOS-D+

Unknown

From:	Norman Lederman <ledermann@iit.edu>
Sent:	13 May 2020 12:22 PM
To:	Chuene, Karabo
Subject:	Re: Request to use VNOS

Dear Karabo Chuene,

You absolutely have my permission to use the VNOS instrument for research. I assume you will be suing VNOS-C, but I would recommend using the VNOS-D+.

Norm

Look Here for: <u>Resources for teaching and assessment of Nature of Scientific Knowledge and Scientific Inquiry</u>

******* AKA Nearly Norm L******************

Dr. Norman G. Lederman, Distinguished Professor
Department of Mathematics and Science Education

Illinois Institute of Technology
3424 S. State St., Rm 4007
Chicago, IL 60616
Phone: (708) 790-3027
Email: ledermann@iit.edu

****

On Wed, May 13, 2020 at 1:53 AM Chuene, Karabo <karabo.chuene@ul.ac.za> wrote:

Greetings

My name is Karabo Justice Chuene I am a PhD candidate at North West University in South Africa.
I am a lecturer by profession at University of Limpopo South Africa under Department of Maths. Science and Technology (school of education).
As a PhD candidate one of the ethics requirements is to have permission from the author of any data collecting instruments one may use.
I therefore humbly request your permission to use VNOS to collect data for my study.

Should this request be granted it will make my study more relevant appropriate.
Warm regards

Karabo

1

Quick Notes Page 2

APPENDIX G: PERMISSION TO USE POSTT MULTIPLE-CHOICE ITEM QUESTIONNAIRE

Unknown

From:	William W Cobern <bill.cobern@wmich.edu>
Sent:	04 July 2020 01:12 PM
To:	Chuene, Karabo
Subject:	Re: Permission to use POSTT for a research project

Dear Karabo,
I apologize for taking so long to respond to your email request. You just caught me at an especially busy time.

Yes, you have my permission to use the POSTT. Presumably you plan to adapt some of the items for use in the RSA. That is fine. Please keep me informed of your progress as I will be interested to know more about your research.

Presumably you have read our initial paper carefully and you know that we designed these items for formative assessment purposes. Because of that we were much more concerned about issues of validity than reliability.

However, now that these items or versions of these items are getting used for research purposes, the question of reliability becomes much more important. One of my students from Indonesia has just finished a thorough reliability study of eight POSTT items transadapted for use in Indonesia. We are not quite ready to release the paper but when we do I will be sure to send you a copy. Perhaps you will find it of interest.

Cheers
bc

Dr. Bill Cobern
The George G. Mallinson Institute for Science Education
Distinguished University Faculty Scholar
College of Arts & Sciences
Western Michigan University
3137 Wood Hall
Kalamazoo, MI 49008-5444
Voice: +269.387.5407 FAX: +269.387.4998
https://works.bepress.com/william-cobern/
SKYPE : bill.cobern

Yes, there *really* is a Kalamazoo!

Pascal's Rule: The certainty with which we can know things is inversely proportional to their significance for our lives.

From: Chuene, Karabo <karabo.chuene@ul.ac.za>
Sent: Wednesday, July 1, 2020 10:54 AM
To: William W Cobern <bill.cobern@wmich.edu>
Subject: Permission to use POSTT for a research project

My name is Karabo Justice Chuene and I am a PhD candidate at North West University Potchefstroom campus South Africa.
I am a lecturer by profession at the University of Limpopo under the Department of Maths, Science and Technology (school of education).
As a PhD candidate one of the ethics requirements is to have permission from the author of any data collecting instruments one may use.

1

Quick Notes Page 2

APPENDIX H: PERMISSION TO USE SDLI QUESTIONNAIRE

Unknown

From:	sufen <sufen@ntunhs.edu.tw>
Sent:	03 July 2020 05:23 PM
To:	Chuene, Karabo
Subject:	Re: Permission to use SDLI for research project

Dear Karabo,

Thank you for your interesting in self-directed learning instrument (SDLI). You are welcome to use the SDLI. You have my permission to use it for research purposes. In that case, please use the citation list below for your study. Besides, I strongly suggested you to read another article written in 2014. Besides, Cadorin, Bressan & Palese (2017) had reviewed self-directed learning related instruments and published in BMC Medical Education, they mentions our SDLI could be the gold standard to evaluate nursing students' or nurses' SDL. You may search that article, the tittle of the article is "instruments evaluating the self-directed learning abilities among nursing students and nurses: A systematic review of psychometric properties.

Cheng, S. F., Kuo, C. L., Lin, K. C.,& Lee-Hsieh, J. (2010). Development and preliminary testing of a self-rating instrument to measure self-directed learning ability of nursing students. International Journal of Nursing Studies, 47(9), 1152~1158.

Cheng, S. F., Lee-Hsieh, J. Turton, M. & Lin, K. C. (2014). Validation of self-directed learning instrument and establishment of normative data for nursing students in Taiwan: Using polytomous item response theory. Journal of Nursing Research, 22(2), 90-100.

Best regards

Su-Fen Cheng, RN, PhD
Professor, Department of Allied Health Education and Digital Learning
National Taipei University of Nursing and Health Sciences
Office: B305
Tel: 02-28227101 ext 3203 or 3200
-----Original message-----
From: Chuene, Karabo<karabo.chuene@ul.ac.za>
To:sufen<sufen@ntunhs.edu.tw>
Date: Wed, 01 Jul 2020 22:39:06
Subject: Permission to use SDLI for research project

Good afternoon

My name is Karabo Justice Chuene and I am a PhD candidate at North West University Potchefstroom campus South Africa.
I am a lecturer by profession at the University of Limpopo under the Department of Maths, Science and Technology (school of education).
As a PhD candidate one of the ethics requirements is to have permission from the author of any data collecting instruments one may use.
I therefore humbly request your permission to use Self-Directed Learning Instrument (SDLI) to collect data for my study.

Should this request be granted it will make my study more appropriate.

Warm regards
Karabo Chuene

--

1

Quick Notes Page 6

APPENDIX I: VNOIK QUESTIONNAIRE

VIEWS OF NATURE OF INDIGENOUS KNOWLEDGE (VNOIK)

Personal details

a. Name: ______________________________

b. Date: / /

c. Date of birth: ....

d. Sex: M / F

e. Name of school: ....

f. Highest qualification: ....

g. Teaching experience in years: ....

h. All subjects taught in the past 3 years: ....

i. All grades taught in the past 3 years: ....

Instructions

- Please answer each of the following questions. You can use all the space provided and the backs of the pages to answer a question.
- Some questions have more than one part. Please make sure you write answers for each part.
- This is not a test and will not be graded. There are no "right" or "wrong" answers to the following questions. I am only interested in your ideas relating to the following questions.

Views of the nature of indigenous knowledge (VNOIK) questionnaire

Instructions:

- Please answer each of the following questions. Include relevant examples whenever possible.
- There is no 'right' or 'wrong' answer to the questions. We are only interested in **your opinion** on a number of issues regarding indigenous knowledge.

Questions:

1. In your view what is indigenous (or traditional) knowledge?
   What makes indigenous knowledge different from other types of knowledge systems (such as Western knowledge)?

2. Practitioners of indigenous science (e.g. elders, herbalists, traditional healers) observe nature to generate knowledge. Do they do experiments and tests in order to verify or validate this knowledge?
   - If yes, explain how they test or validate their knowledge
   - If no, explain why not

3. Practitioners of indigenous knowledge observe nature and give explanations about their observation. Elders in a community can, for example, explain where lightning comes from. Do the elders always use natural causes to explain their observations such as lightning, or do they sometimes include supernatural causes in their explanations?
   - If they only use natural causes, explain why and give examples of some of the causes
   - If they sometimes use supernatural causes, explain why and give examples of some of the causes.

4. Indigenous knowledge is transferred from one generation to the next over many decades and centuries.
   Does this knowledge stay the same or does it change over time?
   - If yes, explain why it stays the same
   - If no, explain the causes of such changes

5. *Hoodia gordinii* is a plant that was used by Khoi-San hunters to suppress their hunger and thirst when they went on hunting expeditions. How **do you think** the Khoi-San people came to know that this particular plant has these properties?

6. Sustainable development is an emerging concept that includes topics such as hunger, poverty and underdevelopment. Globally governments and organisations struggle to find solutions for these important issues. **Do you think** indigenous knowledge can be used to alleviate some of these problems?
   - If you say yes, please explain why and how indigenous knowledge can be used to solve these problems

APPENDIX J: VNOS-D+ QUESTIONNAIRE

VIEWS OF NATURE OF SCIENCE (VNOS-D +)

Personal details

a. Name: ___________________________

b. Date: / /

c. Date of birth: ....

d. Sex: M / F/Other

e. Name of school: ....

f. Highest qualification: ....

g. Teaching experience in years: ....

h. All subjects taught in the past 3 years: ....

i. All grades taught in the past 3 years: ....

Instructions

- Please answer each of the following questions. You can use all the space provided and the backs of the pages to answer a question.
- Some questions have more than one part. Please make sure you write answers for each part.
- This is not a test and will not be graded. There are no "right" or "wrong" answers to the following questions. I am only interested in your ideas relating to the following questions.

1. What is science?

2. What makes science (or a scientific discipline such as physics, biology, etc.) different from other subject/disciplines (art, history, philosophy, etc.)?

3. Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.

4. (a) How do scientists know that dinosaurs really existed? Explain your answer.

(b) How certain are scientists about the way dinosaurs looked? Explain your answer.

(c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what caused this to happen. Why do you think they disagree even though they all have the same information?

(d) If a scientist wants to persuade other scientists of their theory of dinosaur extinction, what do they have to do to convince them? Explain your answer.

5. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.
(a) Do you think weather persons are certain (sure) about the computer models of the weather patterns?

(b) Why or why not?

6. The model of the inside of the Earth shows that the Earth is made up of layers called the crust, upper mantle, mantle, outer core and the inner core. Does the model of the layers of the Earth *exactly* represent how the inside of the Earth looks? Explain your answer.

7. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments?

a. If **NO**, explain why.

b. If **YES**, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

8. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

9. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.

10. Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

APPENDIX K: POSTT LFSC MULTIPLE-CHOICE ITEM QUESTIONNAIRE

Thinking about Science Teaching Pedagogy of Science Teaching Test for Life Sciences (POSTT LFSC)

Dear Teacher:
This assessment is composed of classroom science teaching test similar to teaching practices one can find in any classroom today. Practicing teachers contributed ideas for many of the vignettes; others are based on teacher observations, or on science curriculum standards.

As you read through the test, think about how you might teach science in a similar situation. Respond accordingly.

Personal details

a. Name: ____

b. Date: / /

c. Date of birth: ....

d. Sex: M / F/Other

e. Name of school: ....

f. Highest qualification: ....

g. Teaching experience in years: ……………………………………

h. All subjects taught in the past 3 years: ....

i. All grades taught in the past 3 years:..

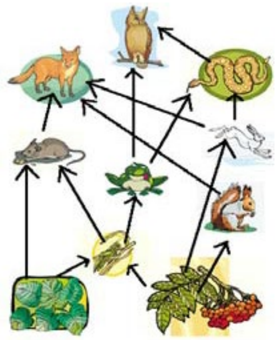
Frog dissection 1 Mr. Goodchild is doing a frog dissection with his grade10 learners to help teach them about anatomy. 		
1	Thinking about how you would teach a lesson, of the following, which is most similar to what you believe is the best way to incorporate a dissection into a lesson?	
	A	It should be used as a stand-alone step-by-step activity for learners to explore the frog's anatomy and raise discussion questions on their own.
	B	It should be used as a follow-up step-by-step learner activity after Mr. Goodchild explains exactly what learners will need to notice about the frog anatomy.
	C	It should be used as a step-by-step learner activity while answering probing questions, followed up by teacher-led discussion and clarifications.
	D	It should be used as a step-by-step demonstration by Mr. Goodchild while he explicitly points out what learners need to know about frog anatomy.
Organisms respond to environment Ms. Pendleton wants to teach her grade 8 learners that living organisms respond to their environment. The learners did an experiment on how earthworms respond to their environment. Then in small groups they discussed a series of questions about the experiment. Ms. Pendleton now needs to wrap up the lesson. 		
2	Of the following, which one is most similar to how you would wrap up this lesson?	
	A	Have the learners come up with a general conclusion based on the evidence they gathered from their earthworm experiment, guiding them toward the concept objective.
	B	Restate the concept objective for the learners, and ask learners to provide supporting evidence from their earthworm experiment.
	C	Have learners report their conclusions, based on the evidence gathered from their

		earthworm experiment.
	D	Restate the concept objective for the learners, relating it to the observations they gathered in their earthworm experiment.

Structure and function

Mr. Danzit will be teaching his grade 10 learners a lesson on “structure and function” as applied to digestive systems. He has a set of pictures showing the mouths of different animals, including a finch beak, a dog jaw with teeth, and horse jaw with teeth. He also has a chart that he can distribute to the learners, which will allow them to fill in information about what each of these animals can and cannot eat.

3	Thinking about how you would teach this lesson, of the following, which is the best statement on how Mr. Danzit should begin the lesson?	
	A	Mr. Danzit should begin the lesson by carefully explaining the concept of structure and function as it relates to the digestive system, specifically mouth parts. He should then ask the learners to fill out the chart using the pictures and his discussion as a guide.
	B	Mr. Danzit should allow the learners to explore a set of photos showing animal mouths. He should then have the learners write their own stories about how these animals are similar and different, what they eat.
	C	Mr. Danzit should begin the lesson by carefully explaining the concept of structure and function, while helping learners fill in their charts, so they can clearly see examples of this concept as it relates to digestive systems.
	D	Mr. Danzit should begin the lesson by showing his learners a picture of a shark mouth, asking learner what this animal might eat. After a discussion, he should give each learner a copy of the chart and the other pictures, asking learners to complete the chart based on their early discussion.

Field trip Ms. Piper is taking her grade 9 class to the local nature center, because they are currently studying food webs, she would like to use the field trip as a way to learn more about this topic. 		
4	Thinking about how you would teach, of the following, how would you most likely use a field trip to teach learners about food webs?	
	A	I would inform them that on our upcoming field trip they will be looking for examples of food webs. During the field trip, learners could make their own list of interactions they observe relating to food webs, which we would discuss later as a group.
	B	I would inform learners before the field trip that we are going to look for specific examples of food webs, providing them a checklist of interactions they should see. During the field trip, I would point out to them interactions, having them mark off each as we go.
	C	I would not tell learners exactly what to look for during the field trip, but would ask them to make observations about any of the interactions they see between organisms. Afterwards we could discuss what they saw relating to food webs.
	D	I would inform learners before the field trip that we are going to look for specific examples of food webs, providing them a checklist of interactions they should see. During the field trip, learners could look for those examples and mark them off as we go.
Predator and prey Mr. Peoples is conducting a unit on food chains and is about to introduce his grade 10 learners to predator/prey relationships. He has a good computer simulation game for this subject that he can use with his class. 		
5	Thinking about how you would teach this lesson, of the following, which is the best	

	advice for conducting this lesson?	
	A	Mr. Peoples should explain to his learners that balance typically exists in nature such that the numbers of predators and their prey are related. For example, he can tell them that a rabbit population will increase if disease reduces the coyote population in the same region. He should then project the simulation game to demonstrate relationships between rabbit and coyote populations.
	B	Mr. Peoples should explain to his learners that balance typically exists in nature such that the numbers of predators and their prey are related. For example, he can tell them that a rabbit population will increase if disease reduces the coyote population of the same region. Using the computer simulation game, he should have the learners monitor and record the rabbit levels over a simulated ten year period during which the population of coyotes rises and falls, so that they can confirm the predator/prey concept he explained.
	C	Mr. Peoples should ask what would happen with rabbits if many coyotes died suddenly of disease. After some discussion, Mr. Peoples should suggest that the learners explore their ideas using the computer simulation game he has for this subject, by recording yearly counts over a simulated period of ten years. The learners will then have data to be used in a class discussion on predator/prey relationships.
	D	Mr. Peoples should begin by asking the learners what they know about predators and prey. Without responding other than to encourage their ideas, Mr. Peoples should then show them the computer simulation game he has for this subject and invite them to use the simulation in any way they wish to explore their ideas. The lesson would end with learners writing up their findings.

Inheritance

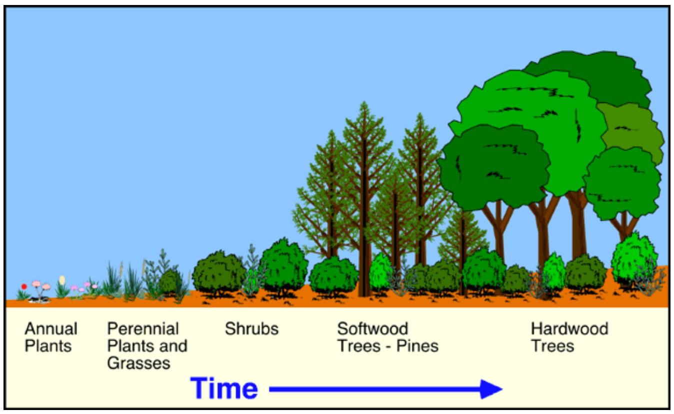
Mr. Montgomery was teaching his grade 11 learners about inheritance. After introducing the topic and demonstrating how to use a Punnett square to determine genotypes and phenotypes of possible offspring, he asked learners to solve a variety of application problems in small groups.

	T	**t**
T	**TT**	**Tt**
t	**Tt**	**tt**

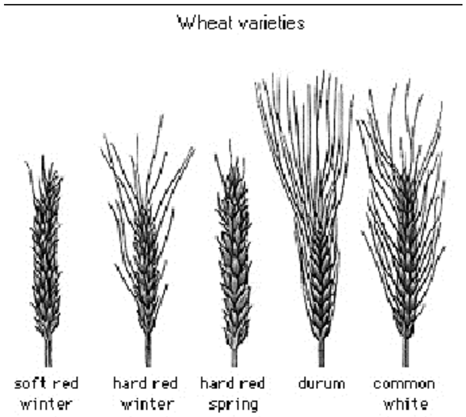
6	Thinking about how you would teach, how would you end this lesson?	
	A	Since learners would have already discussed the problems in their small groups and developed their own understanding of the topic, I would end the lesson here.
	B	I would give the learners the right answers to the problems.
	C	I would ask learners to explain their answers to the class. Drawing on their explanations, I would guide them to the correct answers.
	D	I would review the correct answers to the problems with the learners as a class discussion.

Succession

Ms. Tutt’s grade 11 class has just finished an introductory lesson on plant succession. The learners now understand that succession can be initiated either by the formation of a new, unoccupied habitat (*primary succession*) or by some form of disturbance of an existing community (*secondary succession*). She is now considering the use of a follow up activity at a green space near campus and has several options.



7	Thinking about how you would teach, of the following, which is most similar to what you would do?	
	A	Provide the learners with a map of the green space demarcating succession. I would then walk the learners through the succession areas pointing out the plant life specific to each area.
	B	Provide the learners with a map of the green space demarcating succession. The learners’ task would be to identify the types of plant life in each succession area.
	C	Ask the learners if they thought they could identify succession and how they would do it. Then we would go to the green space, and the learners’ task would be to map out succession at the green space, developing and documenting their own maps.
	D	Take the learners to the green space and ask them to observe as much as they could be corresponding to our recent studies on succession. I would leave it to the learners’ own imaginations on how best to use their observations of a real succession environment, and how to document those observations.

Varieties of wheat Ms. Coker will be teaching her grade 8 a unit on edible plants. Today’s topic is that wheat comes in many different varieties. 		
8	Thinking about how you would teach, of the following, which is most similar to how you would use a transparency such as the one shown in this diagram?	
	A	I would give my learners many types of wheat to sort by appearance. Once the task was completed, I would show the transparency and ask the learners how their sorting compared with the pictures on the transparency. I would then conclude the lesson by reviewing the intended learning outcome.
	B	I would give my learners samples of wheat to look at. As I explained the concepts to be learned, I would have them identify the wheat samples by referring to the transparency.
	C	It is important to state the intended learning outcome at the start of the lesson, so I would use the transparency as I explain the concepts to be learned, and show them an example of a wheat stalk of each kind.
	D	I would not use a transparency such as this, as it would make the lesson too teacher directed. I would give my learners samples of wheat to sort by characteristics of their choosing and then record their results. The lesson would conclude with a discussion of their findings.

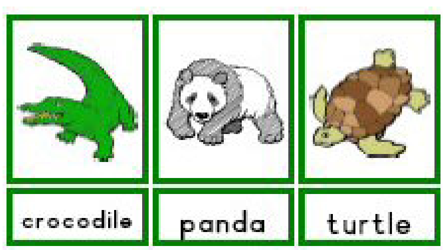
Planets and life

Having already learned the requirements for life on Earth, Ms. Taylor wants her grade 9 class to consider whether or not life might be possible on *other* planets. To do this, she has small groups of learners' research each of the other planets, paying special attention to the characteristics that would and would not make them suitable for life, and report back to the class on their findings.

9	Thinking about how you would teach this lesson, of the following, which best describes how you might *change* the lesson?	
	A	Instead of having learners research the other planets, I would describe their characteristics and after that give them this group assignment.
	B	I would instead simply pose the question of whether life might be possible on other planets, and allow the learners to discuss and research this question in small groups, reporting back to the class.
	C	I would instead describe the characteristics of the other planets for my class, highlighting whether the ones which are necessary for life are present or absent.
	D	I would teach this lesson in a similar manner to Ms. Taylor, because she gives the learners a focus but allows them to do their own research.

Animal sorting

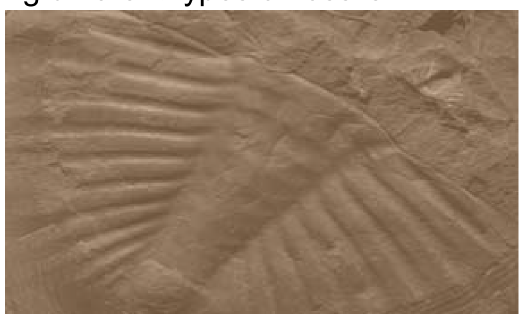
Ms. Lodge is teaching her grade 8 that the process of sorting involves identifying characteristics and grouping accordingly. She gives each learner a set of 10 animal cards, and asked them to sort the animals into groups with similar characteristics.



10	Thinking about how you would teach, of the following, how would you make this lesson more effective?	
	A	This lesson would be more effective if Ms. Lodge had started by explaining the process of sorting and then allowed the learners to sort the animals based on

		characteristics.
	B	I wouldn't change this lesson; the learners choose their own approach to sorting.
	C	This lesson would be more effective if Ms. Lodge explained and demonstrated the process of sorting using animals cards.
	D	This lesson would be more effective if Ms. Lodge had concluded by drawing on the learners' work to highlight the process of sorting.

Fossils provide evidence for change
Ms. Jefferson's grade 12 is learning about how fossils can provide evidence of how life has changed over time. She poses a question: "How do fossils help show us changes on Earth over time?" Ms. Jefferson continues by asking the learners to examine several different rock samples, all containing different types of fossils.



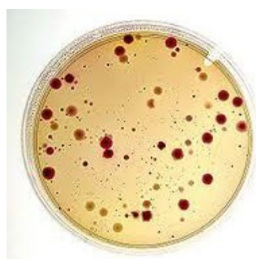
11	Thinking of how you would teach this lesson, of the following, how would you evaluate this lesson so far?	
	A	The learners are making asked to make observations before being instructed on what to look for. Instead, Ms. Jefferson should have described how fossils provide evidence of change over time, using the fossil samples as examples to demonstrate her point.
	B	The learners are asked to make observations before being instructed on what to look for. Instead, Ms. Jefferson should have described how fossils provide evidence of change over time, and then have the learners examine the different rock samples to verify Ms. Jefferson's explanation.
	C	This lesson is fine the way it is. Ms. Jefferson states a question for the learners to think about and then provides materials the learners can utilize to explore this question.
	D	Ms. Jefferson should have not posed such a detailed question prior to learner investigations. The learners should have been allowed to examine the rock samples and, as a class, discussed their ideas about the fossils.

Hand sanitizers: a teachable moment Ms. Simmons' grade 10 class is learning about where bacteria are found and their influence on humans, when one of the learners asks, "Why do we use hand sanitizers?" Ms. Simmons is not sure of the best way to respond to this learner's question with respect to the lesson objectives. 		
12	Thinking about how you would teach, of the following, which is most similar to how you would deal with this teachable moment?	
	A	I would encourage the learners to think of ways to answer this question, and give them time and materials to pursue their own investigations.
	B	I would give my learners a brief explanation of how hand sanitizers work and tie this information to what we had been studying about bacteria. Then we would get back to the lesson objectives.
	C	I would give my learners a brief explanation of how hand sanitizers work and then ask my learners if they could think of ways to test their effectiveness. I would conclude the lesson by tying their ideas back to the objectives.
	D	I would elicit the learners' ideas about the question, including how to test those ideas. We would try some of those tests and I would conclude the lesson by tying their findings back to the objectives.
Plant misconceptions The learners in Mr. Gordon's grade 8 class are learning how plants grow, what parts plants are composed of, and what they can be used for. Mr. Gordon has the learners create a book about what they are learning. As learners work on their books; he notices that some have the misconception that plants "eat dirt." What can Mr. Gordon do to address this misconception? 		

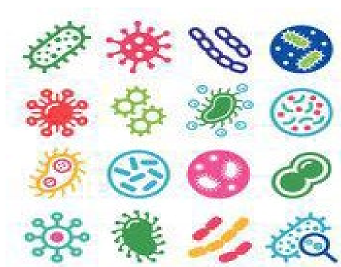
13	Thinking about how you would teach this lesson, of the following, which offers the best advice for dealing with this misconception?	
	A	Mr. Gordon should explicitly point out the evidence that indicates plants do not eat dirt. He should then reinforce this with an additional short activity that illustrates his point.
	B	Mr. Gordon should explicitly point out the evidence that indicates plants do not eat dirt. The learners can then revise their books to match this understanding.
	C	Mr. Gordon should ask learners to develop and conduct their own investigations into what plants eat.
	D	Mr. Gordon should have learners conduct a short activity that demonstrates that plants do not eat dirt. He should then ask them to challenge their ideas about what plants eat, given the results.

Bacteria

Ms. Simon's grade 10 class is studying bacteria. She tells her learners that it is important to wash our hands before eating, even though we cannot see bacteria on them. Ms. Simon explains that, although we cannot see individual organisms, given nutrients, thousands more bacteria can grow in one place until the colony becomes visible. She demonstrates this by showing learners the bacterial colonies that grew on some agar plates she had inoculated several days previously. She finishes the lesson with a reminder to wash the bacteria off your hands before eating.



14	Thinking about how you would teach this lesson, of the following, which one is most similar to what you would likely do?	
	A	I would begin by simply giving learners fresh agar plates to inoculate (in any safe manner), and having them observe the plates over several days. I would end with a class discussion about what they learned from their observations and how it relates to being healthy.
	B	I would begin and end the lesson the same as Ms. Simon. However, rather than showing them plates with bacteria already on them, I would allow learners to touch their fingers onto their own fresh agar plates and then make observations over several days.
	C	I would begin by having a class discussion on whether it is important to wash our hands before eating. Then I would have learners touch their fingers onto their own fresh agar plates and make observations over several days. We would finish the

		lesson by relating learner observations to the importance of hand-washing.
	D	I would conduct this lesson in a similar way to Ms. Simon.
Microbes Mr. Green is introducing his grade 8 learners to the idea that tiny living microbes are found all around us. He has his learners create a list of places where they think that microbes would or would not be found. The learners then share their lists while Mr. Green writes their ideas on the board. 		
15	Thinking about how you would teach, of the following, which is most similar to how you would follow up on this introductory activity?	
	A	I would applaud the learners for their participation, and then end the lesson by having them write a short paragraph on where they believe microbes can be found.
	B	I'd ask the learners what generalizations they might reach based on the lists they created. Then, based on the learners' ideas, I would confirm the point that microbes can be found most everywhere in daily life.
	C	I would explain that microbes can be found almost everywhere in daily life. Then I would use learners' ideas from their lists for support, so that the lesson objective is clearly tied to the learners' ideas.
	D	Rather than beginning the lesson this way, I would have clearly stated what learners were to learn before engaging in any activities.

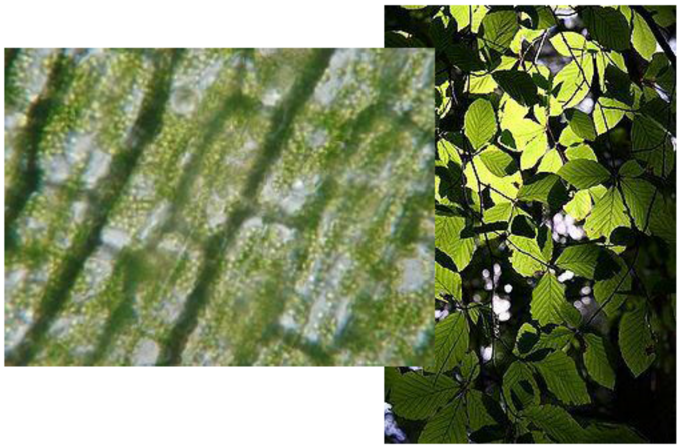
Animal classification

Mr. Clark will be teaching animal classification to his grade 11 learners. Prior to any instruction, Mr. Clark asks his learners to help him make a list of 25 animals. Then each learner works on classifying the animals any way they choose.

16	Thinking about how you would teach, of the following, which is the best evaluation of this introductory lesson?	
	A	This introductory lesson is fine the way it is, because it gives learners the opportunity to discover that there are different ways to classify.
	B	Mr. Clark should have shown the learners how to scientifically classify the listed animals, demonstrating the proper convention.
	C	Mr. Clark should have first described how animal classification using characteristics is done, also providing an example. To verify learner understanding, the learners should then be asked to classify their own list of animals.
	D	This introductory lesson is fine, except Mr. Clark should have provided more guidance on the kinds of characteristics learners should use to group the animals.

Chlorophyll

"Chlorophyll is a natural pigment found in green plants. It is the primary pigment that absorbs light energy from the sun for photosynthesis. This energy is then used by the plant to synthesize carbohydrates from carbon dioxide and water." This is what Ms. Pozner's grade 10 life science textbook says, and she is wondering how best to teach a lesson on chlorophyll and the process of photosynthesis. She has several ideas but each one has limitations.



17	Thinking about how you would teach, of the following ideas that Ms. Pozner is considering, which is most similar to how you would teach this lesson? I would…	
	A	Have the learners read the textbook section on photosynthesis and chlorophyll. We would then have a classroom discussion where we draw out and clarify the important points. I would then summarize the concepts for the learners.
	B	Have the learners read the textbook section on photosynthesis and chlorophyll. I would then explain these concepts while showing relevant slides.
	C	Read aloud the textbook section on photosynthesis and chlorophyll to the class. Then I would explain these concepts while showing relevant slides.
	D	Have the learners use the textbook and online resources to investigate photosynthesis and the role of chlorophyll. I would then have the learners summarize their findings for the class.

APPENDIX L: SDLI QUESTIONNAIRE

Cheng's Self-Directed Learning Instrument

Dear Teacher

Thank you for your willingness to answer a few questions. The purpose of this short questionnaire is to determine what your views are on your own self-directed learning. There are no right or wrong answers. Your real name will not be revealed when we report on the findings.

Name/ pseudonym:

Instructions: Please read each statement and circle the number that best describes your thoughts and feelings about your own learning. There is no right or wrong answer.

5 = Strongly agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly disagree

	5 Strongly agree	4	3	2	1 Strongly disagree
Motivation for learning					
1. I know what I need to learn					
2. Regardless of the results or effectiveness of my learning, I still like learning					
3. I strongly hope to constantly improve and excel in my learning					
4. My successes and failures inspire me to continue learning					
5. I enjoy finding answers to questions					
6. I will not give up learning because I face some difficulties					
Planning and implementation					
7. I can pro-actively establish my learning goals					
8. I know what learning strategies are appropriate for me in reaching my learning goals					
9. I set the priorities of my learning					
10. Whether in the clinical practicum, classroom or on my own, I am able to follow my own plan of learning					
11. I am good at arranging and controlling my learning time					
12. I know how to find resources for my learning					
Self-monitoring					
13. I can connect new knowledge with my own personal experiences					
14. I understand the strengths and weakness of my learning					
15. I can monitor my learning progress					

16. I can evaluate on my own learning outcomes					
Interpersonal communication					
17. My interaction with others helps me plan for further learning					
18. I would like to learn the language and culture of those whom I frequently interact with					
19. I am able to express messages effectively in oral presentations					
20. I am able to communicate messages effectively in writing					

APPENDIX M: RTOP OBSERVATION TOOL

RTOP: Reformed Teaching Observation Protocol

Teacher Candidate: ______________________________

Observer: ______________________________

Grade Level: ____________ Date of Observation: ____________________

Lesson Plan & Implementation

	Never Occurred				Very Descriptive
1.) Instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.	0	1	2	3	4
2.) The lesson was designed to engage students as members of a learning community.	0	1	2	3	4
3.) In this lesson, student exploration preceded formal presentation.	0	1	2	3	4
4.) This lesson encouraged students to seek and value alternative modes of investigation or of problem solving	0	1	2	3	4
5.) The focus and direction of the lesson was often determined by ideas originating with students.	0	1	2	3	4

Content

		Never Occurred				Very Descriptive
Propositional	6.) The lesson involved fundamental concepts of the subject.	0	1	2	3	4
	7.) The lesson promoted strongly coherent conceptual understanding.	0	1	2	3	4
	8.) The teacher had a solid grasp of the subject matter content inherent in the lesson.	0	1	2	3	4

Procedural Knowledge	9.) Elements of abstraction (i.e., symbolic representations, theory building) were encouraged where it was important to do so.	0	1	2	3	4
	10.) Connections with other content disciplines and/ or real world phenomena were explored and valued.	0	1	2	3	4
	11.) Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	0	1	2	3	4
	12.) Students made predictions, estimations and/or hypotheses and devised means for testing them.	0	1	2	3	4
	13.) Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.	0	1	2	3	4
	14.) Students were reflective about their learning.	0	1	2	3	4
	15.) Intellectual rigor, constructive criticism, and the challenging of ideas were valued.	0	1	2	3	4

Classroom Culture

		Never Occurred				Very Descriptive
Communicative Indicators	16.) Students were involved in the communication of their ideas to others using a variety of means and media.	0	1	2	3	4
	17.) The teacher's questions triggered divergent modes of thinking.	0	1	2	3	4
	18.) There was a high proportion of student talk and a significant amount of it occurred between and among students.	0	1	2	3	4
	19.) Student questions and comments often					

	determined the focus and direction of classroom discourse.		0	1	2	3	4
	20.) There was a climate of respect for what others had to say.		0	1	2	3	4
Student/ Teacher Relationships	21.) Active participation of students was encouraged and valued.		0	1	2	3	4
	22.) Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.		0	1	2	3	4
	23.) In general the teacher was patient with students.		0	1	2	3	4
	24. The teacher acted as a resource person, working to support and enhance student investigations.		0	1	2	3	4
	25.) The metaphor "teacher as listener" was very characteristic of this classroom.		0	1	2	3	4

Feedback

APPENDIX N: SEMI-STRUCTURED INTERVIEW SCHEDULE

SEMI-STRUCTURED INTERVIEW

QUESTIONS

1. In your view of the lesson, would you say the overall lesson was a success? Why?
2. Are you satisfied with the way you introduced your lesson? Why?
3. Are you satisfied with your interaction with the learners? Why?
4. Would you say you used a relevant teaching method for this class? Why?
5. If there were some things you could change about your lesson, what would it be and why?

APPENDIX O: PERMISSION TO CONDUCT RESEARCH FROM LIMPOPO DEPARTMENT OF BASIC EDUCATION HOD

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
EDUCATION

CONFIDENTIAL

Ref: 2/2/2 Enq: Makgati DC Tel No: 015 290 9409 E-mail:MakgatiDC@edu.limpopo.gov.za

Chuene KJ
P O Box 1497
Mogodumo
0735

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal: **"THE INFLUENCE OF AN INTERVENTION ON LIFE SCIENCE TEACHERS PERCEPTIONS OF THE NATURE OF SCIENCE, INDIGENOUS KNOWLEDGE AND IMPLICATIONS FOR THEIR PEDAGOGY AND SELF-DIRECTED LEARNING "**
3. The following conditions should be considered:

3.1 The research should not have any financial implications for Limpopo Department of Education.

3.2 Arrangements should be made with the Circuit Office and the School concerned.

3.3 The conduct of research should not in anyhow disrupt the academic programs at the schools.

3.4 The research should not be conducted during the time of Examinations especially the fourth term.

REQUEST FOR PERMISSION TO CONDUCT RESEARCH: CHUENE KJ

Cnr. 113 Biccard & 24 Excelsior Street, POLOKWANE, 0700, Private Bag X9489, POLOKWANE, 0700
Tel: 015 290 7600, Fax: 015 297 6920/4220/4494

The heartland of southern Africa - development is about people!

3.5 During the study, applicable research ethics should be adhered to; in particular the principle of voluntary participation (the people involved should be respected).

3.6 Upon completion of research study, the researcher shall share the final product of the research with the Department.

4 Furthermore, you are expected to produce this letter at Schools/ Offices where you intend conducting your research as an evidence that you are permitted to conduct the research.

5 The department appreciates the contribution that you wish to make and wishes you success in your investigation.

Best wishes

Dedere

03/11/2020

Mrs Dederen KO
Acting Head of Department

Date

REQUEST FOR PERMISSION TO CONDUCT RESEARCH: CHUENE KJ

APPENDIX P: PERMISSION TO CONDUCT RESEARCH FROM DIMAMO CIRCUIT MANAGER

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF EDUCATION
CAPRICORN SOUTH DISTRICT
DIMAMO CIRCUIT

CONFIDENTIAL

18 November 2020

Chuene K.J
P.O.BOX 1497
Mogodume
0735

PERMISSION TO CONDUCT RESEARCH: CHUENE K.J.

1. The above matter refers.
2. The Circuit office under the Limpopo Department of Education appreciates your study and approve your request to conduct research project in our area.
3. We hope you will observe ethical principles or practices of the study.
4. King be aware that this term 4, 2020 examination are running and you will not be allowed to intervene.
5. Therefore this permission will be effective from January 2021.
6. May this project yield fruitful results in developing and revive the spirit of lifelong learning in our teaching staff.

LIMPOPO PROVINCE
DEPARTMENT OF EDUCATION
CAPRICORN SOUTH DISTRICT
DIMAMO CIRCUIT
2020 -11- 18
MANKWENG TOWNSHIP
KGORO YA THUTO LIMPOPO PROVINCE

Circuit Manager

APPENDIX Q: PERMISSION TO CONDUCT RESEARCH FROM PIETERSBURG CIRCUIT MANAGER

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
EDUCATION

CAPRICORN SOUTH DISTRICT
PIETERSBURG CIRCUIT

Enq: Tladi NP
Tel No: 015 290 9484/ 082 954 3476
Date: 23 November 2020

To: Mr Chuene KJ
&
Principals of Secondary Schools
Pietersburg Circuit

Dear Sir/ Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH: CHUENE KJ

1. The above mentioned student attached to NORTH-WEST UNIVERSITY, has been granted permission to conduct research in schools in this Circuit.
2. Pietersburg Circuit secondary schools have been identified as one where he could conduct the research on this research topic **'The influence of an of Life Sciences perceptions of the nature of science, indigenous knowledge and implications for that pedagogy and self-dedicated learning'.**
3. The student is encouraged to come to your school to make final arrangements with you and ensure that this research does not disrupt teaching and learning in the school.
4. Attached kindly find the permission from Head of Department (signed on the 03/11/2020) and application letter from the student.
5. I hope and believe you will be of assistance to the researcher.

CIRCUIT MANAGER: RATALE SM

23/11/2020
DATE

"We Belong, We Care, We Serve"

APPENDIX R: LETTER TO LIMPOPO DEPARTMENT OF BASIC EDUCATION

NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Private Bag X1290,
Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
Fax: +2718 299-4910
Web:http://www.nwu.ac.za

The Faculty of Health Sciences Ethics Office of the North-West University is acknowledged for the use of their document with minor adjustments made by the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-EMELTEN-REC).

NWU-EMELTEN-REC Stamp

The Circuit Manager
Pietersburg Circuit
Capricorn North District

Dear Sir/Madam

Permission to conduct research involving teachers and learners in your circuit.

I hereby request your permission to conduct research involving teachers and learners in your circuit. Information about the research study can be found below.

TITLE OF THE RESEARCH STUDY: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

ETHICS REFERENCE NUMBER: NWU-01115-20-A2

PROJECT SUPERVISOR: Prof. N.T. Petersen
CO-SUPERVISOR: Prof. J.J.J. de Beer
ADDRESS: Potchefstroom Campus, Building B10, Room G51
CONTACT NUMBER: 018 299 1906

POST GRADUATE STUDENT: Karabo Justice Chuene
ADDRESS: P.O. Box 1497
Mogodumo
0735
CONTACT NUMBER: chuenekj@gmail.com or Tel: 083 775 9733

Life Sciences teachers in your circuit will be invited to take part in a **research study** that forms part of Mr Karabo Justice Chuene's PhD study. Please take some time to read the information presented here, which will explain the details of this study. It is very important that you are fully satisfied that you clearly understand what this research is about and how teachers and learners in these circuits might be involved. Participation is **entirely voluntary,** and teachers and learners will be free to say no to participate. If they say no, this will not affect them negatively in any way whatsoever. Teachers are also free to withdraw from the study at any point, even if they initially agree to take part.

This study has been approved by the **North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-01115-20-A2)** and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records once the permission to conduct the research has been granted.

What is this research study all about?

This research study is designed to help Life Sciences teachers in their own professional development as self-directed learners. This study investigates the influence of an intervention on Life Sciences teachers' perceptions of the nature of Science, indigenous knowledge and implications for their pedagogy and self-directed learning. This study will be conducted by Mr Karabo Justice Chuene who is a PhD student at the North-West University, Potchefstroom campus and is supervised by experienced researchers trained in the field of Life Sciences education and engaging pedagogies to support self-directed learning. This study will be conducted in schools situated in Petersburg and Dimamo circuits at venues of the researcher's choice (mainly an intervention at the African Centre for DNA Barcoding at the University of Johannesburg and the participants' respective schools).

Why will schools in your circuit be invited to participate in this study?

High schools in your circuit will be invited to be part of this research (which forms part of a larger NRF project on engaging pedagogies), because they offer Life Sciences as a school subject. The contribution that this study will make is to focus firstly on the development of the teachers' knowledge of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning.

What will be expected of Life Sciences teachers in your circuit?

The teachers will be participating in a study that will take about 6 months to two years, depending on how the Covid-19 pandemic plays out. We would like to involve all 42 Life Sciences teachers in the two districts (Capricorn North and South), 27 as the control group and 15 as the experimental group. All 42 teachers will be requested to complete the Cheng's Self-Directed Learning Instrument (SDLI) instrument before and after the intervention. The 15 sampled teachers will be requested to complete the following instruments before and after the intervention: two open-ended questionnaires namely: Views on the Nature of Science (VNOS) and Views on the Nature of Indigenous Knowledge (VNOIK), a test called Pedagogy of Science Teaching Test (POSTT). In addition, three to four weeks after the intervention, nine out of the fifteen teachers' lesson presentations will be observed in their classrooms by means of the Reformed Teaching Observation Protocol (RTOP). Lastly the observed teachers will individually have a face-to-face interview with the researcher in the comfort of their respective staffrooms during a time of their choice. The teachers will be required to respond freely in their own terms, explain and clarify their answers. The interviews will be audio recorded after which it will be transcribed. The participating teachers will be asked to read through the transcripts in order to determine if it is a true reflection of the conversations that took place during the interviews. All the teachers will have to hand in a voluntary reflection portfolio three to four months after the intervention, if they like to obtain a certificate.

Will schools in your circuit gain anything from taking part in this research?

The gains for the schools if they take part in this study, are that the teachers will enjoy the benefit of a well-designed professional development programme that might assist them as self-directed learners in pursuing their professional growth needs e.g. developing informed views about the nature of science, indigenous knowledge and the implications for their pedagogy and their self-directed learning.

Are there risks involved for schools in your circuit taking part in this research and what will be done to prevent them?

There are no intentional risks anticipated as a result of the teachers' participation. The researcher will treat all participants fairly, honestly, with consideration and with respect. However, teachers will have to give up some of their spare time during the interventions and to complete the instruments. This will be minimized by limiting such sessions to the minimum, and by providing refreshments during the interventions and interviews. Since teachers will be travelling to Johannesburg, as part of the intervention, there could be the danger of road accidents. Only public transport vendors approved by the NWU will be used, and these companies need to comply with a comprehensive list of safety issues, and should have excellent insurance, in the case of an accident.

How will we protect the confidentiality of schools and teachers and who will see your findings?

Confidentiality and anonymity will be ensured by not using any descriptors or names that could lead to the teachers' or schools' identification during data collection, analysis and interpretation. The researcher, as well as the supervisors of the study will be the only individuals who will have access to the data which will be safely stored for a period of 7 years.

What will happen with the findings?

The findings collected will primarily be used by the researcher for obtaining a PhD in Natural Sciences Education. However, the research results could be used for presentations at academic conferences or for the publication of scientific articles. The researcher will still protect the identities of participants and schools during presentations and in scientific articles. Teachers will have access to the findings, and a formal presentation will be made to them, highlighting the outcomes of the research.

How will you know about the results of this research?

A summarized copy of the research findings will be shared with the circuit manager, principals and participating teachers of the respective schools in the circuit.

Will the participant teachers be paid to take part in this study and are there any costs for schools?

Participants will not be paid because there are no costs for them. During the interventions and interviews refreshments will be given to the participants as a sign of appreciation. All participants will also receive a resource kit for teaching Life Sciences, which will become the property of the school. Participants will benefit by participating in interventions that will be offered free of charge to them. All their costs, e.g. travelling to Johannesburg, and accommodation during the UJ intervention, will be paid by the NWU (funding provided by the Fuchs Foundation).

Is there anything else that you should know or do?

- You can contact Prof Neal Petersen at 018 299 1906 or Neal.petersen@nwu.ac.za if you have any further questions or have any problems.
- You can contact Karabo Justice Chuene at 083 775 9733 or via email at chuenekj@gmail.com if you have any further questions or have any problems.
- You can also contact the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee via Mrs Villera le Roux at 018 299 4707 or

Villera.leroux@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.

I would appreciate it very much if you could respond to my request at my following e-mail address: neal.petersen@nwu.ac.za

Yours sincerely

Prof Neal Petersen: Principal Investigator

APPENDIX S: LETTER TO PIETERSBURG CIRCUIT MANAGER

Private Bag X1290,
Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
Fax: +2718 299-4910
Web:http://www.nwu.ac.za

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NWU-EMELTEN-REC Stamp

The Circuit Manager
Dimamo Circuit
Capricorn South District

Dear Sir/Madam

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POST GRADUATE STUDENT: Karabo Justice Chuene
ADDRESS: P.O. Box 1497
Mogodumo
0735
CONTACT NUMBER: chuenekj@gmail.com or Tel: 083 775 9733

Life Sciences teachers in your circuit will be invited to take part in a **research study** that forms part of Mr Karabo Justice Chuene's PhD study. Please take some time to read the information presented here, which will explain the details of this study. It is very important that you are fully satisfied that you clearly understand what this research is about and how teachers and learners in these circuits might be involved. Participation is **entirely voluntary,** and teachers and learners will be free to say no to participate. If they say no, this will not affect them negatively in any way whatsoever. Teachers are also free to withdraw from the study at any point, even if they initially agree to take part.

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What is this research study all about?

This research study is designed to help Life Sciences teachers in their own professional development as self-directed learners. This study investigates the influence of an intervention on Life Sciences teachers' perceptions of the nature of Science, indigenous knowledge and implications for their pedagogy and self-directed learning. This study will be conducted by Mr Karabo Justice Chuene who is a PhD student at the North-West University, Potchefstroom campus and is supervised by experienced researchers trained in the field of Life Sciences education and engaging pedagogies to support self-directed learning. This study will be conducted in schools situated in Petersburg and Dimamo circuits at venues of the researcher's choice (mainly an intervention at the African Centre for DNA Barcoding at the University of Johannesburg and the participants' respective schools).

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Will schools in your circuit gain anything from taking part in this research?

The gains for the schools if they take part in this study, are that the teachers will enjoy the benefit of a well-designed professional development programme that might assist them as self-directed learners in pursuing their professional growth needs e.g. developing informed views about the nature of science, indigenous knowledge and the implications for their pedagogy and their self-directed learning.

Are there risks involved for schools in your circuit taking part in this research and what will be done to prevent them?

There are no intentional risks anticipated as a result of the teachers' participation. The researcher will treat all participants fairly, honestly, with consideration and with respect. However, teachers will have to give up some of their spare time during the interventions and to complete the instruments. This will be minimized by limiting such sessions to the minimum, and by providing refreshments during the interventions and interviews. Since *teachers will be travelling to Johannesburg, as part of the intervention, there could be the danger of road accidents. Only public transport vendors approved by the NWU will be used, and these companies need to comply* with *a comprehensive list of safety issues, and should have excellent insurance, in the case of an accident.*

How will we protect the confidentiality of schools and teachers and who will see your findings?

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What will happen with the findings?

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How will you know about the results of this research?

A summarized copy of the research findings will be shared with the circuit manager, principals and participating teachers of the respective schools in the circuit.

Will the participant teachers be paid to take part in this study and are there any costs for schools?

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Is there anything else that you should know or do?

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Research Ethics Committee via Mrs Villera le Roux at 018 299 4707 or Villera.leroux@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.

I would appreciate it very much if you could respond to my request at my following e-mail address: neal.petersen@nwu.ac.za

Yours sincerely

Prof Neal Petersen: Principal Investigator

APPENDIX T: LETTER TO DIMAMO CIRCUIT MANAGER

Private Bag X1290,
Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
Fax: +2718 299-4910
Web:http://www.nwu.ac.za

The Faculty of Health Sciences Ethics Office of the North-West University is acknowledged for the use of their document with minor adjustments made by the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-EMELTEN-REC).

NWU-EMELTEN-REC Stamp

The Circuit Manager
Dimamo Circuit
Capricorn South District

Dear Sir/Madam

Permission to conduct research involving teachers and learners in your circuit.

I hereby request your permission to conduct research involving teachers and learners in your circuit. Information about the research study can be found below.

TITLE OF THE RESEARCH STUDY: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

ETHICS REFERENCE NUMBER: NWU-01115-20-A2

PROJECT SUPERVISOR: Prof. N.T. Petersen
CO-SUPERVISOR: Prof. J.J.J. de Beer
ADDRESS: Potchefstroom Campus, Building B10, Room G51
CONTACT NUMBER: 018 299 1906

POST GRADUATE STUDENT: Karabo Justice Chuene
ADDRESS: P.O. Box 1497
Mogodumo
0735
CONTACT NUMBER: chuenekj@gmail.com or Tel: 083 775 9733

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There are no intentional risks anticipated as a result of the teachers' participation. The researcher will treat all participants fairly, honestly, with consideration and with respect. However, teachers will have to give up some of their spare time during the interventions and to complete the instruments. This will be minimized by limiting such sessions to the minimum, and by providing refreshments during the interventions and interviews. Since *teachers will be travelling to Johannesburg, as part of the intervention, there could be the danger of road accidents. Only public transport vendors approved by the NWU will be used, and these companies need to comply* with *a comprehensive list of safety issues, and should have excellent insurance, in the case of an accident.*

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How will you know about the results of this research?

A summarized copy of the research findings will be shared with the circuit manager, principals and participating teachers of the respective schools in the circuit.

Will the participant teachers be paid to take part in this study and are there any costs for schools?

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I would appreciate it very much if you could respond to my request at my following e-mail address: neal.petersen@nwu.ac.za

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Yours sincerely

Prof Neal Petersen: Principal Investigator

APPENDIX U: LETTER TO SCHOOL PRINCIPALS

NWU®

NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Private Bag X1290, Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
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NWU-EMELTEN-REC Stamp

The Principal
Name of school
Address of school

Dear Sir/Madam

Permission to conduct research involving teachers and learners of your school.

I hereby request your permission to conduct research involving teachers and learners of your school. Information about the research study can be found below.

TITLE OF THE RESEARCH STUDY: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

ETHICS REFERENCE NUMBER: NWU-01115-20-A2

PROJECT SUPERVISOR: Prof. N.T. Petersen

CO-SUPERVISOR: Prof. J.J.J. de Beer

ADDRESS: Potchefstroom Campus, Building B10, Room G51

CONTACT NUMBER: 018 299 1906

POST GRADUATE STUDENT: Karabo Justice Chuene

ADDRESS: P.O. Box 1497
Mogodumo
0735
CONTACT NUMBER: chuenekj@gmail.com or Tel: 083 775 9733

Teachers in your school are invited to take part in a **research study** that forms part of Mr Karabo Justice Chuene's PhD study. Please take some time to read the information presented here, which will explain the details of this study. It is very important that you are fully satisfied that you clearly understand what this research is about and how teachers and learners in these circuits might be involved. Participation is **entirely voluntary,** and teachers and learners will be free to say no to participate. If they say no, this will not affect them negatively in any way whatsoever. Teachers are also free to withdraw from the study at any point, even if they initially agree to take part.

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What will be expected of your school and teachers?

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How will we protect the confidentiality of your school and teachers and who will see the findings?

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What will happen with the findings?

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How will you know about the results of this research?

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Is there anything else that you should know or do?

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____

Yours sincerely

Prof Neal Petersen: Principal Investigator

APPENDIX V: LETTER TO SGB CHAIRPERSONS

NWU®
NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Private Bag X1290, Potchefstroom
South Africa 2520
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NWU-EMELTEN-REC Stamp

The School Governing Body chairperson
Name of school
Address of school

Dear Sir/Madam

Permission to conduct research involving teachers and learners of your school.

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TITLE OF THE RESEARCH STUDY: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

ETHICS REFERENCE NUMBER: NWU-01115-20-A2

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CO-SUPERVISOR: Prof. J.J.J. de Beer
ADDRESS: Potchefstroom Campus, Building B10, Room G51
CONTACT NUMBER: 018 299 1906

POST GRADUATE STUDENT: Karabo Justice Chuene

Page 1 of 5

ADDRESS: P.O. Box 1497
Mogodumo
0735
CONTACT NUMBER: chuenekj@gmail.com or Tel: 083 775 9733

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- You can contact Karabo Justice Chuene at 083 775 9733 or via email at chuenekj@gmail.com if you have any further questions or have any problems.

- You can also contact the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee via Mrs Villera le Roux at 018 299 4707 or Villera.leroux@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.

I would appreciate it very much if you could respond to my request at my following e-mail address: neal.petersen@nwu.ac.za

____

Yours sincerely

Prof Neal Petersen: Principal Investigator

APPENDIX W: INVITATION LETTER TO THE LIFE SCIENCES TEACHERS

NWU®
NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Private Bag X1290, Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
Fax: +2718 299-4910
Web: http://www.nwu.ac.za

Prof Neal Petersen

Deputy School Director: School of Mathematics, Science and Technology Education

Faculty of Education

Tel: 018 299 1906

Neal.petersen@nwu.ac.za

Date:

TO: The Life Sciences Teacher
(NAME OF SCHOOL)
Limpopo Province

RE: INVITATION TO PARTCIPATE IN A RESEARCH

Dear Sir/Madam

You are hereby cordially invited to participate in a research Involving as a dedicated Life Sciences teacher in your school.

TITLE OF THE RESEARCH STUDY: The influence of an intervention on Life Sciences teachers' perceptions of the nature of Science, indigenous knowledge and implications for their pedagogy and self-directed learning

ETHICS REFERENCE NUMBER: NWU-01115-20-A2

PRINCIPAL INVESTIGATOR: Prof Neal Petersen

POST GRADUATE STUDENT: Karabo Justice Chuene

ADDRESS: G51, B10 Building, Faculty of Education, North-West University, Potchefstroom

CONTACT NUMBER: Cell: 084 616 0026/ Office: (018) 299-1906.

POST GRADUATE STUDENT:
ADDRESS: Ga-Chuene Maratapelo Village House no.049
CONTACT NUMBER: 083 775 9733/071 860 0104/ 015 268 3888

As a dedicated Life Sciences teacher you are invited to take part in a **research study** that forms part of Mr Karabo Justice Chuene's PhD study. Please take some time to read the information presented here, which will explain the details of this study. It is very important that you are fully satisfied that you clearly understand what this research is about and how you and learners of your school might be involved. Participation is **entirely voluntary,** and you and your learners will be free to say no to participate. If you and your learners say no, this will not affect you and your learners negatively in any way whatsoever. As a Life Sciences you are also free to withdraw from the study at any point, even if you initially agreed to take part.

This study has been approved by the **North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-01115-20-A2)** and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records. Permission to conduct the research has been granted by the Provincial Department of Basic Education of the Limpopo Province.

What is this research study all about?

This research study is designed to help Life Sciences teachers in their own professional development as self-directed learners. This study investigates the influence of an intervention on Life Sciences teachers' perceptions of the nature of Science, indigenous knowledge and implications for their pedagogy and self-directed learning. This study will be conducted by Mr Karabo Justice Chuene who is a PhD student at the North-West University, Potchefstroom campus and is supervised by experienced researchers trained in the field of Life Sciences education and engaging pedagogies to support self-directed learning.
This study will be conducted in schools situated in the Capricorn North and South districts at venues of the researcher's choice (mainly an intervention at the African Centre for DNA Barcoding at the University of Johannesburg and the participants' respective schools).

Why have you been invited to participate?

Your have been invited to be part of this research (which forms part of a larger NRF project on engaging pedagogies), because you are a Life Sciences as a school teacher with a minimum of three years teaching experience. The contribution that this study will make is to focus firstly on the development of the teachers' knowledge of nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning.

What will be expected of you as a Life Sciences teacher?

You will be participating in a study that will take about 6 months to two years, depending on how the Covid-19 pandemic plays out. You will be requested to complete two open-ended questionnaires namely: Views on the Nature of Science (VNOS) and Views on the Nature of Indigenous Knowledge (VNOIK). You will further be requested to complete a test called Pedagogy of Science Teaching Test (POSTT) and The Cheng's Self-Directed Learning Instrument (SDLI). You will be requested to complete the aforementioned instruments before the intervention (to take place at the DNA Barcoding laboratory workshop at the University of Johannesburg that will be funded by the NWU). The cost for the intervention will be incurred by the Fuchs Foundation. Three to four months after the intervention, you will again be requested to complete two open-ended questionnaires namely: Views on the Nature of Science (VNOS) and Views on the Nature of Indigenous Knowledge (VNOIK). You will further be requested to complete a test called Pedagogy of Science Teaching Test (POSTT) and The Cheng's Self-Directed Learning Instrument (SDLI). In addition, nine of you, out of the fifteen will be observed once in once in your classrooms through the administration of the Reformed Teaching Observation Protocol (RTOP). The observations will be video recorded, with the entire focus of the record on you, the Life Sciences teacher. Lastly, you will individually have a face-to-face interview with the researcher in the comfort of their respective staffrooms during the time of their choice. You will be required to respond freely in your own terms, explain and clarify your answers. In other words, open-ended face-to-face interviews will allow you to respond in whatever way you find it appropriate based on your personal experiences and knowledge through the use of audio recorder for safe keeping and recording of the correct responses made by the you and other participating teachers. You will be requested will to hand -in a reflection portfolio at the end of the interventions, in order to obtain a certificate.

Will you gain anything from taking part in this research?

The gains for you if you take part in this study, is that you will enjoy the benefit of a well-designed professional development programme, that might assist you as a self-directed learner in pursuing your professional growth needs, e.g. developing informed views about the nature of science, indigenous knowledge and the implications for your pedagogy and your self-directed learning.

Are there any risks involved in participating in this research and what will be done to prevent them?

There are no intentional risks or harm that are anticipated as result of your participation. The researcher will treat you fairly, honestly, with consideration and with respect. However, you will have to give up some of your spare time during the interventions, completing of the open-ended questionnaires, the test, being involved in observations and interview sessions. This will be minimized by limiting such sessions to the minimum, and by providing refreshments during the interventions and interviews. Since you will be travelling to Johannesburg, as part of the intervention, there is always the danger of road accidents. Only public transport vendors approved by the NWU will be used, and these companies need to comply to a comprehensive list of safety issues, and should have excellent insurance, in a case of an accident.

How will we protect your identity and the identity of your school and who will have access to the research data?

Confidentiality and anonymity will be ensured by not using any descriptors or names that could lead to you or your schools' identification during data collection, analysis and interpretation. The researcher, as well as the supervisors of the study will be the only individuals who will have access to the data which will be safely stored for a period of 7 years.

What will happen with the findings?

The findings collected will primarily be used by the researcher for obtaining a PhD in Natural Sciences Education. However, the research results could be used for presentations at academic conferences or for the publication of scientific articles. The researcher will still protect the identities of participants and schools during presentations and in scientific articles. You will have access to the findings, and a formal presentation will be made to you, highlighting the outcomes of the research.

How will the findings of this research be shared with the school?

A summarized copy of the research findings will be shared with the principals and participating teachers of the respective schools.

Will participants be paid to take part in this study and are there any costs for them?

You will not be paid because there are no costs for you. During the interventions and interviews you will be given refreshments as a sign of appreciation. You and other participating Life Sciences teachers will also receive a resource kit for teaching Life Sciences, which will become your property and that of your school. You will benefit by participating in interventions that will be offered free of charge to them. All their costs, e.g. travelling to Johannesburg, and accommodation during the UJ intervention, will be paid by the NWU (funding provided by the Fuchs Foundation).

Is there anything else that you should know or do?

- You can contact Prof Neal Petersen at 018 299 1906 or neal.petersen@nwu.ac.za if you have any further questions or have any problems.
- You can contact Karabo Justice Chuene at 083 775 9733/ 071 860 014/ 015 268 3888 or via email at chuenekj@gmail.com if you have any further questions or have any problems.
- You can also contact the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee via Mrs Villera le Roux at 018 299 4707 or Villera.leroux@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.

I would appreciate it very much if you could respond to my request at my e-mail address given above: neal.petersen@nwu.ac.za

____

Yours sincerely

Prof Neal Petersen: Principal Investigator

APPENDIX X: INFORMED CONSENT FOR TEACHER PARTICIPANTS

NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Private Bag X1290, Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
Fax: +2718 299-4910
Web: http://www.nwu.ac.za

The Faculty of Health Sciences Ethics Office of the North-West University is acknowledged for the use of their document with minor adjustments made by the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-EMELTEN-REC).

NWU-EMELTEN-REC Stamp

INFORMED CONSENT DOCUMENT FOR TEACHER PARTICIPANTS

TITLE OF THE RESEARCH STUDY: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

ETHICS REFERENCE NUMBER: NWU-01115-20-A2

PROJECT SUPERVISOR: Prof. N.T. Petersen

CO-SUPERVISOR: Prof. J.J.J. de Beer

ADDRESS: Potchefstroom Campus, Building B10, Room G51

CONTACT NUMBER: 018 299 1906

POST GRADUATE STUDENT: Karabo Justice Chuene

ADDRESS: P.O. Box 1497

Mogodumo

0735

CONTACT NUMBER: chuenekj@gmail.com or Tel: 083 775 9733

As a Life Sciences teacher in your school, you are cordially invited to take part in a **research study** that forms part of Mr Karabo Justice Chuene's PhD study. Please take some time to read the information presented here, which will explain the details of this study. It is very important that you are fully satisfied that you clearly understand what this research is about and how teachers and learners in these circuits might be involved. Participation is **entirely voluntary,** and teachers and learners will be free to say no to participate. If they say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you initially agreed to take part.

This study has been approved by the **North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-01115-20-A2)** and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records once the permission to conduct the research has been granted.

What is this research study all about?

This research study is designed to help Life Sciences teachers in their own professional development as self-directed learners. This study investigates the influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning. This study will be conducted by Mr Karabo Justice Chuene who is a PhD student at the North-West University, Potchefstroom campus and is supervised by experienced researchers trained in the field of Life Sciences education and engaging pedagogies to support self-directed learning. This study will be conducted in schools situated in Pietersburg and Dimamo circuits at venues of the researcher's choice (mainly an intervention at the African Centre for DNA Barcoding at the University of Johannesburg and your respective school).

Why have you been invited to participate in this study?

You have been invited to be part of this research (which forms part of a larger NRF project on engaging pedagogies), because you and your school teach and offer Life Sciences as a school subject. The contribution that this study will make is to focus firstly on your development of knowledge of the nature of science, indigenous knowledge and implications for your pedagogy and self-directed learning as a Life Sciences teacher.

What will be expected of you as a teacher?

You will be participating in the study that will take about 6 months to two years, depending on how the Covid-19 pandemic plays out. We like to involve all 42 Life Sciences teachers in the two districts (Capricorn North and South), 27 as the control group and 15 as the experimental group. All the 42 teachers will be requested to complete the Self-Directed Learning Instrument (SDLI) instrument (Cheng et al., 2010) before and after the intervention. The 15 sampled teachers will be requested to complete the following instruments before and after the intervention: two open-ended questionnaires namely: Views on the Nature of Science (VNOS) and Views on the Nature of Indigenous Knowledge (VNOIK), a test called Pedagogy of Science Teaching Test (POSTT). In addition, three to four weeks after the intervention, nine teachers out of the fifteen will be observed in their classrooms by means of the Reformed Teaching Observation Protocol (RTOP). Lastly the observed teacher will individually engage in a face-to-face interview with the researcher in the comfort of his/her respective staffroom during a time of his/her choice. The teacher will be required to respond freely in his/her own terms, explain and clarify his/her answers. The interviews will be audio recorded after which it will be transcribed. The participating teacher will be asked to read through the transcripts in order to determine if it is a true reflection of the conversation that took place during the interview. You will have to hand in a voluntary reflection portfolio three to four months after the intervention, if you wish to obtain a certificate.

Will you gain anything from taking part in this research?

The gains for you if you take part in this study, is that the you will enjoy the benefit of a well-designed professional development programme, that might assist you as a self-directed learner in pursuing your professional growth needs, e.g. developing informed views about the nature of science, indigenous knowledge and the implications for your pedagogy and their self-directed learning.

Are there risks involved in you taking part in this research and what will be done to prevent them?

There are no intentional risks anticipated as result of your participation. The researcher will treat all participants fairly, honestly, with consideration and with respect. However, you will have to give up some of your spare time during the interventions and to complete the instruments. This will be minimized by limiting such sessions to the minimum, and by providing refreshments during the interventions and interviews. Since you as a teacher will be travelling to Johannesburg, as part of the intervention, there is the danger of road accidents. Only public transport vendors approved by the NWU will be used, and these companies need to comply to a comprehensive list of safety issues, and should have excellent insurance, in a case of an accident. All the prevailing Covid-19 procedures and protocols will be adhered to at the time of the research.

How will we protect your confidentiality as a teacher and who will see the findings?

Confidentiality and anonymity will be ensured by not using any descriptors or names that could lead to you' or your schools' identification during data collection, analysis and interpretation. The researcher, as well as the supervisors of the study will be the only individuals who will have access to the data which will be safely stored for a period of 7 years.

What will happen with the findings?

The findings collected will primarily be used by the researcher for obtaining a PhD in Natural Sciences Education. However, the research results could be used for presentations at academic conferences or for the publication of scientific articles. The researcher will still protect the identities of participants and schools during presentations and in scientific articles. You as a participant will have access to the findings, and a formal presentation will be made to you, highlighting the outcomes of the research.

How will the results of this research be disseminated to you?

Would you like the researcher to send you a short summary of the study results when it is finished around 31 December 2022, you can request so.
If you selected yes, please provide an address where you would like us to send it to you:

Address: ____________________
____
____________________ Email: ____________________________

If you selected no, and you later change your mind, you can still contact me at 083 775 9733 or chuenekj@gmail.com and request that a summary be sent to you.

Will you be paid to take part in this study and are there any costs for you?
Participants will not be paid because there are no costs for them. During the interventions and interviews refreshments will be given to you as a sign of appreciation. You will also receive a resource kit for teaching Life Sciences, which will become the property of the school. You will benefit by participating in the interventions that will be offered free of charge to you. All your costs, e.g. travelling to Johannesburg, and accommodation during the UJ intervention, will be paid by the NWU (funding provided by the Fuchs Foundation).

Is there anything else that you should know or do?

- You can contact Prof Neal Petersen at 018 299 1906 or neal.petersen@nwu.ac.za if you have any further questions or have any problems.
- You can contact Karabo Justice Chuene at 083 775 9733 or via email at chuenekj@gmail.com if you have any further questions or have any problems.

- ➢ You can also contact the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee via Mrs Villera le Roux at 018 299 4707 or Villera.leroux@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.
- ➢ You will receive a copy of this information and consent form for your own purposes.

Declaration by participant

By signing below, I …………………………………...…………. agree to take part in the research study titled: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

I declare that:

- I have read this information/it was explained to me by a trusted person in a language with which I am fluent and comfortable.
- The research was clearly explained to me.
- I have had a chance to ask questions to both the person getting the consent from me, as well as the researcher and all my questions have been answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be handled in a negative way if I do so.
- I may be asked to leave the study before it has finished, if the researcher feels it is in the best interest, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ....…........…………….. on (*date*) …………....……….. 20....

....

Signature of participant   **Signature of witness**

Declaration by person obtaining consent

I *(name)* ……………………………………………..……… declare that:

- I clearly and in detail explained the information in this document to ……………………………………………….
- I did/did not use an interpreter.
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I gave him/her time to discuss it with others if he/she wished to do so.

Signed at (*place*) ....…........…………….. on (*date*) …………....……….. 20....

....

Signature of person obtaining consent

Declaration by researcher

I *(name)* ……………………………………………..……… declare that:

- I explained the information in this document to ……………………………….. **or** I had it explained by …………………………………… who I trained for this purpose.
- I did/did not use an interpreter
- I encouraged him/her to ask questions and took adequate time to answer them or I was available should he/she want to ask any further questions.
- The informed consent was obtained by an independent person.
- I am satisfied that he/she adequately understands all aspects of the research, as described above.
- I am satisfied that he/she had time to discuss it with others if he/she wished to do so.

Signed at (*place*) ....…........…………….. on (*date*) …………....……….. 20....

……………………………

Signature of researcher

Yours sincerely

Prof Neal Petersen

Principal Investigator

APPENDIX Y: ASSENT FORM FOR LEARNERS

Private Bag X1290, Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
Fax: +2718 299-4910
Web: http://www.nwu.ac.za

The Faculty of Health Sciences Ethics Office of the North-West University is acknowledged for the use of their document with minor adjustments made by the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-EMELTEN-REC).

NWU-EMELTEN-REC Stamp

ASSENT FORM FOR LEARNERS

TITLE OF THE RESEARCH STUDY: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

ETHICS REFERENCE NUMBERS: NWU-01115-20-A2

PROJECT SUPERVISOR: Prof. N.T. Petersen
CO-SUPERVISOR: Prof. J.J.J. de Beer
ADDRESS: Potchefstroom Campus, Building B10, Room G51
CONTACT NUMBER: 018 299 1906

POST GRADUATE STUDENT: Karabo Justice Chuene
ADDRESS: P.O. Box 1497
Mogodumo
0735
CONTACT NUMBER: chuenekj@gmail.com or Tel: 083 775 9733

Page 1 of 5

Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher or person explaining the research to you any questions about any part of this study that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research is about. You will not be involved in the research. The researcher will observe your Life Sciences teacher, while he/she is teaching. However, since you will be present in the classroom, I need your consent, that I may observe the lesson while you are present in the classroom.

This study has been approved by the **North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-01115-20-A2)** and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records.

What is this research study all about?

This research study is designed to help Life Sciences teachers in their own professional development as self-directed learners. This study will be conducted by Mr Karabo Justice Chuene who is a PhD student at the North-West University, Potchefstroom campus and is supervised by experienced researchers trained in the field of Life Sciences education and engaging pedagogies to support self-directed learning. This study will be conducted in schools situated in Pietersburg and Dimamo circuits.

How does this research involve you?

Your school and your Life Sciences teacher have been selected to take part in the study. The focus of the research is not on you as a Life Sciences learner at the school, but on your Life Sciences teacher. Because you take Life Sciences as a school subject, you will be present in the class when your Life Sciences teacher's lessons are observed by the researcher. Thus, you are an indirect participant of the study.

What will be expected of you?

The lesson observations will only focus on your Life Sciences teacher and his/her classroom teaching and not on you as a learner. As such, you will be expected to do nothing, except being yourself and behaving in the same way when you attend your Life Sciences lesson. The only difference is that the researcher will be in the classroom with you and observe the teacher while he/she is presenting the lesson.

Will you gain anything from taking part in this research?

There are no direct gains for you, however the findings of the study may promote and improve your Life Sciences teacher's teaching methods and hopefully your learning as well.

Are there any risks involved for you by being present in the classroom when his/her teacher's lessons are observed?

Your presence in the classroom during the teacher's lesson observations pose no conceivable risks to you or your classmates.

How will we protect your identity?

As previously stated, the focus of this research is on your Life Sciences teacher and not on you as a Life Sciences learner. Thus you will not be in any way directly involved in the research itself.

What will happen with the findings of the research?

The findings of the research will be mostly being used for obtaining a PhD degree in Natural Sciences Education.

Is there anything else that you should know or do?

Kindly feel free to contact any one of the researchers involved in the research should you have any questions, or if you encounter any difficulties understanding this letter or need more information concerning the research. We will be happy to answer your questions. You are also welcome to contact the principal of the school, who is fully aware of this research.

- You can contact Prof Neal Petersen at 018 299 1906 or neal.petersen@nwu.ac.za if you have any further questions or have any problems.
- You can contact Karabo Justice Chuene at 083 775 9733 or via email at chuenekj@gmail.com if you have any further questions or have any problems.
- You can also contact the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee via Mrs Villera le Roux at 018 299 4707 or Villera.leroux@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.

Kindly specify/indicate on the next page whether you give your permission to be present in the classroom when the researcher conducts observations of your teacher's Life Sciences lessons.

____

Yours sincerely

Prof Neal Petersen

Principal Investigator

Declaration by the learner

Hereby I (*name and surname*) ……………………………………..………… give my permission to be present when the researcher, Mr Karabo Justice Chuene, conducts observations of my Life Sciences teacher's lessons, in the research study titled: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

Signed at (*place*) ....……..……………… on (*date*) …………..………. 20....

....	....
Signature of learner	**Signature of witness**

Declaration by person obtaining consent

I (*name*) ……………………………………………….……… declare that:

- I clearly and in detail explained the information in this document to

  ……………………………………………………

- I did/did not use an interpreter.
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I gave him/her time to discuss it with others if he/she wished to do so.

Signed at (*place*) .... on (*date*) .... 20....

....
Signature of person obtaining consent

Declaration by researcher

I *(name)* .... declare that:

- I explained the information in this document to .... **or** I had it explained by .... who I trained for this purpose.
- I did/did not use an interpreter
- I encouraged him/her to ask questions and took adequate time to answer them or I was available should he/she want to ask any further questions.
- The informed consent was obtained by an independent person.
- I am satisfied that he/she adequately understands all aspects of the research, as described above.
- I am satisfied that he/she had time to discuss it with others if he/she wished to do so.

Signed at (*place*) .... on (*date*) .... 20....

....
Signature of researcher

APPENDIX Z: INFORMED CONSENT TO LEARNERS' PARENTS

Private Bag X1290, Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
Fax: +2718 299-4910
Web: http://www.nwu.ac.za

The Faculty of Health Sciences Ethics Office of the North-West University is acknowledged for the use of their document with minor adjustments made by the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-EMELTEN-REC).

NWU-EMELTEN-REC Stamp

INFORMED CONSENT DOCUMENT TO CONDUCT CLASSROOM OBSERVATIONS OF LIFE SCIENCES TEACHER'S LESSONS, WHILST YOUR CHILD IS ATTENDING THE LESSON

TITLE OF THE RESEARCH STUDY: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

ETHICS REFERENCE NUMBER: NWU-01115-20-A2

PROJECT SUPERVISOR: Prof. N.T. Petersen
CO-SUPERVISOR: Prof. J.J.J. de Beer
ADDRESS: Potchefstroom Campus, Building B10, Room G51
CONTACT NUMBER: 018 299 1906

POST GRADUATE STUDENT: Karabo Justice Chuene
ADDRESS: P.O. Box 1497
Mogodumo

Page 1 of 6

0735

CONTACT NUMBER: chuenekj@gmail.com or Tel: 083 775 9733

Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher or person explaining the research to you any questions about any part of this study that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research is about.

This study has been approved by the **North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-01115-20-A2)** and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records.

What is this research study all about?

This research study is designed to help Life Sciences teachers in their own professional development as self-directed learners. This study investigates the influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning. This study will be conducted by Mr Karabo Justice Chuene who is a PhD student at the North-West University, Potchefstroom campus and is supervised by experienced researchers trained in the field of Life Sciences education and engaging pedagogies to support self-directed learning. This study will be conducted in schools situated in Pietersburg and Dimamo circuits.

How does this study effect your child?

Your child's school and Life Sciences teacher have been selected to take part in the study. The focus of the research is not on your child as a Life Sciences learner at the school, but on your child's Life Sciences teacher. Because your child takes Life Sciences as a school subject and will be present in the class when his/her Life Sciences teacher's lessons are observed by the researcher, we need your permission that your child may be present during his/her teacher's lesson observation. Thus, your child will be an indirect participant in the study. I will not have any personal contact with your child whatsoever, and nothing will be expected of your child during the lesson observation, as my focus as a researcher will be solely on the Life Sciences teacher's lesson presentation.

What will be expected of your child?

The lesson observation will only focus on your child's Life Sciences teacher teaching and not on your child as a learner. As such, your child will not be expected to do anything, except being a learner and behaving in the same way he/she would normally behave during a Life Sciences lesson. The only difference is that the researcher will sit in the classroom with your child and observe the teacher while he/she is presenting the lesson.

Will your child gain anything from taking part in this research?

There are no direct gains for your child, however the findings of the study may promote and improve his/her Life Sciences teacher's teaching and hopefully your child's learning.

Are there any risks involved for your child by being present in the classroom when his/her teacher's lessons are observed?

Your child's presence in the classroom during the Life Sciences teacher's lesson observations does not pose a foreseeable risk to your child or his/her classmates.

How will we protect your child's identity?

As previously stated, the focus of this research falls on your child's Life Sciences teacher and not on your child as a Life Sciences learner. No form of communication will take place between the researcher and your child and **no video recordings will be made** during the lesson observations. The researcher will not have access to your child's written schoolwork and no assessments of any kind will be conducted by the researcher with your child. Your child's identity will not be revealed in any way by the research, and the name of the school that your child attends, nor the name of his/her Life Sciences teacher will be revealed in the research report.

What will happen with the findings?

The findings of the research will be primarily be used for obtaining a PhD degree in Natural Sciences Education.

Will you or your child be paid to take part in this study and are there any costs for you or your child?

The observations of teachers' Life Sciences lessons will take place during school hours as scheduled on the school's timetable. Consequently, you and your child will not be paid as there are no costs involved for you or your child.

Is there anything else that you should know or do?

Kindly feel free to contact any one of the researchers involved in the research should you have any questions, or if you encounter any difficulties understanding this letter or need more information concerning the research. We will be happy to answer your questions. You are also welcome to contact the principal of the school, who is fully aware of this research.

- You can contact Prof Neal Petersen at 018 299 1906 or neal.petersen@nwu.ac.za if you have any further questions or have any problems.
- You can contact Karabo Justice Chuene at 083 775 9733 or via email at chuenekj@gmail.com if you have any further questions or have any problems.
- You can also contact the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee via Mrs Villera le Roux at 018 299 4707 or Villera.leroux@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.

Kindly specify/indicate on the next page whether you give your permission to be present in the classroom when the researcher conducts observations of your teacher's Life Sciences lessons.

____

Yours sincerely

Prof Neal Petersen

Principal Investigator

Declaration by the parent/guardian

Hereby I (*name and surname*) ……………………………………………… give my permission that my child may be present when the researcher, Mr Karabo Justice Chuene, conducts observations of his/her Life Sciences teacher's lessons, in the research study titled: The influence of an intervention on Life Sciences teachers' perceptions of the nature of science, indigenous knowledge and implications for their pedagogy and self-directed learning

Signed at (*place*) .... on (*date*) .... 20....

....

Signature of parent/guardian **Signature of witness**

Declaration by person obtaining consent

I *(name)* .... declare that:

- I clearly and in detail explained the information in this document to

  ....

- I did/did not use an interpreter.
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I gave him/her time to discuss it with others if he/she wished to do so.

Signed at (*place*) .... on (*date*) .... 20....

....

Signature of person obtaining consent

Declaration by researcher

I *(name)* .... declare that:

- I explained the information in this document to .... **or** I had it explained by .... who I trained for this purpose.
- I did/did not use an interpreter
- I encouraged him/her to ask questions and took adequate time to answer them or I was available should he/she want to ask any further questions.
- The informed consent was obtained by an independent person.

- I am satisfied that he/she adequately understands all aspects of the research, as described above.
- I am satisfied that he/she had time to discuss it with others if he/she wished to do so.

Signed at (*place*) .... on (*date*) .... 20....

....
Signature of researcher

APPENDIX AA: INDEMNITY FORM

NWU®

NWU-EMELTEN-REC

The Faculty of Health Sciences Ethics Office of the North-West University is acknowledged for the use of their document with minor adjustments made by the NWU Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-EMELTEN-REC).

INDEMNITY FORM (NWU-EMELTEN-REC)

I, the undersigned

____

identity number: ________________________________,

hereby indemnify the North-West University ("NWU") and/or any of its office-bearers and staff (temporary or permanent) against any liability in respect of personal losses and/or damages suffered by me or any other person arising from or resulting as a consequence of my participation in the research entitled : **The influence of an intervention on Life Sciences teachers' perceptions of the nature of Science, indigenous knowledge and implications for their pedagogy and self-directed learning** (the "Research"), and hereby hold harmless the NWU against above-mentioned liability.

I confirm that I voluntarily consent to participate in the Research, and that I was in no way forced or coerced by the NWU to participate in the Research, and that the waiver and release shall apply to any claims that may arise during and/or after the Research.

I declare that I am aware of the risks involved in the Research, as explained to me, and of the implications of this waiver and release, and agree that this document shall also be binding upon my executor, curator or other assigns.

Signature ____________________________

Date ____________________________

NWU-EMELTEN-REC Indemnity Form 1

APPENDIX AB: ETHICS TRAINING CERTIFICATES

Zertifikat

Certificado

Certificat

Certificate

TRREE

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

KARABO JUSTICE CHUENE

a complété avec succès - has successfully completed

Introduction to Research Ethics

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2019/07/08

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

FMH

FPH

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TRREE

Zertifikat

Certificat

Certificado

Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
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Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

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a complété avec succès - has successfully completed

Informed Consent

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2019/07/09

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

FMH Continuing Education Program (3 Credits)
Programme de Formation continue (3 Crédits)

Fondation Pharmaceutica Helvetiae FPH Programmes de formation continue
Continuing Education Programs
Programmes de formation continue

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Zertifikat

Certificado

Certificat

Certificate

TRREE

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
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Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

KARABO JUSTICE CHUENE

a complété avec succès - has successfully completed

Research Ethics Evaluation

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2019/07/09

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

FMH Continuing Education Program
Programme de Formation Continue

FPH Programmes de formation continue

Continuing Education Programmes
Programmes de Formation Continue

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TRREE

Zertifikat Certificado Certificat Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

KARABO JUSTICE CHUENE

a complété avec succès - has successfully completed

South Africa

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2019/07/09

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

FMH

FPH

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