ENHANCING GRADE 12 PHYSICAL SCIENCES TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE TO TEACH WORK, ENERGY, AND POWER BILINGUALLY IN THE EASTERN CAPE

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By

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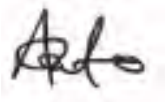
DECLARATION

I Alfred Khumbulani Mapfumo (10M7590) declare that this thesis is my original work and has not been submitted in its entirety or part for examination for a degree to any other university or education institution. Any information that has been obtained from other scholars has been acknowledged by citation and included in the references list.



Signature: Date: June 2024

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[1] My participants permitted me to publish their names.

DEDICATION

My dearly departed grandmother Ambuya Sinisiya Mapfumo, who was the first to inculcate in me the value of hard work and education, is the one to whom I dedicate this thesis. Even though she had little formal education, Makulu (as she preferred to be called) would check my schoolbooks and get me up at dawn so that I could study. This work is the result of the seeds she sowed decades ago.

ABSTRACT

South Africa has been performing very poorly in consecutive Trends in International Mathematics and Science Study (TIMSS) in Science and Mathematics, where it has been ranked last among all participating countries. Similarly, in the recent National Senior Certificate examinations (2017–2023), the percentage of candidates who scored at least 40% in Physical Sciences ranged from 39% to 51%. This points to a possible problem in the teaching and learning of Physical Sciences in schools. On close analysis, the question on the topic of Work, Energy, and Power, in particular, is usually one of the most poorly answered in the Physics paper of the Physical Sciences examination. Some South African studies have concluded that there is poor mastery of the energy concept in the Further Education and Training Phase by both learners and teachers. Against this backdrop, this formative interventionist study sought to support Grade 12 Physical Sciences teachers in co-developing and enacting exemplar lessons on Work, Energy and Power that incorporate everyday and home language through pedagogical translanguaging and transknowledging.

The five teachers from township and rural schools and I formed a Professional Learning Community (PLC) to co-develop lessons later enacted by the teachers. The study was underpinned by an interpretivist paradigm and complemented by the critical theory paradigm. A qualitative case study research design was employed. Data were gathered using semi-structured interviews, document analysis, workshops, lesson observations and participant-teacher reflections. Vygotsky's sociocultural theory was my theoretical framework, while Mavhunga and Rollnick's five components of Topic-Specific Pedagogical Content Knowledge were used as an analytical lens. An inductive-deductive approach to data analysis was used.

This study demonstrated how teachers in a PLC can work together to develop their individual pedagogical content knowledge in particular practice areas. The PLC created lesson plans that guided their use of pedagogical translanguaging techniques, such as code-switching, code-mixing, translation, and versioning of scientific terminology, to facilitate learning. In addition, the PLC created an IsiXhosa glossary for concepts related to Work, Energy, and Power. The study's main contribution is that teachers involved in this study displayed transformative agency through co-constructing their pedagogical content knowledge (PCK) for pedagogical translanguaging.

The study thus recommends that if the goal of improving epistemological access for learners who are learning Physical Sciences in a second language is to be realised, in-service teachers should be capacitated to apply pedagogical translanguaging, which brings about transknowledging using PLCs such as the one-formed for this study.

Keywords: Physical Sciences; Work, Energy and Power, Pedagogical translanguaging; Transknowledging; Professional Learning Community; Sociocultural Theory; Topic-Specific Pedagogical content knowledge

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LIST OF ABBREVIATIONS AND/OR ACRONYMS

ACE:	Advanced Certificate in Education
AI	Artificial Intelligence
ATP:	Annual Teaching Plan
CAPS:	Curriculum and Assessment Policy Statement
CHAT	Cultural Historical Activity Theory
ChatGPT:	Chat Generative Pre-trained Transformer
cPCK:	Collective Pedagogical Content Knowledge
CoP:	Community of Practice
CS	Curriculum Saliency
CTS	Conceptual Teaching Strategies
DBE:	Department of Basic Education
DT:	Difficult to Teach
ePCK:	Enacted Pedagogical Content Knowledge
EFL:	English as a First Language
ESL:	English as a Second Language
FAL:	First Additional Language
FET:	Further Education and Training
GET:	General Education and Training
HELTASA:	Higher Education Learning and Teaching Association of Southern Africa
HoD:	Head of Department
LiEP:	Language in Education Policy
LKO:	Less Knowledgeable Others
LoLT:	Language of Learning and Teaching
MKO:	More Knowledgeable Others
MST:	Mathematics, Science and Technology

MTbBE: Mother Tongue-based Bilingual Education

NCS: National Senior Certificate

OBE: Outcomes Based Education

PCK: Pedagogical Content Knowledge

PGCE: Post Graduate Certificate in Education

PhET: Physics Education Technology

PIRLS: Progress in International Reading Literacy Study

PK: Prior Knowledge

PLC: Professional Learning Community

plPCK: Planned Pedagogical Content Knowledge

pPCK: Personalised Pedagogical Content Knowledge

RCM: Refined Consensus Model

REP: Representations

SAARMSTE: Southern African Association for Researchers in Mathematics, Science and Technology Education

SCT: Sociocultural Theory

SMK: Subject Matter Knowledge

SoTL: Scholarship of Teaching and Learning

STeLLA: Science Teachers Learning from Lesson Analysis

STEM: Science, Technology, Engineering and Mathematics

TEFOL: Teaching English as a Foreign Language

TIMSS: Trends in Mathematics and Science Study

TSPCK: Topic-Specific Pedagogical Content Knowledge

ZPD: Zone of Proximal Development

ZPTD: Zone of Proximal Teacher Development

CHAPTER ONE: CONTEXTUALISATION OF THE STUDY

> The medium of instruction is not just a technical issue, but a social and political one, shaping not only what is taught, but also who is empowered to teach and learn. (Garcia, 2009, p. 9)

1.1 Introduction

This chapter contextualises the study. I start by describing the context of the study in terms of the international benchmark study, Trends in International Mathematics and Science Study (TIMSS) before I indicate the poor performance of candidates in National Senior Certificate examinations in Physical Sciences for the period 2017–2023. The professional development of in-service teachers is also included in the context since the study has an element of teacher professional development. I refer to the findings of my master's study because they also informed this study. From discussing contextual issues, I move on to a statement of the problem and the significance of the study. The research goal, objectives and research questions are presented. Keywords and terms used in this study are defined and explained to clarify how they were used.

1.2 Contextual Background

The International Association of Educational Achievement established the TIMSS, the largest and most comprehensive large-scale assessment of learner achievement in Mathematics and Science for primary and secondary education. South Africa has been competing in TIMSS since grade 9 in 1995. South Africa and a few other African countries such as Morocco, Botswana and Egypt compete at the Grade 9 level in TIMSS. South Africa has had the lowest results in TIMSS studies since 2003 (Reddy et al., 2020).

The TIMSS focuses on Natural Sciences and the findings can be used to identify potential issues in Science teaching and learning at the high school level. The Natural Sciences curriculum in the General Education and Training (GET) Phase, which is the focus of TIMSS, introduces most of the concepts taught in the FET Phase. In South Africa, at the end of Grade 12 school achievement is measured

nationally through the National Senior Certificate examination. In 2021, for instance, 69% of candidates who took the National Senior Certificate Physical Sciences exams scored 30% or higher. Just 44.8% received a score of 40% or above (Department of Basic Education, 2022). This, in my opinion, suggests a problem with the teaching and learning of Physical Sciences in South Africa. Although achievement rates have gradually increased between 2015 and 2020, there is still a need for improvement in the performance of the candidates (Department of Basic Education [DBE], 2022).

For there to be a continued improvement in learner attainment in the National Senior Certificate (NSC) examination, there is a need to improve the pedagogical practices of the Physical Sciences teachers in South Africa. One way to enhance teachers' pedagogical content knowledge (PCK) is through the continuing professional development of teachers, as advocated by Ngcoza and Southwood (2019) and many others. Kriek and Grayson (2009) propose that Physical Sciences teachers' professional development programmes need to address three dimensions: content knowledge, teaching approaches and professional attitudes. Since 2005, there have been several curriculum revisions in South Africa. These revisions have brought in new content that some teachers may not have studied during their initial training. This makes it imperative that there should be continuing professional development of teachers for them to cope with the new curriculum.

Traditionally, in-service teacher professional development programmes are delivered in workshops, seminars, conferences or courses. However, Ono and Ferreira (2010) note that many scholars have criticised these programmes as being brief, fragmented and incoherent encounters that have been removed from their natural context and taken out of the context of actual classroom settings. Bantwini (2019) similarly reports that some Science teachers claim that the workshops were ineffective in addressing their PCK needs as they were not given enough time to assimilate and accommodate the new knowledge.

For instance, workshops are usually conducted at central venues in a district where many teachers are brought together for a day or just a few hours to address a topic or an aspect of the curriculum; up to 100 teachers could be accommodated in a single room. This makes it impossible for the facilitator to pay attention to individual participants' questions and needs. Moreover, workshops rarely provide opportunities for reflection, discussion with colleagues, and continued support is needed to bring about real change in PCK (Murray, 2014). Herein lies the importance of a professional learning community (PLC), noted by Brodie (2013) and her colleagues.

Against this backdrop, this interventionist study attempted to contribute to the professional development of a small group of Grade 12 Physical Sciences[2] teachers who worked *with* me in co-developing exemplar lessons on Work, Energy and Power. The focus of the workshops to pedagogic translanguaging and transknowledging using English and IsiXhosa. The teachers in this PLC were afforded an opportunity to reflect on and discuss issues with other group members (Murray, 2014). The professional development that the teachers experienced in this study was focused on developing Topic-Specific Pedagogical Content Knowledge (TSPCK) as propounded by Mavhunga and Rollnick (2013).

The topic of Different Types of Energy and the Conservation of Mechanical Energy is part of the Physics section of the Physical Sciences curriculum that learners use in Grade 10. The work concept and the work-energy theorem are studied in Grade 12 in South African schools. Learners are expected to be able to state and apply the principle of conservation of mechanical energy in Grades 10 and 12 and use the work-energy theorem in Grade 12 to solve problems in various contexts. In my master's research study, it emerged that Grade 12 learners had inadequate relevant prior content knowledge related to energy concepts (Mapfumo, 2016). Similarly, the examiners and diagnostic reports have, over the years, indicated that learners are not successfully answering questions involving Work, Energy and Power. Moreover, the overall performance in Physical Sciences has been below expectations in the recent past (Department of Basic Education, 2018–2024). See Table 1.1.

Table 1.1: Overall achievement rates in Grade 12 Physical Sciences from 2019 to 2023

Year	No. wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2019	164 478	124 237	75,5	85 034	51,7
2020	174 310	114 758	65,8	73 982	42,4
2021	196 968	135 915	69,0	88 164	44,8
2022	209 004	155 877	74,6	103 811	49,7
2023	206 399	157 368	76,2	105 414	51,1

Source: Adapted from Department of Basic Education (2024, p. 235)

[2] At these schools, only one teacher is teaching Physical Sciences from Grades 10–12.

One of the recommendations that I made from the master's study was that there should be an investigation into the application of translanguaging[3] and transknowledging[4] in the teaching and learning of Work, Energy and Power. In this interventionist study, I thus worked with a group of five Grade 12 Physical Sciences teachers and collectively developed exemplar lessons that applied pedagogic translanguaging and transknowledging between English, the official language of learning and teaching (LoLT), and IsiXhosa, the home language of both the teachers and learners in the study.

1.3 My Lived Experiences with Language and Science Learning - Situating Myself in the Study

I grew up in Mbare, a township in Harare, Zimbabwe's capital. My father passed away when I was just six years old, which made our already dire financial circumstances worse. Growing up in the dusty streets of Mbare, I knew from an early age that education was the only way to escape poverty. As a primary school learner, I dreamed of being an engineer, a dream that strengthened my resolve to work hard in school. After graduating high school, I became interested in the sciences, since these subjects would help me realise my dreams. I passed my Ordinary Level examinations well enough to qualify for the Advanced level where I naturally selected to study Mathematics, Physics and Chemistry.

I was fortunate to attend a secondary school that had reasonably equipped Science laboratories – this increased my interest in Science subjects (Biology and Physical Sciences) as I always looked forward to the practical demonstrations of various experiments. I was also fortunate enough to have good English teachers. For instance, my Form 3 and Form 4 English teacher was a first-language English speaker and the author of one of the prescribed English language textbooks. Before A-level large classes and shortage of space and equipment meant that teachers could only demonstrate the various experiments. The teacher's explanations preceded the demonstrations and notetaking sessions. The lessons were largely teacher-centred and in English only, even though the teachers and learners in my school were mostly chiShona home language speakers. This did not seem problematic at all as my mastery of the English language was good enough for me to make sense of the concepts presented by the teachers and in the textbooks.

[3] Translanguaging is "the process of making meaning, shaping experiences, gaining understanding and knowledge through the use of two languages" (Baker, 2011, p. 288).

[4] Transknowledging is the process of knowledge exchange and production between the colonial and the indigenous epistemologies (Stroud & Kerfoot, 2020).

While I was in high school, there were only two universities in Zimbabwe and as a result, the admission criteria were very high. Unfortunately, although I passed all three A-level subjects I narrowly missed the cut-off point for university admission. The criteria were based on a point system allocated to your grades with an A carrying five points and an E worth one point. Sadly, this was how the engineering dream died but the dream of higher education did not.

Two years after leaving high school I enrolled at a teachers' college where I trained as a high school Science teacher. All the courses were in English and there was never a discussion on teaching sciences by incorporating Indigenous languages. English was the only language of teaching and learning in Zimbabwe at the time and that was not questioned. It was a colonial legacy, and our Indigenous languages were viewed as too primitive to be used for something as advanced as the teaching and learning of Science. I remember we used to look down upon fellow student teachers majoring in chiShona and isiNdebele as we viewed them as majoring in 'useless' subjects. Little did I know at that time that I was a victim of coloniality[5] and self- hate.

After qualifying as a Science teacher, I was deployed to teach in a remote rural village in the Mutoko area in the Mashonaland East province of Zimbabwe. That is a district where the language spoken was a different chiShona dialect. ChiShona is an umbrella term for six different but similar languages (dialects), namely chiZezuru, chiKaranga, chiBuja, chiManyika, chiKorekore and chiNdau. The dialect spoken in the district where I was deployed was chiBuja. The learners' language context was quite different from where I came from. Unfortunately, the learners had little access to radio and television or any other media where they could get access to learn English outside the classroom. As a result, their English proficiency was not at the level where they could learn exclusively in English, – yet the government policy dictated that they could not learn in any language other than English. This was a rude awakening for a young novice teacher, as I realised the challenge posed by learning in English only.

Inexperienced as I was, I viewed the learners' poor English proficiency as a deficiency on their part and not a problem with the system. This is when I started to smuggle my chiZezuru into the Science classroom of chiBuja learners. The situation demanded that I assist learners (with no

[5] The term "coloniality" describes enduring power structures that resulted from colonialism but that go well beyond the precise bounds of colonial governments to shape work, culture, intersubjectivity connections, and knowledge production (Ndlovu, 2018).

training at all) in developing the English proficiency that was needed to learn the Science content (Lee & Buxton, 2013).

After staying in that village for about a year I transferred to Bulawayo, a city where the main Indigenous language spoken was isiNdebele. This language is different from chiShona. The school I was teaching at was in a medium-density suburb and the learners' proficiency in the English language was much stronger than the learners from Mutoko. Although their mastery of the LoLT was better, there were instances where they could not engage fully with me and the concepts in English. This motivated me to learn isiNdebele and again I found spontaneous translanguaging (although I did not know this term at the time) to be helpful. As my isiNdebele proficiency improved with time, I allowed learners to use their home language to ask and answer questions and in oral class discussions. Unfortunately, learners' home language still needed to be smuggled into the classroom (Probyn, 2015). Since using indigenous languages in teaching sciences was not officially permitted, I always made sure to stick to English and insisted that learners do the same whenever we had a visitor in class, such as the head of the department or an official from the Ministry of Education.

After staying in Bulawayo for nine years during which I improved my isiNdebele and smuggled it more and more into the classroom I relocated to South Africa. My first teaching job was in a remote rural village whose economic status was comparable to the Mutoko village in Zimbabwe. It was a tiny senior secondary school (offering Grades 10–12 only) with a total learner population of about 60. As was the case with the Zimbabwean village, there was no electricity in that village; hence most learners did not have access to television, radio, or any other digital media where they could learn English. The only chance they had of learning English was at school. Once more, I sat with a major problem related to the LoLT. This time it was compounded not only by my lack of understanding of IsiXhosa, the home language of my learners, but by being in a different cultural context.

One of my classes in that school was composed of 10 girls. I noticed that they hardly asked anything in class and struggled to answer questions or make any contribution in English. Two weeks into the term the learners in that class decided they could not continue with me as their teacher because of the language barrier. I was the only teacher who taught exclusively in English, a practice they had never experienced before. They raised this concern with their parents who approached the principal requesting that I be removed from the school and replaced by a teacher who spoke IsiXhosa. However, the principal was able to convince the parents that there was nothing wrong with me teaching in English

since it is the official LoLT.

Upon hearing this I decided to make the Physical Sciences lessons more exciting by including language learning. Drawing on my experience I had to use language supporting strategies. One of the strategies was that the learners would teach me IsiXhosa, and I would help them improve their English. This was possible because IsiXhosa and isiNdebele were both Nguni languages and had similarities. My knowledge of isiNdebele became the foundation for my learning of IsiXhosa. Little did I know that what was happening in that classroom was pedagogical translanguaging. What amazed me was that by the time I moved to another school (after just four months) the learners' performance in Science (as well as my IsiXhosa and their English) had greatly improved. Since then, I have learned IsiXhosa to the level where I can speak, read and write nearly fluently. The three language contexts I outlined above, chiBuja, isiNdebele and IsiXhosa planted the seed that ultimately germinated into this PhD study.

1.4 My Positionality and Reflexivity

Holmes (2020) contends that positionality describes a researcher's ontological and epistemological assumptions that they will adopt within a research project, and it influences not only what the researcher chooses to investigate, but also how the research is done. This scholar elaborates that positionality is normally identified in three areas, namely 1) the subject under investigation; 2) the choice of research participants, and 3) the research context and process. Creswell and Creswell (2018) similarly state that in qualitative research, researchers consider how their role in the study and their background, culture, and experiences, can shape their interpretations, such as the themes they advance and the meaning they ascribe to the data.

In this study, I took the relativist ontological position – one that views reality as subjective and differs from person to person. From a relativist perspective, "language activity shapes and moulds reality" (Scotland, 2012, p. 11). This view on the role of language makes it imperative that the language used in constructing knowledge on concepts of Work, Energy, and Power be accessible to both teachers and learners. Epistemologically, I assumed a subjectivist stance. This is the view that "knowledge and meaning of reality are constructed in and out of the interaction between humans and their world and are developed and transmitted in social contexts" (Scotland, 2012, p. 12).

My ontological and epistemological positions may have influenced my interest in exploring the affordances and/or hindrances that can be created by developing Physical Sciences teachers' TSPCK through the pedagogical translanguaging and transknowledging in the mediation of the Physics concepts of Work, Energy and Power. The latter worldview informed my choice of participants. The participants' reality of language usage in their teaching was explored in their own contexts.

My position as a former teacher gave me lived experiences of the challenges faced by learners and teachers who were teaching and learning through a second language. On one hand, I was perceived as the more knowledgeable other (Vygotsky, 1978) while on the other, I was a learner. Being a PhD scholar, who had experience as a lecturer of pre-service teachers, positioned me as a more knowledgeable person. This had the potential to affect their participation in the study. They could have felt that they were to learn *from* me instead of learning *with* me. This was evident in our early encounters and to overcome this, I emphasised my position as an insider rather than an outsider in the PLC meetings and stressed that they are not coming to learn *from* me but to learn *with* me. In my case, I convinced my participants that they were colleagues in the research process and that I was carrying out the research *with* them and not *on* them (Ngcoza & Southwood, 2015). This put them at ease as evidenced by the free flow and contestation of ideas during the workshops.

I was an outsider from one viewpoint and an insider from another. I was an insider because I was a former Physical Sciences teacher in the same province as the participants and had experience working with two of them as NSC examination paper markers. The advantages of an insider position include that it allows the researcher easier access to the participants and the ability to ask more meaningful questions resulting in more valid findings (Holmes, 2020). However, insiders are often accused of being inherently biased and this can affect their ability to observe and interpret their findings objectively (Chavez, 2008; Holmes, 2020). Thus, with this notion of bias in mind, I tried to be as objective as possible and the TSPCK components as analytical lenses helped in this regard.

From another viewpoint, I may also be considered an outsider by the group of teachers I worked with based on my ethnicity, home language and culture. The participants in this study were IsiXhosa home language speakers born and bred in the Eastern Cape, South Africa, while I was a Shona home language speaker born and bred in Zimbabwe. This outsider position could bring some level of mistrust, especially since the study involved the use of pedagogical translanguaging that involved IsiXhosa, which happened to be my fourth language after chiShona, English and isiNdebele. The fact

that I could speak, read and write IsiXhosa quite well helped to mitigate my outsider position to a large extent. Moreover, this placed my participants in the position of more knowledgeable others (MKOs) (Shabani, 2016).

Whether the research is on or with the participants, it is important to adhere to professional ethics. Merriam and Tisdell (2016) note that the research must be conducted ethically to ensure validity and reliability in qualitative research. These authors add that relational ethics which have to do with the researcher's positionality should be considered. This involves being aware of one's role in relationships with participants and treating them with respect and not just as sources of information. In this study, I ensured that I respected my participants' language, culture and values despite being a PhD scholar whom they might have viewed as in a more powerful position than they were.

I considered the cultural and contextual issues when applying the university's code of ethics. For example, everyone in the Xhosa culture (as well as many other African cultures) is a clan member, and clan members can call each other by this name. People regard it as a show of respect to address someone by their clan names rather than by a title like Professor or Doctor (Mutanho, 2021). For instance, when I asked the participants in this study to select their pseudonyms, two of them proudly requested that I use their clan names. Dlamini and MaRadebe (Rhadie) were these people. Clan names also played a role in levelling the power gradients I previously discussed.

Bridges (2017) argues that codes of ethics used by some universities may not be applicable in some cultural settings and contexts such as in Africa. He contends that "openness is secured not by the reassuring terms of contractual engagement (the consent form) but by culturally embedded relationships" (Bridges, 2017, p. 306). For this study, I first explained the study, what roles I expected my participants to play and the level of commitment I expected them to have. Verbal consent was given after all questions and concerns were addressed, and mutual trust was established before the presentation and the signing of the formal consent forms.

Self-reflection is a necessary part of reflexivity. Researchers must be aware of their traits, blind spots, and limits. Although prejudice cannot be eliminated, by revealing it researchers can lessen its effects and improve the quality of their work (Hurst, 2023). As I indicated in Section 1.3, my own experiences influenced my stance concerning the language of teaching, hence the interventionist approach. I was able to adjust and allow my own views and prejudices to be challenged by allowing the participants'

voices to be heard. For instance, mixed views from the participants challenged the view that the language used in the textbooks was inaccessible to the learners. In addition, the data-gathering process kept evolving because of reflecting on the input from the participants. For instance, the initial plan was to conduct face-to-face work, but the participants preferred using MS Teams and I adjusted my plan to accommodate their choice.

1.5 Statement of the Problem and Significance of the Study

As noted earlier, the NCS examination questions on Work, Energy and Power are among the most poorly answered in NSC examinations (Department of Basic Education, 2019–2024). Furthermore, some South African studies, for example, Jita and Ndlalane (2005) and Mchunu (2012), have concluded that there is poor mastery of the energy concept in the FET Phase both by learners and teachers. Students' understanding of the conservation of momentum and the work-energy theorem in Grade 12 suffers from an inadequate grasp of the energy concept taught in Grade 10. This, in turn, contributes to poor achievement in the NSC Physical Sciences examinations. Continuing professional teacher development can be one way of mitigating this poor performance.

Professional development programmes are vehicles to improve teachers' PCK, which in turn goes a long way to enhancing learner achievement. As mentioned earlier, the state of teacher professional development in South Africa is not at its best. Both researchers and teachers have criticised the workshop approach (Bantwini, 2019; Murray, 2014; Ono & Ferreira, 2010). There is a need to employ professional development approaches that help to transform teachers' classroom practice. An approach to teacher development that gives teachers opportunities to co-develop exemplar lessons and teach and reflect on the lessons together with the co-developers was employed in this study.

The primary purpose of this interventionist study was to improve the mediation of the learning of Work, Energy and Power concepts in Grade 12 Physical Sciences using pedagogical translanguaging and transknowledging. This study focus was motivated by studies that indicated that both learners and teachers face challenges with the use of English for pedagogic purposes (Msimanga & Lelliott, 2014; Msimanga & Erduran, 2018) as well as my own lived experiences as outlined in Section 1.3. Considering this, a PLC for Grade 12 Physical Sciences teachers was formed. This small group of five participants and I met regularly to exchange ideas, integrate practices and continuously reflect on their teaching using the Microsoft Teams online platform (Brodie, 2016; Chauraya & Brodie, 2018; Ngcoza & Southwood, 2015). From the activities of the learning community approaches, including the use of

both English and IsiXhosa in teaching Work, Energy and Power were discussed, and common lesson plans were developed. It was also envisaged that the activities of the PLC helped members have a deeper understanding of the relevant content and improve their instructional strategies.

It was hoped that an improvement in the teachers' TSPCK would contribute to improving learner performance when answering questions involving these concepts, which in turn would contribute to a better general performance in Physical Sciences examinations. The study results could also inform teachers, curriculum advisors, teacher trainers and authors of the teaching and learning materials. Moreover, the findings of this study would inform educational policymakers at the national level on how to incorporate learners' home languages into the teaching and learning of Physical Sciences.

The Language in Education Policy of 1997 makes provision for learners to choose to be taught in any of the 12 official languages[6] of South Africa. However, only English and Afrikaans are the languages of learning and teaching beyond the 3rd Grade (Wildsmith-Cromarty & Balfour, 2019). Teachers are not trained to teach in languages other than English or Afrikaans beyond the 3rd grade. This current study attempted to bridge the gap between policy and practice by developing a way to incorporate IsiXhosa as one of the official languages that, according to policy, learners have the right to learn. Translanguaging in mediating the concepts of Work, Energy and Power is preferred to the exclusive use of IsiXhosa for two main reasons.

First, IsiXhosa is a historically marginalised language and is not yet fully accepted as an academic subject. Some academics maintain that IsiXhosa (like other Indigenous African languages) is not developed as an academic language (Kaschula & Kretzer, 2019). With the lack of teacher training and teaching and learning materials written in IsiXhosa, it is difficult at this stage to teach subjects like science exclusively in IsiXhosa. Secondly, the world has become a global village with English fast becoming the language of that global village. Learning Science and entering related careers with a good command of IsiXhosa only may restrict the incumbents' access to opportunities in other parts of South Africa where IsiXhosa is not spoken by the majority as well in the global village where English has a hegemony. In this regard, translanguaging improves access to the powerful knowledge of Physical Sciences and opportunities outside areas where IsiXhosa is the dominant language.

[6] The 12 official languages of South Africa are: Sepedi, Sesotho, Setswana, siSwati, Tshivenda, Xitsonga, Afrikaans, English, isiNdebele, IsiXhosa, isiZulu and sign language.

Translanguaging also improves proficiency in the languages used (Cenoz & Gorter, 2021).

1.6 Research Goal and Objectives

The main goal of this formative interventionist study was to develop Grade 12 Physical Sciences teachers' PCK which focused on using pedagogical translanguaging in IsiXhosa and English when mediating learning of the concepts of Work, Energy and Power.

The objectives of this study were:

1. To establish the Grade 12 Physical Sciences teachers' TSPCK on Work, Energy and Power before the intervention.
2. To establish the learning opportunities that are created through:
   a) Co-analysing curriculum documents focusing on the topic of Work, Energy, and Power concepts
   b) Capacity development workshops focusing on the co-development of exemplar lessons on Work, Energy and Power that take into consideration everyday and home language
3. To explore the influence of the PLC intervention on:
   a) The quality of the participant teachers' bilingual mediation of Work, Energy, and Power in their lessons.
   b) The participant teachers' TSPCK for Work, Energy, and Power.

4. To explore teachers' reflective insights and perspectives on the effectiveness, challenges, and outcomes of the intervention.

1.7 Research Questions

1. What TSPCK (including language usage) on Work, Energy, and Power do Grade 12 Physical Sciences teachers have before the intervention?

2. What learning opportunities are created through:

   a) Co-analysing curriculum documents focusing on Work, Energy and Power concepts?
   b) Capacity development workshops focusing on the co-development of exemplar lessons on Work, Energy and Power that consider learners' home and everyday language?

3. What are the effects of the PLC intervention on:

    a) The quality of the participant teachers' bilingual mediation of Work, Energy, and Power in their lessons?
    b) The participant teachers' TSPCK of Work, Energy, and Power

4. What are teachers' reflective insights and perspectives on the intervention's effectiveness, challenges, and outcomes?

1.8 Theoretical Overview

This study is grounded in Vygotsky's (1978) sociocultural theory as the theoretical framework. I also used Mavhunga and Rollnick's (2013) five components of TSPCK as an analytical/conceptual framework. Cohen et al. (2018) contend that a conceptual framework specifies the key concepts being employed in a particular study while a theoretical framework contains the general ideas that underpin the conceptual relationships. Furthermore, these authors allude to the fact that a theoretical framework is at a higher level of abstraction and generality compared to a conceptual framework.

1.8.1 Theoretical Framework: Vygotsky's sociocultural theory

The sociocultural theory is centred on the premise that knowledge construction is a result of social interactions between more knowledgeable and less knowledgeable individuals. Vygotsky (1987) states that all the uniquely human aspects of consciousness children develop come from a foundation of cooperation and imitation.

Among other authors, Shabani (2016) and Eun (2008) argue that Vygotsky's sociocultural theory originally targeted school children and applies to adult learners such as teachers who were the focus of this study. There are five assumptions form the core ideas of the social learning theory, namely:

> 1. Learning precedes development, 2. Language is the main vehicle (cultural tool) of thought, 3. Mediation is central to learning, 4. Social interaction is the basis of learning and development and 5. The zone of proximal development (ZPD) is the primary activity space in which learning occurs. (Walqui, 2006, p. 160)

Within Vygotsky's sociocultural theory, I used the tenets of mediation of learning, culture and language, social interactions and the ZPD.

1.8.2 Analytical framework: Topic-specific pedagogical content knowledge

Pedagogic content knowledge (PCK) is a concept propounded by Shulman (1986; 1987). Shulman (1987) describes PCK as "the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (p. 15). Kind (2009) posits that PCK provides a theoretical framework for examining and understanding teachers' skills. Members of the PLC co-developed their content knowledge on how to employ pedagogic translanguaging and transknowledging to mediate the construction of knowledge on Work, Energy, and Power in their respective classrooms. This teaches knowledge specific to the topic such as Work, Energy and Power is TSPCK.

Shulman (1986) argues that many of the pedagogical practices that teachers use apply to specific topics and are not transferable to other topics. TSPCK is a version of PCK defined concerning a given topic within a subject such as Science. In other words, it is PCK within a topic (Mavhunga & Rollnick, 2016). Mavhunga and Rollnick (2016, p. 834) define TSPCK as "the knowledge that enables teachers to transform their understanding of content knowledge of a topic". This study explored Grade 12 Physical Sciences teachers' knowledge of energy and work and how they could effectively mediate learning. Mavhunga and Rollnick (2016), drawing on the seminal work of Geddis and Wood (1997) contend that five knowledge components make up a teacher's TSPCK namely (i) learners' prior knowledge including misconceptions, (ii) curricular saliency, (iii) what makes the topic easy or difficult to understand, (iv) representations including powerful examples and analogies, and (v) conceptual teaching strategies. These five components were used in the study as the analytical lenses for exploring and developing the TSPCK of the teachers in the PLC.

1.8.3 The refined consensus model of PCK

The refined consensus Model (RCM) (Mavhunga, 2020) shows that there are three realms of PCK, namely collective PCK (cPCK), personalised PCK (pPCK), which is also referred to as planned PCK (plPCK), and the enacted PCK (ePCK). Mavhunga (2020) says that collective PCK is the knowledge for teaching that teachers develop from initial teacher training, textbooks and other sources available. Mavhunga (2020) clarifies that this realm of PCK is developed through formal courses where public and published knowledge on PCK is discussed. The next realm, the (personal/planned) pPCK develops from (collective) cPCK and is influenced by individual teachers' personal beliefs, contextual and other factors unique to the teacher. Mavhunga (2020) explains that from this pPCK emerges the actual

classroom pedagogical practices, the enacted PCK (ePCK). The workshops developed the teachers' plPCK at a topic level and ultimately developed their ePCK, exhibited during the observed and video-recorded lessons.

1.9 Data Generation Methods in This Study

To gather data to answer my research questions I used semi-structured interviews, document analysis, workshops with participants, video recordings of lessons and reflections from participants. I now briefly discuss each of these data-gathering techniques.

1.9.1 Semi-structured interviews

Merriam and Tisdell (2016) contend that interviewing is the best data-gathering technique when conducting an intensive case study involving a few individuals. This study was a case study involving five teachers working with me. Different types of interviews lie on a continuum from structured to unstructured interviews. Structured interviews are characterised by rigid adherence to prepared questions. These types of interviews do not fully capture the perspective and understanding of the participants (Merriam & Tisdell, 2016). At the other end of the continuum, there are unstructured interviews which are more like conversations, whose goal is to get to know the respondent in preparation for a more structured interview. Somewhere between the two extremes, we find semi-structured interviews which were the type used in this study. The interviews explored the teachers' current pedagogical practices concerning the concepts of Work, Energy and Power before the intervention. The interviews gathered data to answer research question 1.

1.9.2 Document analysis

According to Merriam and Tisdell (2016), documents that can be a source of data in qualitative research are a natural part of the research setting. Analysing relevant documents helps the researcher to have a better understanding of the setting and the context of the research participants. In this study, the analysed documents included curriculum documents, chief examiners' reports, South Africa Department of Basic Education policies about the language of teaching and learning and learners' textbooks. Textbooks were also critiqued for their alignment with the Curriculum and Assessment Policy Statement (CAPS) and the ways they present the concepts. Data gathered from document analysis were used to answer research question 2(a).

1.9.3 Workshops

The co-construction of knowledge on the mediation of the concepts of Work, Energy and Power with the incorporation of everyday and home language was carried out in a series of workshops with the participating Grade 12 teachers. One workshop was done face-to-face, and others were conducted virtually using the Microsoft Teams platform. Studies have identified flaws in South Africa's use of workshops for in-service teacher development, as highlighted by Bantwini (2012), Ono and Ferreira (2010) and Murray (2014). It emerged that some teachers in the studies complained they did not have time to ask questions and share experiences and reflections after trying out what they had learned during the workshops. Another concern identified was the large number of teachers attending workshops (Bantwini, 2019). In this study, the workshop approach was used with a small group of teachers. After enacting the co-constructed lessons, participant teachers wrote reflections on the strengths and weaknesses of the lessons taught using the co-planned lesson plans. These lessons were video recorded to capture how teachers enacted the lessons. Data gathered from workshop discussions were used to answer research question 2(b).

1.9.4 Observation

The distinctive feature of observation is that it allows the researcher to gather first-hand data as it happens (Cohen et al., 2018). In addition, Merriam and Tisdell (2016) state that observation takes place in the natural setting of the phenomenon in question which in this case was the mediation of learning of Work, Energy and Power. As the researcher, I could not visit each of the classrooms taught by my research participants and relied on video recordings of the lessons. Videos can overcome the partialness of the observer's view as they can be shared and reviewed by other researchers (Cohen et al., 2018). These authors add that videos can be viewed several times, unlike a one-time live observation. Although videos give thick data, they are time-consuming in transcription and analysis. In this study, my analysis focused more on those episodes where the teacher used everyday language or IsiXhosa to mediate the concepts of Work, Energy and Power.

To mitigate teachers' reactions to being filmed, the video cameras were used before the teachers taught the topics from which data were gathered, to ensure that the camera was a familiar part of the class. This allowed the teacher to adjust the settings and positioning of the camera to the best possible position in the classroom. Data gathered from observations were used to answer research question 4.

1.9.5 Reflections

As suggested by Gutierez (2015), many researchers maintain that personal reflection is the best method of capacity building among teachers. The author also adds that professional development, which includes personal reflection, improves the quality of teachers' instruction which translates into enhanced student learning. After enacting the co-constructed lessons the participant teachers wrote their reflections on the lessons. These reflections were then shared with other members of the PLC. This was done to serve at least two purposes. The first purpose was to highlight the lessons' strengths and other positive aspects that need to be reinforced. The second was to identify weaknesses or aspects of the lesson that could be improved upon. As Gutierez (2015) further contends, group reflections encourage knowledge development through constructive utterances of opinions and feedback. My role as the researcher was mainly to facilitate the process, moderate the discussions and take down notes. Data gathered from reflections were used to answer research questions 2(b) and 4.

1.10 Data Analysis in This Study

Data gathered from the various data-gathering methods outlined in the preceding paragraphs were analysed inductively and deductively. Inductive data analysis involves analysing data gathered "without hypotheses or theory to be tested" (Cohen et al., 2018, p. 712). Themes were allowed to emerge as the data were gathered and analysed. On the other hand, deductive data analysis is where data sets are analysed by looking for predetermined themes or when a theory is being tested.

Mavhunga and Rollnick's (2013) five components of TSPCK were used as themes to analyse data gathered from the semi-structured interviews deductively. Question 1 explored the teachers' pedagogical practices and TSPCK before the intervention. As explained earlier in this chapter, the participant teachers formed a PLC to co-plan lessons on Work, Energy and Power. From the reflections of teachers, after they had enacted co-developed lessons, themes were allowed to emerge, and the data were therefore analysed inductively.

1.11 Dealing with Ethical Issues

This study adhered to the code of ethics laid out by the Rhodes University Research Ethics Committee. The principles of Ubuntu were also observed. Seehawer (2018) contends that an Ubuntu approach to research ethics involves establishing personal relations by following local protocol as well as valuing word of mouth. After satisfying the ethics committee through the research proposal, ethical clearance

was issued before data gathering commenced (Appendix A). Permission to conduct research in the schools was obtained from the Buffalo City Metropolitan Department of Education District Director and the principals of the schools involved in the study (Appendices B and C, respectively). I approached participants in person after making phone appointments with them. The proposed research process and their expected roles were explained in these face-to-face meetings. Consent was given verbally before being formalised in writing. Participants were allowed to choose their pseudonyms – this acknowledged their contribution to the construction of knowledge that emerged from this study. Masking their identities would have trivialised their immense contribution to the study. The self-chosen pseudonyms enabled them to identify themselves within the thesis and in journal articles that would be crafted.

1.12 Definitions and Descriptions of Concepts in the Study

In this section, I present definitions of the key concepts used in the study. This ensured that there should be no ambiguity in terms of the meanings ascribed to these concepts and terms.

1.12.1 Pedagogical content knowledge

"The capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (Shulman, 1986, p. 15).

1.12.2 Topic-specific pedagogic content knowledge

"The knowledge that enables teachers to transform their understanding of content knowledge of a topic" (Mavhunga & Rollnick, 2016, p. 834). The topic in question for this study was Work, Energy and Power.

1.12.3 Professional learning community

A PLC is a group of teachers who meet regularly to reflect on and integrate their practices to improve their PCK (Chauraya & Brodie, 2018). In this study, the participants and I formed the PLC.

1.12.4 Township

A primarily black-occupied high population density suburb historically formally allocated for black occupation by apartheid legislation. People who live in these areas mostly belong to the lower

economic levels of the country.

1.12.5 Village

A small rural settlement is largely characterised by poor infrastructure such as gravel roads and communal sources of drinking water and the absence of commercial facilities such as banks and shopping malls. In IsiXhosa the term used is *ilali* (*iilali – plural*).

1.12.6 Translanguaging

"The process of meaning-making, shaping experiences, gaining understanding and knowledge through the use of two [or more] languages" (Baker, 2011. p. 288). It is an umbrella term covering code-switching, code-mixing, code-meshing, versioning, and translation. In this study, the two languages used were English and IsiXhosa.

1.12.7 Versioning

This technique of translanguaging involves modifying an English word by adding a prefix and or a suffix from another language, such as IsiXhosa. In this way, the words adopted from English are adapted to fit into the structure and orthography of IsiXhosa.

1.12.8 Transknowledging

Transknowledging is the process of knowledge exchange and production between the colonial and Indigenous epistemologies (Stroud & Kerfoot, 2020). The following describes its link to translanguaging: "If multilingualism is the medium, and translanguaging is the linguistic process, then the process of knowledge exchange and production is 'transknowledging' (Heugh, 2021).

1.12.9 Home language

This is the language that one learns from and uses at home. This term is synonymous with 'mother tongue' and 'first language'.

1.13 Thesis Outline

Chapter One introduced the reader to the whole study. I started by outlining the contextual background of the study from a global and continental viewpoint before finally focusing on the Eastern Cape Province. I then moved on to describe the problem that the study sought to address; a statement

of the significance of the study was also presented. The objectives of the study and the research questions that guided data gathering were listed. Important concepts used in this study were defined to contextualise them to this study. Vygotsky's sociocultural theory as the theoretical framework and Mavhungu and Rollnick's TSPCK as the analytical lenses were briefly introduced. The introduction of the theoretical framework was followed by a brief introduction of the data-gathering methods and an indication that deductive and inductive methods were used to analyse the data gathered. A brief discussion of how ethical issues were dealt with is then given and followed by an outline of the thesis before the chapter conclusion.

Chapter Two situates the study in the body of current literature on issues covered in the study. The literature synthesis starts by positioning South Africa in the global arena by reviewing the country's performance in Science in TIMSS since 1995 and in Progress in the International Reading Literacy Study (PIRLS). Trends in the performance of candidates sitting for the NSC Physical Sciences examination in the recent past are discussed and attention is drawn to the performance on the topic of Work, Energy, and Power. The focus of the literature review then moves to an analysis of the South African Science curriculum in terms of the spread of the concepts of Work, Energy and Power-related concepts across the grades from Grade 4 to Grade 12. Studies on the teaching and learning of Work, Energy and Power are discussed to indicate the gaps this study seeks to fill. Literature on professional teacher development and PLC is also reviewed since I worked with a PLC to co-develop lesson plans and improve their TSPCK. Literature on the use of language in the teaching and learning of Science is discussed under the following sub-sections: teaching and learning Science in a second language; the Language in Education Policy; school language policies and the implementation of the Language in Education Policy. Finally, literature on the issues of translanguaging and transknowledging is reviewed. Strategies of translanguaging are defined, explained and differentiated. There have been studies on the application of translanguaging in Science and these are also reviewed and discussed. The literature review ends with a look at Indigenous languages as a vehicle to promote social justice.

Chapter Three lays the theoretical basis for the study. I begin with an outline of the different meanings ascribed to the concepts of theoretical and conceptual frameworks before indicating the meanings that I worked with in this study. My theoretical framework for the study was Vygotsky's sociocultural theory. In Chapter Three, I explain its main tenets and how the theory was relevant to this study. I proceed to explain the key ideas of my analytical framework, TSPCK, and how it was used in the gathering and analysis of the data. The last section of the chapter presents the conceptual framework

in a diagrammatic format accompanied by a narrative.

Chapter Four focuses on the research design and methodological aspects of the study. I start identifying and describing the paradigm used in this study. The study used the interpretive paradigm supported by the critical paradigm and the reasons for using the two paradigms are given. The case study research design employed is discussed followed by a detailed description of the participants and the research site. I go on to declare and explain my insider-outsider positionality. The following data-gathering methods are described: semi-structured interviews, workshops, lesson observation and reflections. I then proceed to describe how data were analysed. How validity and trustworthiness issues were dealt with is also explained. The research goal and the research questions are listed. The study was done in phases, the pre-intervention, the intervention, and the post-intervention phases. I detail the activities of the phases as I outline the research process.

Chapter Five presents and analyses the data gathered from Phase 1 of the study which was the pre-intervention phase. The data presented in this chapter were gathered from the semi-structured interviews with the participants and from document analysis. The interviews explored the teachers' TSPCK espoused by Mavhunga and Rollnick (2013). This data aimed to respond to research question 1 as stated in Section 1.5. Data from document analysis responds to research question 2(a). This data from document analysis is part of the collective PCK (cPCK) described by Mavhunga (2020). Overall, the data presented in Chapter 6 forms the basis for the intervention.

Chapter Six presents and analyses the data from the orientation and lesson planning workshops. The workshops constituted Phase 2 of the study. Orientation workshop data is presented separately from the lesson planning workshop because the orientation and the lesson planning workshops had different foci. The orientation workshop focused on unpacking the research process and concepts for the participants and negotiating and agreeing on a schedule for the forthcoming workshops. Although there were three lesson plan workshops, the data is summarised as one source since the workshops were the same activity split into three sessions to fit into the busy schedules of the participants.

Chapter Seven presents and analyses the data from Phases 3 and 4 which comprised the lessons taught and the evaluation of the intervention. Data were gathered through video recorded lessons from two of the five participant teachers. In addition, data were gathered from reflective questions from the lesson plans and the WhatsApp group that was set up for the CoP. How the components of the TSPCK and

pedagogical translanguaging were enacted is presented, analysed and discussed. The enactment of the lessons by the two teachers is compared. Finally, the chapter ends with a presentation and discussion of the reflections from the participants.

Chapter Eight reflects on the data-gathering journey. Before reflecting on the data gathering, I reflect on my lived experiences in the different language contexts I have taught. I then focus on the frustrations and the triumphs that came after dealing successfully with the frustrations. I also reflect on the commitment shown by my participants and the use of available technologies to overcome obstacles which were encountered. Methodological and ethical lessons learned from the process are also shared.

Chapter Nine summarises my findings, identifies any overarching themes, highlights the contribution of the study to knowledge and presents the recommendations.

CHAPTER TWO: LITERATURE SYNTHESIS

> Teachers and their classroom practice are considered as a major conduit for the transference of reform efforts into student learning outcomes. As such, it is of critical importance to prepare teachers for the challenge of the reforms, as regards new curriculum and effective practice. (Yang et al., 2020, p.1020)

2.1 Introduction

One of the most important things to do as a first step in beginning a research project is to acquaint oneself with the body of knowledge on your topic of interest by reading the current literature. Doing a literature synthesis strengthens and expands the knowledge of the relevant issues while assisting in the later stages of the study by helping you to make connections between the findings and the existing body of information (Torraco, 2016). As alluded to by Yang et al. (2020) in the epigraph above there is a need to capacitate teachers before the implementation of any reforms. In this interventionist study, the teachers were supported in the development of their PCK for translanguaging and transknowledging.

In this chapter, I review some relevant literature to situate the study in the body of related literature. I start by discussing literature about the performance of South African learners in the TIMSS and PIRLS. This will highlight South Africa's learner performance in Science and their reading for understanding skills compared to other countries in the world and Africa. I then proceed to discuss literature on the performance of South African learners in NSC Physical Sciences examinations to highlight the trend in learners' performance in the recent past as an indicator of the state of teaching and learning in Physical Sciences. Within Physical Sciences – which comprises Chemistry and Physics – the concepts of Work, Energy and Power which form part of the Physics (mechanics) section of the subject are the focus of this study. Therefore, the literature on the teaching and learning of these concepts is reviewed.

The quality of teaching and teacher knowledge has a significant bearing on learner accomplishment. I therefore proceed to discuss literature on the state of and practices of continuous professional teacher development in South Africa. For this study, a professional learning committee consisting of me – the researcher – and five Grade 12 Physical Sciences teachers was formed; hence, the literature on PLCs is also reviewed. The study focuses on the use of everyday language and learners' home language

in the teaching of Science. Literature on the use of a second language in the teaching and learning of Science is also discussed. Translanguaging and transknowledging as pedagogic practices that can mitigate the challenge of learning Science in a second language are also discussed; finally, I summarise the key issues addressed in this chapter.

2.2 Performance of Learners in Science Tests and Examinations

In this section, I problematise the performance of South African learners in selected international and benchmark tests and in the NSC examinations.

2.2.1 Performance of South Africa in TIMSS

The TIMSS is a cross-national assessment of the performance of Grade 4 to 8 learners in Mathematics and Science developed by the International Association of Educational Achievement. South Africa has taken part in most TIMSS surveys since 1995. Reddy et al. (2016) report that the latest TIMSS assessment conducted in 2019 included 39 countries that participated mainly in Grades 3 and 8. However, South Africa and a couple of other countries participated at the Grade 9 level as well. These countries included African countries, namely Morocco, Botswana, Egypt, and South Africa. The number of participating learners from all the participating countries totalled 425 000. In TIMSS studies, since 2003, South Africa has been ranked lowest in the scores though there has recently been some improvement in the average national scores. The latest TIMSS was held in 2019 and South Africa was placed last again in both Mathematics and Science.

In the TIMSS report, the authors categorise South African schools into three types: public fee- paying schools, public non-fee-paying schools and independent schools. Over the years, public non-fee-paying schools have achieved the lowest average scores compared to the other two types. Public non-fee-paying schools are primarily located in impoverished rural areas and townships. Reddy et al. (2016) conclude that the wide score distribution reflects high inequalities in access to quality education and reflects societal inequalities. The TIMSS 2015 report also reveals that within South Africa, the Eastern Cape Province had the worst performance in Mathematics and Science across all three school types (Reddy et al., 2016).

Although TIMSS deals with Natural Sciences, the findings can be used to indicate a possible problem in the teaching of Physical Sciences. Most of the concepts taught in the FET Phase are introduced in

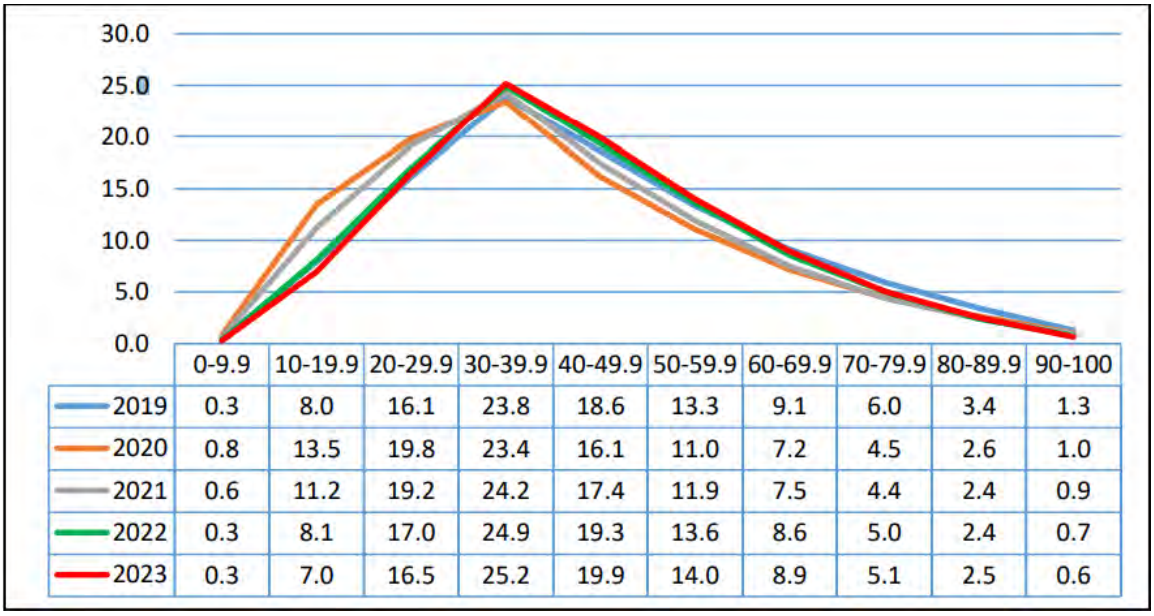
the Natural Sciences curriculum in the General Education and Training (GET) Phase. In South Africa, school achievement is measured nationally at the end of Grade 12 through the NSC examination. Not only are South African learners performing poorly in Mathematics and Science international benchmark tests, but they are also performing poorly in reading for meaning at the Grade 4 level.

2.2.2 Performance in National Senior Certificate examinations

In this section, I review the performance of learners in the NSC (NCS) Physical Sciences examinations in the recent past. The NCS is the exit qualification from basic education and can be used as a measure of achievement of learners over their entire 12 years of schooling. Figure 2.1 tabulates the overall performance of South African learners in the NSC over five years (2019–2023). The percentages of learners who achieved at least 40% in their final assessment ranged from 42.4 % to 51.7 % for the period reviewed (see Table 1.1, Section 1.3).

This learner achievement showing that fewer than 50% of the candidates managed to achieve at least 40% in the Grade 12 examination (except for 2019 and 2023) in the last five years is, in my view, an indication of a problem. This trend, together with the TIMSS study noted earlier, continues to point towards the fact that there are problems with the learning and teaching of Science.

Msimanga and Erduran (2018) observe that more than 20 years after the end of apartheid and differentiated education, the performance in Science and Mathematics continues to follow racial lines as most black candidates perform poorly. Most of these candidates come from poor townships and villages and are excluded from entry into Science programmes in tertiary institutions. This only serves to perpetuate the racial imbalances, and black youths can still not access tertiary education in Science, Technology, Engineering and Mathematics (STEM) fields. To me, this trend could suggest a possible problem with the LoLT among other racial imbalances from the past that still exist.



	0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-100
2019	0.3	8.0	16.1	23.8	18.6	13.3	9.1	6.0	3.4	1.3
2020	0.8	13.5	19.8	23.4	16.1	11.0	7.2	4.5	2.6	1.0
2021	0.6	11.2	19.2	24.2	17.4	11.9	7.5	4.4	2.4	0.9
2022	0.3	8.1	17.0	24.9	19.3	13.6	8.6	5.0	2.4	0.7
2023	0.3	7.0	16.5	25.2	19.9	14.0	8.9	5.1	2.5	0.6

Figure 2.1: Performance distribution curves in Physical Sciences (percentage) from 2019–2023 (adapted from DBE, 2024, p. 236)

From Figure 2.1, I constructed Table 2.1, which shows the percentages of learners who achieved 50% and above.

Table 2.1: Achievement at 50% and above in Physical Sciences from 2019 to 2023

Year	**Percentage of candidates achieved 50% and above**
2019	33.1
2020	23.6
2021	27.1
2022	30.3
2023	31.1

Source: DoE (2020–2024)

Over the past five years, the number of candidates who achieved at least 50% has ranged from 23.6 % to 33.1% of the total number of candidates who sat for the examination (Department of Education, 2020;2021; 2022; 2023 &–2024). I am looking at a pass mark of at least 50% as it is the minimum requirement by most tertiary institutions in the country for enrolment in undergraduate degrees that need Physical Sciences as a prerequisite. These undergraduate degrees are in Engineering, Medical Sciences and Education (for Science teachers) among others.

2.3 Physical Sciences Teachers' Teaching Approaches

The need to have learners pass NSC examinations and qualify for university entry in STEM-aligned degrees is threatened concerning teaching for understanding. A study that explored teachers' perceived autonomy with respect to the implementation of the CAPS curriculum revealed that teachers generally perceived CAPS to be too restrictive and prescriptive (Ramatlapana & Makonye, 2012). The teachers in that study reported that assessments were prescribed and standardised. Ramatlapana and Makonye (2012) argue that, in South Africa, learners' success in national examinations was the benchmark of successful teaching. This mindset results in teachers teaching for the examination and not for conceptual understanding. This finding was supported by Kolobe and Hobden (2022) who also believe that teachers do not teach for conceptual understanding, but merely drill and prepare learners to pass examinations. Consequently, classroom exercises and homework tasks are usually made up of past examination questions.

The findings by Kolobe and Hobden (2022) support earlier findings by Hlabane (2016) who notes that learners lack conceptual understanding and higher-order thinking skills and have difficulties understanding questions. This could be an indicator of the type of teaching that promotes surface learning. Poor mathematical skills and the lack of proficiency in the LoLT (English) were also cited as factors contributing to poor learner performance (Hlabane, 2016). Nyembe (2020) similarly reports that teachers used traditional teacher-centred teaching which lacked learner engagement when mediating the topic of Work, Energy and Power.

Resource constraints are often cited as the reason why teachers use the teacher-centred transmission approach (Lehesvuori et al., 2018). However, innovative Science teachers can make use of easily accessible resources as was the case in two separate Namibian studies by Asheela et al (2021) and Shinana et al. (2021). These two studies demonstrate that Science can be taught with conceptual understanding even in situations where conventional laboratory apparatus is not available.

Despite this emphasis on teaching for the examination the status quo means that less than 34% of candidates who sit for matric examinations annually pass well enough to be admitted into a STEM field of study at the undergraduate level. The diagnostic reports, which are compiled after every examination, are reports on the general performance of the candidates in every subject. The reports also offer a question-by-question analysis of learner performance and comments on common errors made by the candidates. From 2019–2023 the performance of learners on the topic of Work, Energy, and Power based on a representative random sample is shown in Table 2.2.

Table 2.2: Percentage of learners who scored 50% and above on Work, Energy, and Power questions

Examination year	Percentage of learners who scored 50% and above
2019	56
2020	17
2021	45
2022	52
2023	54

Source: DBE (2020–2024)

The statistics show that the topic is still not well comprehended (although there is some improvement), hence the need to explore ways for further improvement. This study focused on teaching this topic. In addition to the statistics on the performance of the question focusing on work, energy, and power, qualitative comments and suggestions are made in the reports. In the recent past (2019–2023), some of these comments and suggestions include the following:

> The concepts of conservative and non-conservative forces were poorly defined and applied. The common errors cited were the omission of words ‘work’ and ‘force’. Additionally, there were learners who used the force in place of work. (DBE, 2018; 2020)

This may be an indicator of the confusion between the concepts of force and work. The apparent failure to differentiate the two concepts could be attributed to poor mastery of English as a language and the

difference between the everyday use of the words *force* and *work* from their scientific meaning. The apparent lack of mastery of the concepts demonstrated by poor defining implies that the application of the concepts in problem-solving becomes problematic (DoE, 2018; 2019).

2.4 Work, Energy and Power Concepts in The South Africa Curriculum from Primary to Secondary School

To put the Physics concept that this study focused on into perspective, I now describe the concepts as they are taught in the South African Science curriculum. The Curriculum and Assessment Policy Statement (CAPS) (Department of Basic Education, 2011) outlines the topics and exact content to be taught in every Grade and subject in South Africa. Every subject has its own separate CAPS document. These documents guide teachers and writers of textbooks used in South African schools. Learners are taught about energy and work concepts starting in Grade 4, and the concepts are built up until the work-energy theorem is done in Grade 12. Learners are first introduced to the energy concept under the Energy Change and Structure knowledge strand in Grade 4 in the subject of Natural Sciences and Technology. At this stage, energy from moving air and vibrations causing sound is introduced (DBE, 2011). The definition of energy is presented in Grade 5 as "something that is needed to be able to do work (the capacity to do work)" (DBE, 2011, p. 35).

However, the same document does not define the concept of work. Also, in Grade 5, various forms of energy, including kinetic energy and potential energy, are studied. Kinetic energy is explained as the energy that a body has when it moves while potential energy is referred to as energy stored in a system that can be used. Learners learn about energy transfer in Grade 6 where reference is made to home appliances such as electric stoves and fans which transfer some of their energy to the surroundings.

In Grade 7, learners are introduced to contact and non-contact forces without a definition of force, which is only given in Grade 9 as a "push or pull exerted on an object" (DBE, 2011, p. 79). The law of the conservation of energy is given in Grade 7 as "energy can neither be created nor destroyed but can be converted from one form to another" (DBE, 2011, p. 27). Gravitational force is introduced in Grade 9 as the attractive force that masses exert on each other and weight is the gravitational force exerted on an object by the Earth or the moon. A distinction between weight and mass is made by explaining that the mass of an object is constant while the weight changes depending on where a body is. Weight on the moon and weight on Earth are used to illustrate the changes in the weight of a body. There are no numerical calculations involving the concept of energy in the GET. In FET, Physical Sciences formulas

and calculations are introduced in Grade 10.

In the FET, mechanical energy and work are part of the mechanics section of the Physics part of Physical Sciences. In Grade 10, formulas used to calculate kinetic energy and potential energy are given in the CAPS document as $\mathbf{E_k = \frac{1}{2}mv^2}$ and $\mathbf{E_p = mgh}$ for kinetic and potential energy respectively (Department of Basic Education, 2011). Box 2.1 shows what the symbols represent.

Box 2.1: Definitions of symbols used in the mechanical energy formulas

E_M = mechanical energy (J) E_k =

kinetic energy (J)

E_p = potential energy(J) m =

mass(kg)

g = gravitational acceleration ($m.s^{-1}$) v =

velocity ($m.s^{-2}$)

h = height(m)

The law of conservation of mechanical energy (in the absence of dissipative forces such as friction) is stated in Grade 10 as the sum of gravitational and potential energy. It is expressed as an equation as $\mathbf{E_M = E_k + E_p}$. The law of conservation of mechanical energy is used to solve numerical problems in Grade 10 as well as in Grade 12.

As outlined in this section, energy concepts are taught progressively from Grade 4 to Grade 10. In Grade 11, however, there is no mention of mechanical energy concepts in the CAPS document. In Grade 12, the 'work' concept and the 'work-energy' theory are introduced. Work done on an object by a force, which is used to define energy in Grade 5 (although it was not linked to a force on an object), is now defined using an equation as; $\boldsymbol{W = F\Delta x cos\theta}$. Box 2.2 shows what the symbols represent.

Box 2.2: Definitions of symbols used in the formula for work done

$W =$ work done in Joules (J);
$F =$ applied force in Newton (N);
$\Delta x =$ displacement in metres (m); and
$\cos\theta =$ angle between the direction of the applied force and direction of displacement of the object (˚).

In Grade 12 the 'work-energy' theorem is verbally described as "net work done on an object causes a change in the object's kinetic energy" (DBE, 2011, p. 118). As an equation, it is stated as $\boldsymbol{W_{net} = \Delta E_k}$ and $\boldsymbol{W_{net}}$ represents the net work done by all forces acting on the body, and $\boldsymbol{\Delta E_k}$ is the change in the object's kinetic energy because of the action of the forces. According to CAPS, learners are supposed to be able to apply the 'work-energy' theorem to objects that are on horizontal and inclined planes that are smooth (frictionless) as well as rough (with friction). In addition to the work-energy theorem, Grade 12 learners are required to "Solve conservation of energy problems (with dissipative forces present) using the equation: $\boldsymbol{W_{nc} = \Delta E_k + \Delta E_p}$" (Department of Basic Education, 2011, p.119). $\mathbf{W_{nc}}$ is the work done by non-conservative forces. A force is conservative if "the net work done by the force in moving an object around a closed path, starting and ending at the same point is zero" (DBE, 2011, p. 119). In the Science curriculum, the concept of power is defined as the amount of energy delivered per unit time or the rate at which work is done (DBE, 2011). Power is a term that is used in everyday contexts.

In this section, I outlined the development of Work, Energy, and Power concepts from Grade 4 to Grade 12. I now review some studies related to teaching and learning Work, Energy, and Power concepts to situate this current study in the body of existing literature.

2.4.1 The teaching and learning of Work, Energy, and Power

Energy has been described as a critical concept in Physics and a core and unifying concept across different Science disciplines and Grade levels (Jewett, 2008; Park & Liu, 2016). The teaching and learning of energy has been the focus of many studies over the years and I will discuss some selected international and South African studies on the topic of Work, Energy, and Power.

2..4.1.1 An international perspective

Jewett (2008) contends that one of the reasons why the energy concept is associated with a lot of confusion is the careless use of language by teachers and texts. The author asserts that learners tend to imitate their teachers' language consciously or subconsciously, and this can lead to confusion if certain words are used incorrectly. Jewett (2008) cites a few examples of the careless use of the language in teaching Work, Energy, and Power concepts. For instance, the statement 'work was done during this process' can be a source of confusion as it does not specify the object on which work is done as well as the who or what does the work. Another example given by Jewett (2008) of a statement commonly used by teachers and textbooks is "potential energy of the ball". This statement incorrectly assigns potential energy to the ball instead of to a system of two or more interacting bodies. The everyday use of some words such as work and power also presents challenges to the learning of Science concepts associated with these words in Physics.

In a study on Ethiopian students' alternative conceptions of energy and momentum, Dega and Govender (2016) found that students have difficulty differentiating commonly used words such as 'work' and 'normal' when they are used in Physics discourse. In the same Ethiopian study, students also confused the terms 'energy' and 'force'. More recently, in a Turkish study, pre-service Science teachers presented the following misconceptions: "power is force … energy is force … and power is the source of energy" (Irmak et al., 2023, p. 162). This particular finding resonates with Lemmer (2011) who asserts that Grade 10 learners confuse the concepts of 'force', energy', and 'power'.

2.4.1.2 Some South African studies

Lemmer (2011) gives an example of the word 'power' which in everyday language can be used to refer to electricity. We often hear phrases such as 'power cuts' to refer to load shedding by the electricity supply company and 'power lines' to refer to cables that transmit electricity. This brings about confusion when the learner comes to the Science classroom, and the word is used for a different concept. One of the findings from my master's study was that the confusion between force, energy and power can be attributed partly to the use of the same word, *amandla,* in the IsiXhosa language, the home language of the participants, to refer to energy, Force and Power (Mapfumo, 2016). In addition to the confusion between the use of terms in everyday speaking and Physics discourse, learners also come to the classroom with some intuitive conceptions of the concepts of work and energy.

Students come to the formal Science learning space with intuitions and beliefs about scientific phenomena that they encounter in everyday life that may not be generally accepted by the scientific community (Dalaklioglu et al., 2015). These alternative conceptions are mainly in the mechanics (Work, Energy and Power are part of the mechanics) section of the Physics curriculum. However, Lemmer (2011) suggests that these intuitive conceptions may not be entirely wrong and hence should be used as resources for conceptual refinement. This view is supported by Nyembe (2020) who points out that teachers need to use learners' conceptions as starting points to construct new knowledge.

Lemmer (2011) also concludes that many Grade 10 learners in South Africa have not yet formed the right conception of energy for them to progress to study Physical Sciences in the FET Phase. This is despite learners learning about energy in the GET Phase as outlined earlier in this chapter. In a cross-sectional survey involving teachers from Gauteng, North-West and Western Cape Provinces of South Africa, it emerged that Grade 10 to 12 Physical Sciences teachers noted that they found Physics content matter in Grade 10 (especially mechanics and waves) challenging (Basson & Kriek, 2012). In the same study, Basson and Kriek (2012) also concluded that the township and rural teachers who participated in the study needed more support in the form of training. Similar findings were made by Nyembe (2020) who concluded that the Grade 12 teachers lacked adequate pedagogical content knowledge for the topic of Work, Energy and Power.

All these studies discussed do not give much consideration to the language used to teach and learn Science. From a sociocultural point of view, mediation is key to the construction of knowledge. Language plays a central role and is one of the key semiotic tools (Stott, 2016). This current study responded to this call for the need to offer support and training by using a Profession Learning Community to help teachers develop skills on the use of pedagogical translanguaging to mediate the learning of the problematic concepts of Work, Energy and Power.

2.5 Everyday Language versus Scientific Language

Some everyday words, such as 'work' and 'power', assume different meanings when used in the context of science. This presents problems even for learners who are home language speakers of English. In multilingual classrooms, the junction of everyday language and scientific language in South African education poses special difficulties. When words such as power and work, they spent time learning in everyday English take on new meanings in the science classroom, second-language learners of English face an extra layer of complexity. This challenge results from students' inability to discern

between the words' specialised scientific meanings and their well-known common meanings (Oyoo, 2017). Studies such as Oyoo and Nkopodi (2020) have revealed that South African teachers prefer teaching in English only despite the Language-in-Education Policy (1997) advocating the promotion of additive bilingualism. However, Probyn (2006) suggests that teaching science through English to learners with a common home language like IsiXhosa can offer opportunities for language development and conceptual challenge. Still, it requires teacher training and a coherent bilingual approach.

2.6 Professional Teacher Development – A Global Perspective

In this study, I worked *with* teachers to co-develop lessons on the concepts of work, energy and Power in Grades 10 and 12 which purposely incorporated learners' home language. The workshops held with the teachers served as spaces for professional development for the participants. I now review some literature on teacher professional development in general and the state of in-service teacher professional development in South Africa in particular.

2.6.1 What effective professional teacher development entails

Villegas-Reimers (2003) contends that professional teacher development is "a long-term process that includes regular opportunities and experiences planned systematically to promote growth and development in the profession" (p. 12). Darling-Hammond et al. (2017) similarly postulate that effective professional teacher development that is well-structured, improves teachers' knowledge and practices, and ultimately, impacts positively on student achievement. These authors highlight the need for proper planning and structure in professional teacher development activities that are sustained over a period.

Darling-Hammond et al. (2017, p. 4) postulate that there are seven characteristics of effective teacher professional development. These are as follows:

- Is content focused;
- Incorporates active learning utilising adult learning theory;
- Supports collaboration, typically in job-embedded contexts;
- Uses models and modelling of effective practice;
- Provides coaching and expert support;
- Offers opportunities for feedback and reflection; and

- Is of sustained duration.

The same authors also suggest that successful teacher professional development models generally include most of the above-listed characteristics. Professional teacher development is approached differently in various contexts depending on factors such as the socioeconomic status of the country as well as the historical factors in a country like South Africa. I now review a few examples of how teachers' professional development is implemented internationally before focusing on teacher professional development in South Africa.

The Science Teachers Learning from Lesson Analysis (STeLLA) programme is a model of professional teacher development that was used in the United States of America (Roth et al., 2011). The professional development programme comprised two groups of teachers and lasted for a whole year. One group experienced Science content instruction from experts only and the other participated in the analysis of video-recorded lessons in addition to receiving instruction from the experts. Half of the group would teach their students and the whole group then analysed the video recordings of the lessons and the students' work. Analysis of the lessons would lead to the revision of the lessons and then the roles were switched, and the other half would teach the revised lesson which would subsequently be analysed. The STeLLA program contained several characteristics of an effective teacher professional development programme as proposed by Darling-Hammond et al. (2017): i) focus on Science content; ii) collaboration; iii) provision of coaching and expert support; provision of opportunities for feedback and reflection; and iv) sustained duration.

Roth et al. (2011) report that students taught by the STeLLA teachers gained more from pre-test to post-test than those taught by the teachers who had received content only. These authors contend that teachers who participated in this programme experienced rapid growth in the level of their Science content knowledge on the topics in which they received instruction during the programme. It also emerged that the average Science learning of the students taught by the STeLLA programme was higher than that of the other students. From the results of this project, it appears that if teachers are allowed to analyse, reflect and revise their own lessons it can improve their PCK which ultimately improves student achievement. This observation is supported by Jan et al. (2012) who point out that the development of PCK is important since it is about how students learn. Findings from the STeLLA programme resonate with Villegas-Reimers (2003) and Darling-Hammond et al. (2017).

Teacher professional development programmes should focus on developing the teachers' PCK (Jan et al., 2012). The authors add that teachers' PCK is highly specific to contextual issues such as the characteristics of school culture, type of students and available time. Jan et al. (2012) conclude that the development of teachers' PCK should go beyond the acquisition of lesson delivery strategies to include an understanding of how learners construct knowledge in a specific subject. Learners use language to construct knowledge and herein lies the importance of giving attention to the LoLT.

In the preceding paragraphs, some common aspects of effective teacher professional development from an international point of view were outlined. I now review some South African studies on the status and implementation of professional development in South Africa. South Africa has a history of a differentiated educational system during the apartheid[6] era. Different racial groups received different types of education whose funding was also differentiated. Black people's education was the lowest funded with schools characterised by poorly trained teachers and poor infrastructure and resources.

2.6.2 The need for teacher professional development in South Africa

To redress the imbalances in the provision of education imposed by apartheid there have been several revisions of the curriculum since the end of apartheid[7] in 1994. The Outcomes Based Education curriculum was launched in 1997 and was meant to overcome the curriculum divisions of the previous regime (DBE, 2011). Challenges in the implementation of OBE resulted in another review which gave birth to the Revised National Curriculum Statement Grades R–9 and the National Curriculum Statement Grades 10–12 (2002). However, implementation challenges were still experienced, and yet another curriculum revision was done in 2009, resulting in the CAPS. The latest curriculum statement "builds on the previous curriculum but also updates it and aims to provide a clearer specification of what is to be taught and learnt on a term-by-term basis" (DBE, 2011, p. 34).

2.6.3 A brief review of teacher professional development in South Africa

Traditional in-service teacher professional development programs in South Africa often take the form of workshops, seminars, conferences, or courses. However, research has highlighted several challenges associated with these programs. First, they are brief and fragmented (Ono & Ferreira, 2010). These

[7] "Apartheid was a South African system of social and political domination between 1948 and 1994. During that period government policies imposed conceptual, legal, and geographical distinctions between people based on race" (Greenstein, 2020, p. 74).

authors also add that these programmes are decontextualised and isolated. The third challenge was time constraints as highlighted by Bantwini (2012), who says that workshops are typically short and teachers need more sustained support. Bantwini (2019) adds that workshops usually involve large numbers of teachers and highlight cases where up to 100 teachers are accommodated in a single room. This large group setting makes it challenging for facilitators to address individual questions and needs effectively. Lastly, the lack of reflection and collaboration during the workshop is also a challenge as workshops rarely provide opportunities for reflection or meaningful discussion with colleagues (Murray, 2014).

To address these limitations, the concept of a PLC becomes crucial. PLCs emphasise collaboration, ongoing dialogue, and sustained support among teachers, allowing for deeper engagement with professional development and better integration of new knowledge into classroom practice. Brodie (2013) and her colleagues emphasise the importance of PLCs in enhancing teacher learning and student outcomes.

2.6.4 Teacher development and professional learning communities in South Africa

The Integrated Strategic Planning Framework for Teacher Education and Development in South Africa (ISPFTED) recommends, among other things, the establishment of PLCs as a vehicle to support South African teachers' developmental needs (Brodie & Borko, 2016). A PLC is a group of teachers who regularly meet to share and integrate their practices reflectively and reflexively (Chauraya & Brodie, 2018). Yang (2020) similarly claims that members of a teacher PLC engage in collaborative inquiry to improve teaching and improve student learning which is the ultimate goal of interventionist studies such as this one.

A PLC can be composed of teachers from the same or different schools. In this study, the teachers were from five different schools. Ngcoza and Southwood (2019) describe PLC as spaces that foster development that is "about educators, for educators, by educators, with educators" (p. 3). These scholars argue that professional networks are composed of individuals whose developmental engagement is informed by their own knowledge bases and experiences and they co-construct new knowledge. Townley (2020) emphasises that the main aim of PLCs is the enhancement of student learning which in the case of this study was through the development of lessons in which learners' home language was used as a resource rather than a hindrance to learning.

In addition to improving content knowledge, PLCs can be a vehicle for improving participant teachers'

classroom practice (Yang, 2020). Teachers' pedagogical orientation and habitus are difficult to change, and PLCs can be a good space for teachers to engage dialogically leading to a shift in their pedagogical orientations and habitus (Feldman & Fataar, 2016).

2.7 Language in Education Policy in South Africa

In South Africa the Language in Education Policy (LiEP) of 1997 makes provision for learners, parents and schools to choose the language of instruction from the 11 official languages. Schools are supposed to have a school language policy that outlines the pedagogical use of language in the school. However, there seems to be a lack of implementation of this policy. In this section, I discuss the historical background, the key aspects and the implementation (or lack thereof) of the LiEP.

2.7.1 Historical background

The LiEP of 1997 is meant to redress historical injustices of the apartheid era where education was differentiated according to race. Probyn (2005) asserts that the LiEP propounded by the Nationalist Party (the Afrikaner governing party) when it came to power in 1948 had political, rather than pedagogical aims. The language policy was part of Bantu Education. This was education offered to black South Africans and was meant to suppress them and keep them inferior to white people. Limited resources were allocated to developing the language and curricula for the black population (Potgieter & Anthonissen, 2017). During the apartheid era (1948–1994), only English and Afrikaans were official languages and were used as languages of learning and teaching. These languages were used for all examinable subjects while learners' home languages were restricted to non-examinable subjects. For black children, early education was in their home languages. This lowered the status of Indigenous languages and their usefulness in learning (Mnyike & Lemmer, 2014). The intention of the government's Bantu Education and language in education policies was made clear in 1953 by the then Minister of Native Affairs, H.F. Verwoerd, who later became the Minister of Bantu Education when he declared: "When I have control over Native education, I will reform it so that Natives will be taught from childhood that equality with Europeans is not for them" (Christie, 1991, p. 12).

The same year, the government extended home language-only education from the first four years of schooling to eight years (Probyn, 2005). Although this decision was driven by political aims, it was ironic that it resulted in a steady rise in the pass rates of black learners until it was abolished in 1976 (Potgieter & Anthonissen, 2017). During this period, it must be noted that white learners were learning

a curriculum that was considered superior and delivered in their home languages from year one to the tertiary level. Learning in the home language became associated with inferior Bantu Education and was hence viewed negatively despite the benefits shown by the steady rise in pass rates.

Black learners were made to learn Afrikaans as a subject from the first year of schooling in addition to English and their home languages. The language use and relative importance afforded to home languages and the two official languages partly led to the Soweto uprisings in 1976. These protests forced the government to pass the Act of 1979 Education and Training Act of 1979. Under this act, learning in the home language as the medium of instruction was reduced from eight to four years. From the fifth year onward, there was a choice of either English or Afrikaans as the medium of instruction in schools (Potgieter & Anthonissen, 2017). These authors report that this reduction in the years of home language instruction coincided with a steady decline in pass rates of black learners to as low as 44% in 1982. This possibly indicated that there were benefits to educating children in their home language. By the mid-1980s, 96% of black learners were learning in English from Grade 5 onwards (Potgieter & Anthonissen, 2017). This indicated the relative value that black people placed on the English language compared to Afrikaans. The status quo persisted until the end of the apartheid era in 1994. The dawn of democracy ushered in a new constitution that sought to redress the injustices that were perpetrated by the apartheid system.

2.7.2 Decoloniality and language in education

The choice of English as a language of instruction by black parents, despite the proven benefits of home language education, points to the extent of coloniality. Ndlovu (2018) describes coloniality as the term used to characterise long-lasting power systems that emerged from colonialism but that influence work, culture, intersubjectivity relationships, and knowledge production far beyond the exact borders of colonial administrations. These systems were designed to place the Indigenous peoples, cultures, language, and epistemologies at a level lower than the European colonisers. The idea that English (or other colonial languages) is superior to indigenous language can be so deeply entranced in peoples' minds that it lingers on long after the end of colonialism (Philipson, 1992). Decolonisation, hence, seeks to reclaim and recentre African knowledge systems challenge Western epistemologies and promote a more inclusive and equitable learning environment.

2.7.3 The Language in Education Policy (LiEP) of 1997

The LiEP of 1997 was based on the new constitution's recognition of cultural diversity and the need to promote multilingualism and the development of official languages. The new policy replaced the apartheid-era policy which was "fraught with tensions, contradictions, and sensitivities, and underpinned by racial and linguistic discrimination" (Department of Education, 1997). The policy statement expressed the wish to make South Africans non-racial and multilingual. In addition to the two official languages, nine Indigenous languages including IsiXhosa – the language in focus in this current study – became official languages. The South African Sign language was also recognised and declared an official language for educational purposes. This bold move positioned the South African LiEP as one of the most progressive in the world (Heugh, 2008). The LiEP of 1997 has six aims of which aims 5 and 6 are:

- to counter disadvantages resulting from different kinds of mismatches between home languages and languages of learning and teaching; and

- to develop programmes for the redress of previously disadvantaged languages, respectively. (Department of Education, 1997, p. 2)

Aim number five suggests that the best language practices that would afford equitable access to powerful forms of knowledge through education would be employed through the use of home languages as languages of instruction. Aim number six refers to programmes that are meant to redress the previously disadvantaged languages, but it does not indicate how this would be done or give an idea of the nature of the programmes. This lack of clear articulation had led to problems in the implementation of the LiEP.

Concerning the language of instruction, the LiEP states that "the language(s) of learning and teaching in a public school must be (an) official language(s)" (Department of Education, 1997, p. 4). This implies that any of the 12 official languages (including sign language) can be used as languages of instruction. The wording of the policy seems not to restrict schools to one language of instruction per school. The policy affords learners the right to choose which one of the 12 official languages is their LoLT. According to the policy, if the school in which the learner is enrolled does not offer the learner's desired language, "the learner may request the provincial education department to make provision for instruction in the chosen language" (Department of Education, 1997). This sounds good on paper but the question one asks is: 'How will the provincial education department make the provision to offer

the learner tuition in a language that might not be offered at all in the province?' As I stated earlier, the South African LiEP is considered one of the most progressive in the world, but the question that one might ask is: 'Is it practicable when it comes to implementation?' In the following section, I discuss the implementation and non-implementation of the LiEP.

2.7.4 School language policies and the implementation of the LiEP

From its inception, there were predictions that the LiEP would fail (Moyo, 2001). Some of the reasons put forward to support this claim were

> the lack of trained teachers in mother-tongues and in the powerful second language, English; lack of curriculum materials, poor infrastructure from books to buildings, and the total lack of the political will to effectively implement the promulgated Language in Education Policy. (Moyo, 2001, p. 97)

In a study conducted in the Limpopo province focusing on the implementation of the LiEP, it emerged that most learners were not even aware that there was a language policy (Madiba & Mabiletja, 2008). From this lack of awareness, one can conclude that the learners were not afforded the right to choose their LoLT. In the same study, it also emerged that schools did not have a school language policy as prescribed by the LiEP of 1997. This resonates with Moyo (2001) who asserts that there was a lack of political will to put measures in place for the actual implementation of the policy. Several studies have concluded that the other reason for the poor implementation of the LiEP was the preference of both learners and teachers for English as the preferred LoLT. (e.g., Madiba & Mabiletja, 2008; Moyo, 2001; Probyn, 2005). There are several reasons put forward for the choice of English as the LoLT, ahead of the learners' home language.

Probyn (2005) asserts that the link between home language education and past injustices of the apartheid era has led to negative attitudes towards using home language as LoLT. In support, Madiba and Mabiletja (2008) aver that English was used as a language of liberation from apartheid and hence its high status in South Africa. This is despite the international consensus that it is necessary to use children's home languages as LoLTs for successful education (Pluddemann, 2014). Probyn (2005) also points out that English is the lingua franca in South Africa and globally, which is another reason why parents prefer it as the LoLT for their children. Tertiary education in South Africa is offered primarily in English and Afrikaans (in a few universities) and using the home language as LoLT is seen to place learners at a disadvantage when they enter tertiary education (Madiba & Mabiletja, 2008).

The lack of, or poor, implementation of the LiEP has largely resulted in the *de facto* maintenance of the status quo, where the black majority is still marginalised and has unequal epistemological access. This has led to the constitutional aim of equitable access to education not being realised.

2.8 Challenges in Teaching and Learning Science in a Second Language

Teachers and learners of Science in a second language have a dual task, that is, teaching and learning English and teaching and learning Science concepts through the new language (Msimanga & Erduran, 2018; Msimanga & Lelliott, 2014). In addition, Probyn (2015) contends that the Science discourse poses challenges for learners because it contains unfamiliar technical words, and some everyday words (e.g., current, table, force) that have different meanings. Smith-Walters et al. (2016) similarly state that school Science is a language of its own with a complex vocabulary. These scholars add that this poses challenges to learners of all ages and language backgrounds. The challenges are compounded for learners who are learning Science in a second language as was the case in this current study. The challenges faced by teachers include an insufficient ability to ask higher-order questions and limited opportunities to develop their PCK for teaching Science to English second language learners (Pun et al., 2023).

These scholars add that for a teacher to use a guided inquiry teaching strategy they need the necessary language to ask higher-order questions. However, studies reviewed by Pun et al. (2023) reveal that this ability was lacking in many Science teachers who teach English as a second language (ESL) or First Additional Language (FAL) learners as they are referred to in South Africa. This current study attempted to address this challenge through the activities of a PLC which afforded the participant teachers opportunities to improve their PCK. Some South African studies looked at the challenges in teaching Science to English FAL learners. I now discuss some of these studies as they are related to the current study.

2.8.1 Challenges in teaching and learning science in a second language – Some South African studies

In a study that involved teachers teaching various subjects such as Mathematics, Science, business studies and accounting, Probyn (2001) identified several language-related challenges faced by teachers who were teaching English FAL learners. Teachers noted that the English proficiency of Grades 8 and 9 learners was generally poor; as a result, the teachers had to code-switch between English and IsiXhosa.

According to the teachers in the study reported by Probyn (2001), using English as LoLT was a hindrance and a source of frustration for the English FAL learners in their learning of content subjects. The LiEP places English and Afrikaans as the only two *de facto* languages of teaching and learning from grade 4, rendering unacceptable the use of code-switching, which includes other languages. One teacher expressed their sentiments by saying, “the vernacular has been smuggled into” the classroom (Probyn, 2001, p. 263). This study cut across several subjects and, therefore, gave a general view of the teaching and learning problems that were related to the language of teaching and learning. I now discuss a few studies that are based on the teaching and learning of science.

Probyn (2005) examined the classroom language usage of six Grade 8 Science teachers who taught Science through English and shared a common home language, IsiXhosa, with their students. She concluded that the use of English as the LoLT was a barrier to learning Science concepts. Probyn (2015) conducted a study concentrating on the classroom language practices of a group of science instructors in rural and township schools in South Africa, where most learners are taught in English. The study revealed that one of the teachers used pedagogical translanguaging to bridge the linguistic gap that hindered the development of scientific concepts by isiXhosa-speaking township learners. Msimanga and Lelliot (2014) observed learners' language use in small group discussions and noted that they engaged meaningfully with the science concepts and each other in their home language. Msimanga and Lelliot (2014) called for further research into multilingual teaching and learning dynamics in science.

In the opinion of Prinsloo et al. (2018), there needs to be a shift in mindset from one that views English as the language of power and prestige to one that values all indigenous languages and sees them as having equal worth as English. Similarly, Clegg and Afiska (2011) suggest that teachers in the sub-Saharan region be trained in the effective use of code-switching and translanguaging to bridge the gap between home language and LoLT for English FAL learners. A research gap exists in how teachers can use learners’ home languages in their science classes by developing teaching and learning activities and materials that promote meaningful comprehension (Mavuru & Ramnarain, 2020). This gap was what this current study sought to fill by having teachers, working with me as the researcher, prepare and teach lessons on the topic of Work, Energy, and Power, which apply pedagogic translanguaging.

2.8.2 Accessibility of language and contexts used in science textbooks

Prinsloo et al. (2018) report that findings of large-scale assessments show that, despite increased investment in education and some amount of improvement, achievement among South African

learners in Science education still need to improve. The language of teaching and learning has been identified as a significant factor contributing to low achievement. The authors also point out that many Science textbooks in South Africa are written from a Western perspective. This perspective shapes the use of vocabulary, examples and phrases that may be unfamiliar to the teacher and learners from Indigenous language backgrounds.

Science textbooks are at the centre of curriculum delivery and access as they guide the teachers and provide content to the learners (Lodge, 2020). However, the language used in some Science textbooks is too advanced, complex and confusing for most English second language learners (Letsoalo, 1996; Lodge, 2020). Not only is the language sometimes inaccessible, but the contexts in which the concepts are presented are also problematic.

For example, in one of the textbooks used by Grade 12 learners, there are examples of skiing down the slope and ice skating (du Plessis, et al., 2013). The words *skiing*, *skating*, and the concept of snow and ice-covered slopes do not exist in the context of many South African learners who do not experience freezing winter conditions. The endeavour to teach learners about work done on a frictionless surface is done decontextually and is less likely to arouse much interest. In the same vein, Ngcoza and Southwood (2019) conclude that in formal education, Indigenous learners seem to lack epistemic access to Western and decontextualised scientific concepts.

2.8.3 Some strategies to mitigate the problems of teaching and learning Science in a second language and Westernised contexts

When Science is taught exclusively in a second, often colonial language such as English, it is not only the Science content that is taught. The cultural and social practices of that language are also taught (Lodge, 2020). This, in my view, may contribute to the marginalisation of the social and cultural practices of the learners.

In an apparent response to Ngcoza and Southwood's (2019) concern, Mutanho (2021) used the making of African traditional beer, *umqombothi*[8], to teach Science concepts such as fermentation and rates of chemical reactions. The in-service teachers in Mutanho's (2021) study were mostly IsiXhosa-

[8] Umqombothi is a traditional beverage among the Xhosa and Zulu tribes in South Africa that is prepared from sorghum, millet, maize flour through the process of alcoholic fermentation (Mutanho, 2021).

speaking and were teaching in village and township schools. The Xhosa people brew umqombothi regularly for traditional ceremonies. Using the umqombothi-making process as a learning resource put Science into context and was likely to arouse learners' interest. Similarly, in a Namibian study, Liveve (2022) used traditional drumbeat music to teach about waves and sound. Learners in Liveve's (2022) context were from homes where traditional music, which included homemade drums, was commonly played for celebrations and other ceremonies.

In another study, Mavuru and Ramnarian (2020) studied language affordances and pedagogical challenges in multilingual Grade 9 Natural Sciences classes in South Africa. Teachers in the study drew on learners' home language through translation and code-switching and used real-life examples from the learners' context to facilitate understanding of concepts. Similar strategies were also employed by the Grade 8 teachers in Probyn's (2001) study. However, the teachers in both studies faced difficulties in translating some scientific concepts into the learners' home languages. Herein lies the value of translanguaging as used in this current study. Instead of trying to translate everything, the teachers in the PLC used English and IsiXhosa, and alternatively, they used each language where it was most appropriate to mediate learning. Mavuru and Ramnarain (2020) also noted that learners had problems understanding and answering test questions that were written in English.

The issue of test items being in English only was also a problem in the present study. When the study was conducted, only English and Afrikaans were recognised as languages for assessment. Although teachers can translanguage while teaching and allow learners to do the same, learners will still face assessment in English or Afrikaans. Bilingual approaches such as translanguaging will, in my view, have limited success as long as assessments are still written in English only. However, since 2020, the Eastern Cape Department of Basic Education has printed bilingual question papers for trial examinations, but learners are still expected to write in English or Afrikaans. This could be a step towards allowing learners to answer questions bilingually.

In a Tanzanian study by David and Venuste (2021), it emerged that Biology teachers teaching Kiswahili home language speakers employed some pedagogical language strategies to mitigate the challenge of learners learning in a second language. The strategies used included the following:

1. Translation of part of the text from English to Kiswahili;
2. Interpretation of the text for the learners;

3. Making use of practical activities and drawing on examples from the learners' Indigenous knowledge;
4. Helping learners to read the text and pronounce the biological terms correctly; and
5. Provide an English glossary of scientific terminology.

The students in the study used Kiswahili in group discussions but would make their presentations in English (David & Venuste, 2021). A similar observation was made by Msimanga and Lelliott (2014) in a South African study involving IsiXhosa home language learners. The strategies used in the Tanzanian study by David and Venuste (2021) still regarded English as the target language while Kiswahili was merely used to support the LoLT. However, in this study, English and IsiXhosa were afforded equal value. Like many other countries, South Africa has a policy that governs the language(s) of teaching and learning.

2.9 Translanguaging and Transknowledging

To bridge the epistemological gap imposed by linguistic complexities, translanguaging can be employed to tap into the learners' linguistic capital and use it to increase access to powerful knowledge. Transknowledging can be achieved through translanguaging, and knowledge can be developed across cultures and linguistic barriers (Heugh, 2021). In this section, I interrogate the literature on the definition of these two closely related concepts in the context of this study.

2.9.1 What is translanguaging?

It emerged from my master's study (Mapfumo, 2016), as in several other studies that learners seem to struggle to differentiate the concepts of *energy, force,* and *power*. Partly, the lack of standard terms in indigenous language for the three concepts is the cause of the confusion. Similarly, Karlsson et al. (2019) discovered that Arabic home language learners learning Science in Swedish struggled to differentiate between the terms, 'stalk' and 'tree trunk' in a Biology lesson because, in their home language, the two are referred to by the same word, '*gid*'. In both studies (Karlsson et al., 2019; Mapfumo, 2016) the problem was resolved when a further explanation was given using the learners' home language. That is, the two languages were used to make meaning of scientific concepts. This is a process referred to as translanguaging (Garcia, 2009).

Notably, this study involved teachers and learners whose home language was not the official LoLT, which is English. In a study by Karlsson et al. (2019), it emerged that Arabic home language learners

learning Science in Swedish used both languages to successfully learn Science concepts. Swedish was used for subject-specific concepts like 'chlorophyll' but explanatory descriptions and interconnecting words and phrases were in Arabic. In two separate South African studies, it was observed that learners used IsiXhosa (home language) more than English (LoLT) in small group discussions during Science lessons (Msimanga & Lelliot, 2014; Probyn, 2015). Similar findings on using LoLT and learners' home language were made in a study by Charamba and Zano (2019) where chemistry learning materials were written in both Sesotho and English. The practice of teaching one part of the lesson in one language and another in a different language is referred to as code-switching (Heugh, 2021).

Translanguaging has several advantages including promoting an in-depth understanding of subject matter and facilitating links between what is learned in the classroom and learners' everyday experiences (Lewis et al., 2012). Facciani (2019) posits that translanguaging in the classroom can facilitate the cooperation between home and school and make it possible for parents whose home language is not the official language of teaching and learning to assist their children better with their schoolwork. Lewis et al. (2012) state that "translanguaging allows more effective learning due to cross-language semantic remapping that occurs when the encoded information in one language is retrieved to enable production in the other language" (p. 650).

Most international studies on translanguaging, for example, Karlsson et al. (2019), involved situations where the LoLT was the language of the major language groups in those countries. In contrast, African studies involve situations where most of the learners are learning in a language which is not their home language, for example, English and IsiXhosa in the context of my study. Various researchers in Africa and beyond have recommended further research on the use of translanguaging. For instance, Lewis et al. (2012) call for further research to explore when, where and how translanguaging is a suitable learning approach and how it relates to learner achievements in tests and examinations. Charamba and Zano (2019) also recommend similar studies in different South African Indigenous languages. These recommendations partly motivated this current study which explored the translanguaging practices of IsiXhosa home language Physical Sciences teachers. However, translanguaging has its critics.

For instance, Bhatt and Bolonyai (2019) dismiss translanguaging as more rebranding of code-switching, while Holmen (2019) adds that it has little or no more scientific value than code- switching and language mixing. Duarte (2018) points out that the practice lacks empirical evidence as far as tangible effects on learner achievements are concerned. In apparent response to the criticism and

misunderstanding of translanguaging, Probyn (2019) cites Garcia and Flores (2012):

> These dynamic plurilingual pedagogies should not be confused with the random code-switching that is sometimes prevalent in classrooms... where language use is accidental and haphazard...plurilingual heteroglossic pedagogies are done with intent and are carefully planned. (pp. 238–239)

In this regard, it is studies like the current one which will provide evidence in support of the practice or against it. In advocating translanguaging practice, Wei (2018) reports that studies have proved that translanguaging is an effective pedagogical practice in situations where the language of teaching and learning is different from the learners' home language. In light of the criticism of translanguaging, Heugh (2021) proposes a new concept which she coined 'transknowledging' which goes beyond the level to which translanguaging takes bilingual education.

2.9.2 Some South African Studies on Translanguaging in Science Education

There is a dearth of studies that focus on pedagogical translanguaging in the South African context. In this section, I highlight some of these studies focusing on or related to pedagogical translanguaging in Science education that were done in South Africa. I will compare their foci and findings with the current study.

2.9.2.1 Translanguaging during mediation of learning

To begin with, Probyn (2001) explored teachers' perceptions of various subjects including Science teaching in township schools. The teachers in the study were teaching Grades 8 and 9 learners whose home language was IsiXhosa through English. According to one of the teachers in the study, learners' home language was "smuggled" into the classroom (Probyn 2001, p. 263). That is, IsiXhosa was used illicitly.

In another study, Msimanga and Lelliot (2014) focused on learner engagement in groups. That study concluded that learners use their home language for 90% of the time they engage in a group setting. Msimanga and Lelliot (2014) recommended more studies on the use of learners' home language to increase epistemological access.

The two studies (Msimanga & Lelliot, 2014; Probyn, 2001) highlighted the problem of learning and teaching in a second language. Probyn's (2015) study explored how Grade 8 Science teachers used linguistic resources in the classroom when teaching Science. The teachers were from township and

rural schools just as in the case of this current study. According to Probyn (2015), only one of the teachers in a group of eight used pedagogic translanguaging and the rest only code-switched from time to time during their teaching. This was despite the teachers in the study admitting that their Grade 8 learners had a low proficiency in the English language. McKinney and Tyler's (2019) study was also an interventionist study.

McKinney and Tyler (2019) focused on Grade nine learners and used pedagogic translanguaging in small group discussions. The learners engaged in a translation exercise where they were working with an English/IsiXhosa Science dictionary. They found that in the process of making meaning of the concepts of chemical reactions, the learners used various translanguaging techniques including translation, code-meshing and code-mixing. The learners did not stick to formal English and IsiXhosa. The learners in that study variously described the language as *"isigingqi* (language of the local area), *tsotsitaal,* (gangster's language), Capetonian Xhosa, *siyamixa* (we mix), and *ekasi* Xhosa (township version of IsiXhosa)" (p. 154).

A recent study by Charamba (2023) explored the role language played in the academic performance of multilingual Grade 5 Science learners. Charamba (2023) confirmed prior research findings that translanguaging practices and pedagogies in multilingual Science classrooms provided learners with more opportunities for meaning making.

2.9.2.2 Translanguaging and assessment (bilingual assessment)

Assessment is an integral part of learning as it not only measures the amount of learning, but if carefully administered it is also part of learning. The language used for assessment is hence as important as that used for teaching. In this regard, Antia (2018) argues that the current monolingual practice in examinations constitutes sociolinguistic abnormalities whose negative effects are evident from the analysis of learners' examination scripts and their performance levels. Since most learners in South Africa write examinations in English, which is their second language, Antia (2018) argues that translanguaging is potentially a democratic model of language use in examinations.

In 2012, the Eastern Cape Department of Education piloted the use of home language-based education beyond Grade 3, extending it to Grade 6. The project was known as the Mother Tongue-based Bilingual Education (MTbBE) project and it was piloted in the Cofimvaba District and included 72 learners (Zimmermann & Ronza, 2023). These authors report that by 2016 the first cohort of the MTbBE was

outperforming the non-MTbBE learners and this prompted the Eastern Cape Department of Education to add more learners to the project in other districts in the province.

The apparent success of the MTbBE project led to the Eastern Cape Department of Education administering trial examinations for matriculants in a bilingual format (English and IsiXhosa) in the whole province including schools that were not part of the MTbBE project (Zimmermann & Ronza, 2023). This has been going on since 2020 in a few subjects including Physical Sciences, Mathematics, life sciences and agricultural sciences. The question paper is written in English from the front and in IsiXhosa from the back.

In 2020, I was a Physical Sciences teacher at one of the township schools in the Eastern Cape Province. The administration of the bilingual trial examination came as a total surprise to me and my learners. There was no prior notice nor was there any form of preparation for either me or the learners. Since we (and all schools in the district) had not been part of the MTbBE project teaching and learning was in English. After the examination, I sought the views of some of my learners who did not find the bilingual examination papers much benefit. The reasons they forwarded included that the flipping back and forth between the two languages was time-consuming, some of the IsiXhosa words used were not familiar to them in the context of the subject and some even rated the translation as 'very poor'.

The translated text contained words that according to the learners' feedback were unfamiliar. This is one of the problems of translating text was cited by Wildsmith-Cromerty and Gordon, (2009). These researchers argue that terms that are newly coined by experts may be unfamiliar to the intended users. Considering the absence of prior training for the teachers, this was bound to happen. Moreover, there could also be different dialects or local area versions of IsiXhosa (McKinney & Tyler, 2019; Strom, 2019).

In a study on bilingual assessment, Buxton et al. (2019) administered a Science test in English and Spanish. Unlike the practice in the Eastern Cape South Africa, the English and Spanish texts were side by side which made it easier for students to compare and make sense of the questions without having to flip through the whole question paper. From that study, Buxton et al. (2019) concluded that this bilingual assessment was beneficial to the learners who were learning in a second language, as it helped them to fully comprehend the questions. This observation could in my view be related to the layout of the paper where the English and Spanish were side by side as opposed to the layout on the

local exam papers cited earlier.

In contrast to the Spanish study, in a study by Alex et al. (2020) primary school pre-service teachers' performance in an Intermediate Phase Mathematics test was better when the test was presented in English compared to when it was presented in their home language IsiXhosa. Alex et al. (2020) explain that the relatively poor performance in the IsiXhosa version of the test was because of the lack of IsiXhosa terms that could be used to describe some mathematical concepts. These scholars point out the need for capacitating pre-service teachers with translanguaging skills as part of their initial teacher training.

The poor performance in the IsiXhosa Mathematics test could be related to McKinney and Tyler's (2019) observation that teachers and learners do not stick to one named language such as English or IsiXhosa during classroom discourse. Instead, the teaching and learning space is heteroglossic. There is "simultaneous use of a diverse range of registers, voices, named languages, or codes" (McKinney & Tyler, 2019, p. 145). This is in contradiction with the monoglossic and monolingual approach used in assessments, including high-stakes assessments such as the South African NSC Examinations. This finding adds weight to the need for a bilingual approach to assessment. However, the above studies also show the need to practise bilingualism in both teaching and learning as well as assessment.

2.10 Contribution Made by this Study to Literature

This study identified some gaps in the literature on the teaching of Science in bi/multilingual classes in South Africa. To begin with, the few studies that I came across, e.g., Probyn (2001, 2015) and Msimanga and Lelliot (2014), focused on Grades 8 or 9 who were doing Natural Sciences. Secondly, the studies, except for McKinney and Tyler (2019), explored or highlighted the problem and made some recommendations from the findings. Not many studies have so far 1) focused on developing the TSPCK of teachers on pedagogic translanguaging, 2) focused on Physics in general, and in particular on the concepts of Work, Energy and Power in Grade 12 and 3) worked on the co-development of lesson plans by a small group of teachers working as a PLC.

2.11 Chapter Summary

This chapter reviewed literature on the performance of South African learners in international benchmark tests, the TIMSS and PIRLS, and the NSC Physical Sciences examination. It identified

English as a major cause of poor performance, with Grade 4 learners' reading for meaning skills below the global standard. The poor performance trend continues to Grade 12 in Physical Sciences in general and at the level of the topic of Work, Energy and Power.

Professional teacher development programmes are identified as key to the development is teachers' PCK and literature highlighting the approach used in teacher professional development is discussed. The chapter also discussed literature pertaining to language issues, particularly learning Science in a second language, which is a major constraint of epistemological access. The literature synthesis proceeds with some studies on interventions involving teachers in mediating strategies, such as translanguaging, using familiar contexts, and using translanguaging in assessments. However, there is a dearth of studies on bilingualism or translanguaging in assessments in South Africa, particularly in Physical Sciences. The chapter concludes by highlighting gaps in the literature review and indicating the contribution made by this study.

CHAPTER THREE: THEORETICAL AND CONCEPTUAL FRAMEWORKS

> Teaching is a highly contextualised activity, and teachers' pedagogical content knowledge is deeply rooted in their understanding of the social and cultural contexts of their students' lives (Shulman, 1986, p. 13).

3.1 Introduction

The above epigraph by Shulman (1986) aptly highlights the connection between pedagogical content knowledge (PCK) and sociocultural contexts. Bearing in mind this connection, I discuss the theoretical and conceptual frameworks that underpin the study in this chapter.

3.2 Theoretical, Conceptual and Analytical Frameworks

Different scholars perceive theoretical and conceptual frameworks differently. I briefly discuss the different views before I state which view or perspective I chose to work with in this study. Kivunja (2018) contends that "a theoretical framework comprises the theories expressed by experts in the field into which you plan to research, which you draw upon to provide a theoretical coat hanger for your data analysis and interpretation of results" (p. 44). Varpio et al., (2020) similarly contend that "a theoretical framework is a logically developed and connected set of concepts and premises - developed from one or more theories - that a researcher creates to scaffold a study" (p. 995). These scholars go on to elucidate that the researcher defines the various theories he or she is working with and also illustrates how they are connected to the research project. These two definitions concur on the notion that a theoretical framework is based on the work of experts in the field and is used to ground one's research. In explaining the importance of theoretical frameworks, Cohen et al. (2018, p. 69) posit that they "connect the researcher to existing knowledge in the field, are a frame of reference, identify new issues and areas in that field and provide a basis for hypothesis formulation and testing". In this study, I used a theoretical framework as well as a conceptual framework. I now discuss the meaning of the conceptual framework before I compare and contrast it with the theoretical framework.

As is the case with theoretical frameworks, there are different perspectives that scholars take on conceptual frameworks. Van der Waldt (2020) contends that there are two perspectives as far as conceptual frameworks and social sciences research are concerned. The first perspective views a conceptual framework as a visual representation of a study's main concepts. In the same vein Cohen et al. (2018) state that a conceptual framework comprises concrete concepts that are specific to the study and shows how they are related. Such a representation in a graphical or schematic form shows the interrelationship of the concepts in the study and is constructed by the researcher. The second perspective considers the conceptual framework as something that connects all the main aspects of the research. In the same vein, Ravitch and Riggan (2017) contend that a conceptual framework "may come from multiple sources such as one's own prior research or 'tentative theories' as well as established theoretical or empirical work found in the literature". This view implies that a researcher can work with a conceptual framework that already exists and use it to fashion their study. The main concepts or aspects of the research are fitted into and explained using the existing framework. This former perspective is the one that I adopted in this study.

It is important that I discuss how the two frameworks worked in the study. There are also different views on how these two are related. Van der Waldt (2020) contends that some scholars consider the conceptual framework and theoretical framework as synonymous. This author also states that other scholars consider a conceptual framework to have a much broader scope with a theoretical framework being part of it. Kivunja (2018) proffers that a theoretical framework is just a small subset of the conceptual framework and describes a conceptual framework as the overarching term that embraces all the key ideas and concepts in the study. By contrast, Cohen et al. (2018) state that "theoretical frameworks seek to explain and predict and are at a higher level of abstraction and generality than conceptual frameworks" (p. 69).

The existence of contrasting views on the relative scope of the two phenomena is explained in terms of how one views the meaning of 'theory' in research. Cohen et.al. (2018) argue that there are various views on the meaning of theory in research. One of the views contends that "a theory is a statement, suggestion or proposition that brings together concepts and constructs into a coherent whole, framework or system which has clearly set limits and assumptions" (Cohen et al., 2018, p. 44). In support of this view, Kivunja (2018) adds that a theory consists of a set of interrelated concepts, definitions and propositions. In this understanding a theoretical framework is broader than a conceptual framework. This is the view that I adopted for this study. The theoretical and analytical frameworks

used in this study are explained in the sections that follow.

3.2.1 Theoretical framework: Vygotsky's sociocultural theory

Sociocultural theory's work is to explain how individual mental functioning is related to a cultural, institutional, and historical context; thus, the sociocultural perspective focuses on the roles that social interactions and culturally organised activities play in influencing psychological development (Scott & Palincsar, 2013). The sociocultural theory is centred on the premise that knowledge construction is a result of social interactions between more knowledgeable and less knowledgeable individuals. In this regard, Vygotsky (1987) states that all the uniquely human characteristics of consciousness that children develop come from a foundation of cooperation and imitation.

Vygotsky proposes that there is interdependence between individual and social processes in learning and development (Scott & Palincsar, 2013). Shabani (2016) and Eun (2008), among others, argue that Vygotsky's sociocultural theory, which was originally targeted at school children, is also applicable to adult learners such as teachers. From a Vygotskian perspective, the origin of knowledge lies in the social interaction where there is a co-construction of knowledge between a more knowledgeable other (MKO) and a less knowledgeable other (LKO) (Shabani, 2016). In this study the five participants and I co-constructed knowledge. However, the roles of the MKO and LKO were not fixed and kept shifting between myself and various members of the PLC.

As presented in Section 1.8.1 there are five assumptions that form the core of the social learning theory. Within Vygotsky's sociocultural theory, I used the tenets of mediation of learning, culture and language, social interactions, and ZPD. I now discuss each of these below.

3.2.1.1 Mediation of learning

Learning, from a sociocultural standpoint, is a socially mediated process impacted first and foremost by many types of semiotic instruments, the most significant of which is language (Shabani, 2016). Vygotsky (1978) postulates that development happens after teaching and learning and emphasises that child development occurs through interacting with people and semiotic mediation (Stott, 2016). The semiotic tools include things like computers, cell phones and the internet. Stott (2016) also notes that mediation is primarily through language but other cultural tools such as textbooks are also used. The language of teaching and learning is hence a key determinant of the construction of knowledge.

Learners and teachers in this study did not adhere to the LoLT in mediating the learning of the topic of Work, Energy and Power; instead, they applied pedagogical translanguaging in IsiXhosa and English. In the preparation of the translanguaged lesson, I collaborated with the teachers to co-construct the PCK of our targeted topic. The collaboration between the MKO and the LKO occurs in the learners' ZPD (Zaretskii, 2009). The same author adds that Vygotsky gives examples of collaboration such as giving directions, asking leading questions, explaining the principles of solving the problem, breaking the problem into simpler steps and so forth. These are some of the activities that shaped our collaboration in the PLC.

3.2.1.2 Culture and language

Vygotsky believes that culture plays a central role in shaping an individual's cognitive development. He argues that cognitive processes are influenced by the cultural context in which a person grows up (Clara, 2017). This means that the values, beliefs, traditions and social practices of a specific culture have a profound impact on how individuals learn and think (Verenikina, 2013). This author further explains that culture influences development through cultural artefacts such as language, traditions and beliefs. The language of teaching and learning is the key cultural artefact under consideration in this study. The learners taught by the teachers who participated in this study used their IsiXhosa home language to shape their cognitive development during childhood. From Grade 4 on, the learners were required to use English for cognitive development.

In Vygotsky's view, higher mental functions are products of psychological tools such as verbal language, sign language and logic. The use of socially mediated language allows for interpersonal communication (Burkholder & Palaez, 2000). Wertsch (1991) identifies the mediation of human actions, both at the individual and social level, as one of Vygotsky's sociocultural learning theory's main themes. These tools are used in the mediation of the acquisition of higher mental functions. In this study, the focus was on the language used by teachers to mediate the learning of concepts of work and energy. The cultural artefacts of the teachers in the study had a bearing on the co-construction of the teachers' knowledge.

3.2.1.3 Social interactions

Vygotsky believes that learning is constructed by the individual through interaction with other individuals (Blake & Pope, 2008). Eun (2008) adds that individual mental functions originate from mediation in social settings. Furthermore, Verenikina (2013) contends that high functions in people originate from social interactions, and herein lies the importance of developing teachers' knowledge in a group such as a PLC. The teachers developed their individual pedagogic practices in a social setting within the PLC.

3.2.1.4 Zone of proximal development

Vygotsky (1978, p. 86) defines the ZPD as "the distance between the actual developmental level as 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". This definition was propounded with the development of children in mind, but the ZPD is also applicable to adult development. The ZPD lies between the zone of actual development and the zone of potential insurmountable difficulty (Zaretskii, 2009). This author explains that the ZPD starts at the first difficult assignment that the child cannot manage independently and ends at the point where they cannot operate successfully even with adult collaboration. In other words, learning takes place in the ZPD, and this is where adults, teachers, or any instructors need to apply mediational strategies. The term 'proximal' in Vygotsky's conceptualisation means 'coming next' and it supposes an impression of what the learner can potentially do without any assistance (Stott, 2016). Mediation of learning by teachers will help learners through their current ZPD. The assistance given in the ZPD is called scaffolding (Wood et al., 1976).

In this study, I started by exploring the teachers' current pedagogical practices using interviews which gave me an idea of where their ZPDs lay in terms of their TSPCK. Using findings from the interviews we collaborated using semiotic tools such as IsiXhosa and English, computers, cell phones and internet platforms such as WhatsApp and MS Teams to co-design exemplar lesson plans which focused on the application of pedagogical translanguaging to mediate the topic of Work, Energy and Power.

Some scholars, such as Stott (2016) and Zarestkii (2009), are of the view that Vygotsky died before his theories such as the ZPD were fully developed and are therefore open to misunderstanding and different interpretations. The fact that Vygotsky's works were translated from Russian to English

and other languages is also attributed to the different interpretations and subsequent applications in pedagogical practices. It is in this vein that Stott (2016) postulates that there are complexities in neo-Vygotskian versions of the ZPD. The author highlights the following three areas of complexity:

1. translation and interpretation of Vygotsky's work in educational discourse;

2. the use of the ZPD out of Vygotsky's intended context; and

3. conflation of the notions of learning and development as they relate to the ZPD (p. 27).

Stott (2016) asserts that the first complexity relates to the use of the Russian word *obuchenie* in the definition of ZPD in Vygotsky's original text to refer to both learning and instruction. Different translations have used *obuchenie* to mean either learning or instruction. The different translations have led to a different emphasis on either instruction or learning. However, Stott (2016) stresses that in the ZPD there are social interactions that enhance both instruction and learning in which the teacher will also learn from the child. This was the view that I adopted in this study. For example, the teachers were MKOs in IsiXhosa and I was the LKO, so I also learned from them although I was also the MKO on the concept of translanguaging. With respect to the support given in the ZPD, for example, I used Google Translate to compile some translations of problematic words which became the basis of our usually robust discussions.

On the second complexity, Stott (2016) asserts that in the application of Vygotsky's ZPD the assumptions, meanings and emphases should be historically Vygotskian. She also contends that if they are not historically Vygotskian then one must not claim to be using the ZPD notion as originally envisaged by Vygotsky. The final area of complexity according to Stott (2016) is about the conflation of the notions of learning and development as they relate to the ZPD. Learning and development are considered to be the same process whereas Vygotsky made a distinction between learning and development when he maintained that "development only takes place if the child's learning develops maturing psychological functions" (p. 27). In this study, I was cognisant of this last complexity in my reference to and use of the terms learning and development. My interpretation is that there could be learning with development or learning which is followed by development.

3.2.1.5 Zone of proximal teacher development

Ohta (2005, p. 505) adapted the definition of ZPD given earlier to apply the notion of ZPD to adults learning a second language and defined it as "the distance between the actual developmental level as determined by individual linguistic production, and the level of potential development as determined through language produced collaboratively with a teacher or peer". Ohta (2005) also introduces the idea of co-producing knowledge which is the essence of the PLC this study set up.

Warford (2011) modified the ZPD concept and advanced the Zone of Proximal Teacher Development (ZPTD) to apply it to teachers in training. The ZPTD is "the distance between what teaching candidates can do on their own without assistance and a proximal level they might attain through strategically mediated assistance from more capable others" (Warford, 2011, p. 253). The teachers in this current research were qualified and had varying degrees of experience.

The Vygotskian view of learning and development is that concepts are formed through a mediated process in a social setting (Fani & Ghaemi, 2011). Mediation of teacher learning is applied differently at different stages of the ZPTD. Warford (2011) uses different dynamic intervention strategies to mediate the learning of the student teachers through the four stages of the ZPTD. In this study, the mediation was led by the researcher who was part of a PLC which included five Grade 12 Physical Sciences teachers.

Table 3.1: The zone of proximal teacher development

ZPTD	Sample Interventionist DA	Sample Interactionist DA
I. Self-assistance [Stage II in ZPD (Gallimore & Tharp, 1990)]	Preparing learning autobiographies, Responding to prompts about prior experiences	Discussion, sharing autobiographies, follow-up questions
II. 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
III. Internalization (automatization)	Journaling Micro-teaching Candidate statement of teaching philosophy	Discussion, dialogic partners
IV. Recursion (De-automatization)	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.

Source: Warford (2011, p. 254)

El Kadri et al. (2017) argue that the ZPTD as shown in Figure 3.1 implies a unidirectional movement in which a less competent individual is assisted in learning by a more competent individual. Accordingly, the roles played by the more competent individuals and by the less competent individuals are not only predetermined but maintained throughout the learning process. These authors argue that the roles played by the more competent individuals (MKOs) and the less competent individuals in their ZPTD are continuously being shaped during the social interactions that take place in the learning space. In this regard, Kadri et al. (2017) also contend that as time goes on there is learning for both the 'expert' and 'novice' teachers and roles may from time to time be switched. In this study, I played the role of expert teacher by prompting reflections and asking questions. The expert and novice roles shifted back and forth as the study went on.

As mentioned earlier, the ZPTD is a modification of the ZPD to make it applicable to teacher education. Warford (2011) argues that the first two stages of the ZPD are reversed in the ZPTD so that candidates start by reflecting on their prior teaching experiences and assumptions (self-assistance) before the expert assistance stage. Teacher reflections help teachers to establish the teachers' zone of actual development (Warford, 2011). In this study, semi-structured interviews were used to assist the teachers to reflect on their teaching before the intervention. The same author says that the advanced stages of the ZPTD entail internalisation (stage III) and recurrence (stage IV) of the pedagogical concepts learned. The notion of ZPTD used by Warford (2011) for pre-service student teachers was used in this study on in-service teachers co-developing their PCK on Work, Energy and Power as outlined in the South African Grade 10 and 12 Physical Sciences curriculum with particular focus on the application of pedagogic translanguaging.

The ZPTD is influenced by several factors. Peers and mentors, contextual restrictions and mediatory artefacts and technology are examples of these (Fani & Ghaemi, 2011). These researchers demonstrate that cooperation with colleagues, as demonstrated in this study, is advantageous to teacher learning. The other aspect, according to the same authors, is connected to the contextual circumstances of the teacher. One such contextual factor that influenced teachers in this study was a lack of freedom to adapt new pedagogic approaches owing to school government policies and time constraints.

Mediatory artefacts and technology affect the teachers' ZPTD. Fani and Ghaemi (2011) cite computers and the physical layout of the classrooms as examples. These authors add that teachers can get electronic scaffolding using the internet and learning software. In the case of this study, one teacher

detailed how she used a particular YouTube channel for her own learning as well as a teaching resource. The ZPTD can be improved through several activities such as journaling one's experiences either during or after a lesson, self-scaffolding, analysis of teaching practice and discussion with learners (Fani & Ghaemi, 2011). In this study, teachers were asked to write reflections after every lesson and there were written reflections of the entire programme of the PLC. Self-scaffolding was exemplified by the teacher who used a YouTube channel as mentioned in the preceding paragraph. The teachers in this study video-recorded their lessons and this gave them a chance to review how they had mediated the learning with a particular focus on their application of pedagogic translanguaging.

3.2.2 Conceptual/analytical framework: Topic-specific pedagogical content knowledge

Pedagogic content knowledge (PCK) is a concept propounded by Shulman (1986 & 1987). Shulman (1987) describes PCK as "the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (p. 15). Kind (2009) posits that PCK provides a theoretical framework for examining and understanding teachers' skills. Members of the PLC co-developed their content knowledge as well as ways to apply pedagogic translanguaging in the mediation of concepts. This teachers' knowledge specific to the topic is referred to as topic-specific content knowledge.

PCK can be divided into three levels: general PCK (e.g., Science); domain-specific PCK (e.g. Physics); and topic-specific PCK (e.g. Work, Energy and Power) (Veal & MaKinster, 1999). In this regard, Shulman (1986) argues that many of the pedagogical practices used by teachers apply to specific topics and are not transferable to other topics. Topic-specific pedagogical knowledge (TSPCK) is a version of PCK defined regarding a given topic within a subject such as Science. In other words, it is PCK within a topic (Mavhunga & Rollnick, 2016a). Mavhunga and Rollnick (2016, p. 834) define TSPCK as "the knowledge that enables teachers to transform their understanding of content knowledge of a topic". In this study, I explored Grade 12 Physical Sciences teachers' knowledge of energy and work and how teachers can effectively mediate learning.

Mavhunga and Rollnick (2016), drawing on the seminal work of Geddis and Wood (1997) contend that five knowledge components make up a teacher's TSPCK; namely (i) learners' prior knowledge including misconceptions, (ii) curricular saliency, (iii) what makes the topic easy or difficult to understand, (iv) representations including powerful examples and analogies, and (v) conceptual teaching strategies. Curriculum saliency is a component that describes a teacher's understanding of the

concepts that should be taught or not taught in a topic, their significance, the order in which they should be delivered, and the relationships between the concepts (Mazibe et al., 2020). These five components were used in this proposed study as the analytical lenses for exploring and developing the TSPCK of the teachers in the PLC.

The relationship between PCK and TSPCK and their main constructs is shown in a model by Mavhunga and Rollnick (2013) in Figure 3.1 below:

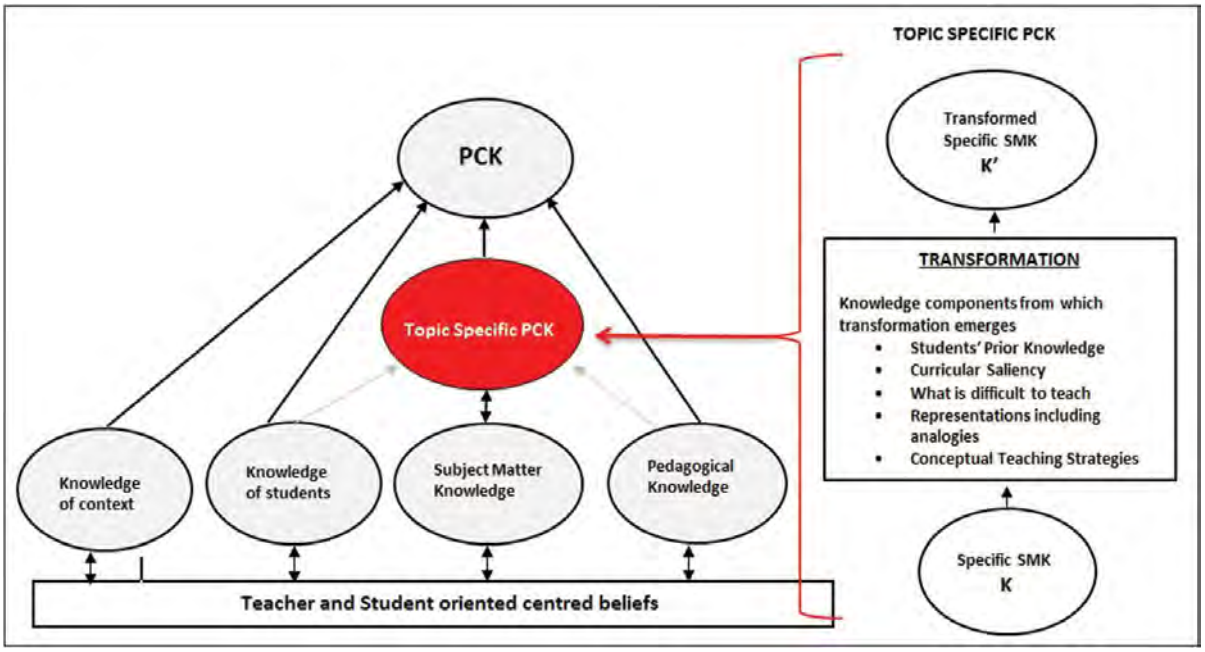


Figure 3.1: Mavhunga and Rollnick's (2013, p. 115) model for TSPCK

On the left-hand side of Figure 3.1, the main components of PCK, which include TSPCK are shown. The right-hand side of the diagram shows the knowledge components that lead to the transformation of teachers' subject matter knowledge into a version that is suitable for teaching learners. This version constituted the teachers' TSPCK. Mavhunga and Rollnick (2013) explain how the five content-specific components are used in the transformation of SMK into TSPCK.

The first component, students' prior knowledge including misconceptions, is the natural starting point for teachers' thinking and planning of the transformations of their SMK. Mavhunga and Rollnick (2013) contend that it is from the identification of prior knowledge and misconceptions that the interplay between the components emerges. In finding strategies to address misconceptions, the teacher is led to think about the second topic-specific component which is curricular saliency. This component

identifies what is important about the topic in question, which in turn leads to the identification of what is difficult to teach, the third component. To mediate what has been identified as difficult the teacher has to think and plan how to represent the content and what analogies to use to make it easier to teach for understanding by the learners. Finally, the teacher can develop conceptual teaching strategies which will address misconceptions, identify the big ideas of the topic, and simplify what is difficult to teach. In this study, the PLC used document analysis as one of the methods to identify the five components of the TSPCK. For instance, analysing the CAPS document helped to identify concepts that were learned in earlier grades required for the construction of new concepts in the current topics (prior knowledge). Analysing the CAPS document also helped to identify the required concepts in this topic of Work, Energy, and Power and how they link with prior content knowledge and other topics (curriculum saliency). The NSC examination reports (2017–2023) were used to identify what was difficult for learners (what was difficult to teach) as well as common misconceptions. The reports also suggested some strategies on how to teach difficult concepts (conceptual teaching strategies). These suggested strategies included the use of free-body diagrams (representations).

Although Mavhunga and Rollnick (2013) identified the five components of TSPCK that I elaborated on in the preceding paragraph they should not be viewed as separate knowledge areas (Mapulanga et al., 2022). These authors argue that the PCK structure relies on the intricate integration of components, and for the PCK structure to function effectively, all connections between the components must be robust and coherent.

3.2.2.1 The refined consensus model of pedagogical content knowledge

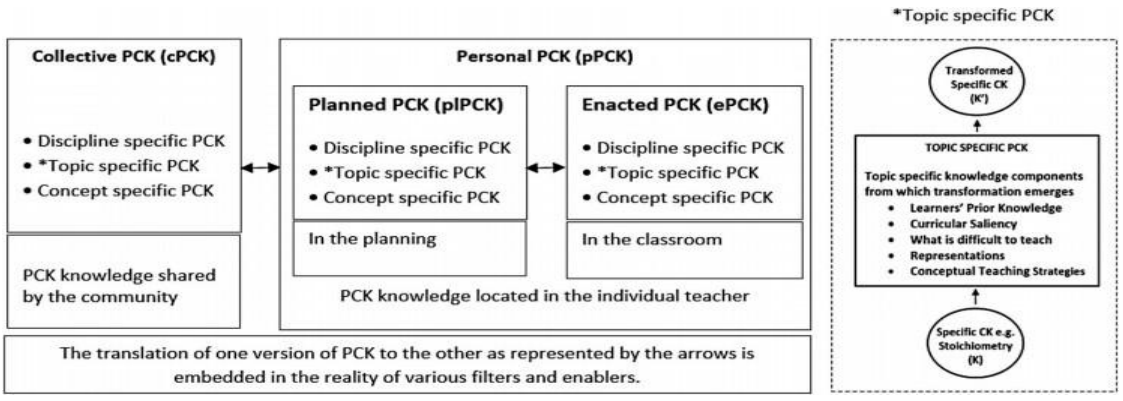


Figure 3.2: Simplified positioning of TSPCK in the RCM of PCK (Mavhunga, 2020, p. 3)

The Refined Consensus Model (RCM) shows that there are three realms of PCK namely, collective PCK (cPCK), personalised PCK (pPCK) – which is also referred to as planned PCK (plPCK) - and the enacted PCK (ePCK). Mavhunga (2020) explains that collective PCK is knowledge about teaching that teachers develop from initial teacher training, textbooks and other resources available to them. Mavhunga (2020) clarifies that this realm of PCK is developed through formal courses where public and published knowledge on PCK is discussed. The next realm, the pPCK, develops from cPCK and is influenced by individual teachers' personal beliefs, contextual and other factors unique to the teacher. Mavhunga (2020) further explains that from this pPCK emerges the actual classroom pedagogical practices. This is termed the enacted PCK (ePCK). The workshops conducted in this study provided a space for teachers to develop their cPCK on the topic of Work, Energy and Power which they went on to enact in their respective classrooms. This ePCK was analysed from the video-recorded lessons. Figure 3.3 shows the positioning of TSPCK in the RCM. The development of teachers TSPCK focused on application pedagogical translanguaging.

3.2.2.2 Accessing teachers' pedagogical content knowledge

As demonstrated in the preceding sections, developing teachers' PCK is important for successful meditation of learning. It is imperative, therefore, that the level and quality of teachers' PCK be ascertained or explored to enhance it through processional teacher development programmes. Ways to access teachers' PCK include interviewing them, analysing their lesson plans and observing them teach (Mapulanga et al., 2022). These scholars explain that analysing lessons can reveal a teacher's plPCK. The goal of this study was to arrange for the best possible use of the learners' home language, as a crucial cultural artefact in the mediation of learning. The plPC, which focused on the application of pedagogical translanguaging was built collaboratively through the PLC. However, PCK in written form - such as lesson plans - has been criticised as it may be well-written but not the same as what was enacted in the classroom (Mazibe et al., 2020).

3.2.2.3 Translanguaging

Garcia (2009) popularised the term translanguaging and developed it as a theoretical framework building on Cen Williams' work. The term 'translanguaging' was derived from the Welsh word *trawsiethu* and was first used by Cen Williams in 1994 to refer to pedagogic practices in a bilingual classroom to develop learners' competence in both languages (Facciani, 2019). Translanguaging is "the process of making meaning, shaping experiences, gaining understanding and knowledge through the use of two languages" (Baker, 2011, p. 288). Wei (2018) similarly contends that translanguaging

is a "process of knowledge construction that goes beyond languages" (p. 10). Furthermore, Chiara (2019) agrees that the implementation of translanguaging rejects the separation of socially and politically defined languages in favour of the simultaneous and fluid use of two or more languages in the classroom. Seals (2021) views translanguaging through three lenses, that is (i) as a theoretical framework, (ii) as a language practice, and (iii) as pedagogy. Similarly, Cenoz and Gorter (2021, p. 1) define pedagogic translanguaging as "a theoretical and instructional approach that aims at improving language and content competencies in school contexts by using resources from the learner's whole linguistic repertoire". Seemingly, this definition by Cenoz and Gorter (2021) emphasises that translanguaging benefits learners in terms of mastering content and helps them strengthen their language proficiencies.

If the content is read or explained in one language, for example, IsiXhosa, and the learner uses the content to answer questions or write it down in another language, for example, English, IsiXhosa is the input language and English is the output language. Cenoz and Gorter (2021) assert that the learner needs to be proficient in the input language and their mastery of the output language should be strong enough to express the message. Some critics of translanguaging say it is the same as code-switching (e.g., Bhatt & Bolonyai, 2019). This, however, is not the case as I illustrate in the following paragraphs.

3.2.2.4 Code-switching

Code-switching is different from translanguaging in that when code-switching, one 'switches off' the LoLT for brief moments and 'switches it back on'; however, translanguaging gives equal weight to the two or more languages that form the learners' language repertoires. The interchange of two languages within a single conversation is called code-switching (Mabule, 2015; Thara & Poornachandran, 2018). According to Park (2020), code-switching is a multilingual action in which individuals employ several languages, usually their first (L1) and second languages (L2), within or between sentences. If code-switching is used intentionally in a pre-planned manner to mediate learning, it becomes one of the strategies used to operationalise pedagogical translanguaging (Cahyani et al., 2018).

Code-switching in the classroom can have multiple purposes. First, code-switching can mediate conceptual understanding for learners (and teachers in some cases) who have a limited command of the language used in the text containing the concepts (Wildsmith-Cromerty & Gordon, 2009). Second, it can be applied to classroom discourse management, including disciplining learners, asking them to contribute and focusing and gaining their attention (Cahyani et al., 2018; Ferguson, 2003). Code-

switching is a useful tool for bridging the communication gap created by the limited command of the LoLT.

Probyn (2015) elegantly distinguishes code-switching from pedagogical translanguaging by indicating that the former involves temporary deviations from the official LoLT while the latter reflects the full use of learners' home language and the LoLT as resources to mediate learning. In support, Wei (2018 maintains that translanguaging is a pedagogy, a goal and a theory that goes beyond code-switching. Code-switching suggests that there are two separate languages, but translanguaging suggests that there is just one cohesive language system (Cenoz & Gorter, 2021). In the context of this study, the participant teachers used a language system made up of IsiXhosa and English both in their deliberations of the PLC as well as to mediate the learning of the concepts of work, energy and Power in the Physics section of their Physical Sciences curriculum. Code-switching is, therefore, just one of the translanguaging strategies. The other strategies are discussed in the paragraphs that follow.

3.2.2.5 Code-mixing

Closely related to code-switching is code-mixing. Some scholars, such as Park (2013) and Mabule (2015) contend that mixing linguistic elements within the same sentence is code-switching, while some scholars prefer to separate using two languages between sentences and within the same sentence into code-switching and code-mixing, respectively. Code-mixing refers to the mixing of numerous linguistic elements (morphemes, words, modifiers, phrases, and clauses) principally from two languages (Kim, 2006) within a sentence. The difference is that code-switching is within an entire conversation, while code-mixing is mixing linguistic elements from two languages in the same sentence. According to Paxton and Tyam (2010, p. 249), "çode-mixing tends to be intrasentential, switching that occurs within a single sentence or even within the word, whereas code-switching is intersentential". In this regard, Kafle and Canagarajah (2017) contend that code-mixing differs from code-switching in that the latter treats learners (and teachers) as using two discreet language systems while the former considers the two languages as parts of one language system. The two can, therefore, be considered as different techniques of translanguaging.

3.2.2.6 Code-meshing

Another term that is used in cases of two languages being used for pedagogic purposes is code-meshing. Choi (2021, p. 5) defines code-meshing as "the use of a variety of dialects, languages, symbols, and communicative modes in a single composition". The term 'code-meshing' is usually used to refer to

written text while code-mixing and code-switching commonly refer to verbal communication (Michael-Luna & Canagarajah, 2007). Studies involving learners and teachers learning and teaching in a second language; for example, Probyn (2015) reveals that they use code-switching and code-mixing in verbal communication but revert to LoLT when it comes to writing. This practice seems to maintain the superior/inferior language dichotomy between the learners' home language and the LoLT (Choi, 2021). The same author adds that code-meshing is therefore a linguistic practice that makes use of the full language repertoire in written texts and is therefore one of the translanguaging strategies.

3.2.2.7 Versioning

Of the 12 official languages in South Africa English and Afrikaans are the languages of teaching and are also used for all official communication and in business and commerce. These are therefore the more powerful languages of the 12 (Sefotho et al., 2023). In one way or another, all the people of South Africa interact with these two languages to varying extents. These interactions result in the mixing of local, Indigenous languages with English and Afrikaans in everyday translanguaging. These researchers go on to claim that translanguaging entails a strategy that permits natural language overlapping and interaction. Consequently, local languages borrow words from English and Afrikaans which are used in everyday communication.

These borrowed words are sometimes altered to a version that fits into the linguistic flow of the language that has incorporated them (Sefotho et al., 2023). In the case of this study, it was observed that English words have been adopted and adapted (words borrowed and modified) to fit into the structure and orthography of IsiXhosa (Chimhundu,2002). Mabule (2015) contends that these borrowed words are adapted phonologically of the foreign language and became established and part of the local language concerned. This technique is referred to in this study as versioning. For example, the phrase 'to calculate' can be versioned to *'uku kalkuleta'*. The pronunciation of *kalkuleta* is like you have removed the 'e' at the end of the word 'calculate' and replaced it with an 'a'.

According to Bylund (2014), the application of prefixes to English words is a type of lexical borrowing, which results in the versioning of English terms into loan words. For example, when the word force is used in an IsiXhosa sentence, it is versioned to *i*-force. Bylund (2014) goes on to state that even in cases where the IsiXhosa word for the noun is easily accessible, loan words are typically used for nouns. For example, a 'flower' is *intyantyambo* in IsiXhosa but the loan form (versioned form), *i*-flower can be used instead during conversations. In this case, the orthography of the English word is

not changed as in the case of 'calculate' changing to *kalkuleta/kalkuleyita*. The term *Xhosalised* words has been used to refer to this isiXhosa versioned English words by authors such as Paxton and Tyam (2010). The Xhosalised words are essentially English words written in a version that will fit into the sentence flow of isiXhosa. Hence the term versioning is used for this linguistic practice.

3.2.2.8 Concept glossaries and Science dictionaries

Content glossaries are yet another technique for putting translanguaging into classroom practice. Efforts by teachers to use Indigenous African languages in teaching sciences face limitations because of the limited vocabulary and difficulty translating between English and learners' home languages (Mavuru & Ramnarain, 2020). This notion is also supported by Phaka and Ovid (2021), who assert that developing life sciences reading material in indigenous languages like isiZulu can be challenging but integrating marginalised languages into education can lead to better outcomes. This integration can be done by compiling bilingual or multilingual concept glossaries. These glossaries do not seek to develop new Indigenous language terms for scientific concepts but explain the terms in the Indigenous language.

Multilingual concept glossaries, such as the ones developed by the University of Cape Town, can benefit a wider range of Indigenous language-speaking learners (Nkomo & Madiba, 2011). There have been several other projects in South Africa that produced multilingual reading materials such as the Mathematics and Natural Sciences dictionary – *Isichazi-Magama SeMathematika neNzululwazi Ibanga 4–9* (The South African National Lexicography Units, 2019) and the book – Understanding Concepts in Mathematics and Science (Young et al., 2005), which is a multilingual resource book in English, IsiXhosa, isiZulu and Afrikaans. In support of multilingual resources, Carstens (2012) contends that a multilingual explanatory dictionary of chemistry can improve learning and promote Science and technology in South Africa by providing information in English, Afrikaans and African languages.

However, these resources tend to use the standard forms of the Indigenous languages which can be problematic in that not all learners speak these standard versions. For instance, people from different parts of the Eastern Cape Province speak different dialects of IsiXhosa. Pronunciation, vocabulary, grammar, idioms and expressions vary among the IsiXhosa dialects, namely Ngqika, Ndlambe, Gcaleka, Thembu, Bomvana, Mpondo, Bhaca, and Hlubi, Xesibe (Strom, 2019). Learners who speak these various dialects may face difficulties in reading and writing the standard IsiXhosa, as was the

case in a study by Majola (2024). This author argues that the spoken varieties are usually different from the standardised version of IsiXhosa which is from the different dialects. In addition to the different dialects, there are also local area variations, and each version is referred to as *'isigingqi'* (the language of the local area) (McKinney & Tyler, 2019). However, consultations with my research participants revealed that the local area language is referred to as *IsiXhosa esengingqi* instead of *isigingqi* as reported by McKinney and Tyler (2019). It is these differences that make the use of some published materials problematic, as some learners may not easily understand some of the definitions or explanations for scientific terms that are written in the standardised version of IsiXhosa.

3.2.2.9 Pedagogical translanguaging

Cenoz (2017, p. 194) defines pedagogical translanguaging as translanguaging that is "planned by the teacher inside the classroom and can refer to the use of different languages for input and output or to other planned strategies based on the use of students' resources from the whole linguistic repertoire". The key aspects of this definition are (i) pedagogical translanguaging is a planned strategy, which does not happen spontaneously and (ii) all the languages spoken by the learners are employed to develop conceptual understanding. The planned and purposeful nature of pedagogic translanguaging distinguishes it from spontaneous translanguaging. Cenoz and Gorter (2021) elaborate by stating that pedagogic translanguaging refers to teaching strategies that use two or more languages, while spontaneous translanguaging is the use of two languages in natural settings in an unplanned way. Furthermore, these scholars assert that the former applies exclusively to educational settings and aims to mediate learning. In this study, pedagogic translanguaging was employed through lesson plans that were co-developed with the participant teachers. The capacity-building workshops attempted to develop the teachers' topic-specific pedagogical content knowledge (TSPCK) with a focus on the application of pedagogical translanguaging in the teaching of the topic of work, energy and power.

3.2.2.10 Transknowledging

Heugh (2021) claims that the fundamental purpose of why people use languages in education is often missing in discussions on code-switching, translanguaging, and multilingualism in education. Multilingualism is more than about language: it is about how to translate, share and exchange knowledge. Heugh contends that "if multilingualism is the medium, and translanguaging is the linguistic process, then the process of knowledge exchange and production is transknowledging" (2021, p. 43). In essence, transknowledging adds another dimension to translanguaging, which is the exchange of knowledge between different knowledge systems whose defined languages are different.

Heugh (2021) elaborates that there is a horizontal, vertical and complementary dimension to multilingualism in education. The horizontal dimension involves the fluid back-and-forth movement between languages for communal and socioeconomic purposes and the use of translanguaging focuses on informal and spoken practices. The vertical dimension, on the other hand, is more formal and is used for hierarchical functions such as education and translanguaging involves written and spoken practices. The third dimension, the complementary dimension, combines the other two and includes a two-way exchange of knowledge systems and this is transknowledging.

Heugh (2021) further expounds that this multilingual education allows students to exercise their voices and agency by providing them access to the language of power. Stroud and Kerfoot (2020) proffer that if translanguaging is to have a place in correcting epistemic injustices of the colonial era it must engage with concepts such as transknowledging which result in a two-way exchange of knowledge between the colonial and the Indigenous epistemologies. In the same vein, Biesta (2021) posits that transknowledging can ease the tension between the Northern-Universalistic and Southern-Pluralistic views of epistemology, ontology and cosmology. The Southern-Pluralistic perspective contends that there is no singular epistemology, ontology or cosmology which is in contrast with the Northern-Universalistic view. This pluriversality has stood the test of time and not even coloniality and neo-colonialism have managed to erase it. Transknowledging, according to Biesta (2021), involves the horizontal and reciprocal exchange of knowledge.

One way to operationalise transknowledging, according to Stroud and Kerfoot (2020), is to translate texts from the colonial languages of power, such as English, into Indigenous languages, such as IsiXhosa, Sesotho and isiZulu. This current study explored the possible benefits of developing teachers' PCK in using pedagogical translanguaging and transknowledging, in addition to other strategies, in the meaning-making of the concepts of work, energy and Power by Physical Sciences teachers. One way of developing teachers' PCK is forming and using PLCs (see Section 2.4).

3.3 Two Complementary Theories

In this study, Vygotsky's SCT is complemented by Mavhunga and Rollnick's (2013) TSPCK. The epigraph at the beginning of the chapter established the link between SCT and PCK. To begin with, TSPCK emphasises the integration of pedagogy and content while SCT provides the social setting for the co-construction of the TSPCK within the PLC. Both a learning theory (SCT) and a teaching theory (TSPCK) were used in this study because, in essence, teachers were learning to teach within the PLC.

Furthermore, through the support offered by the MKOs in the teachers' ZPTD, the teachers co-constructed knowledge on conceptual teaching strategies specific to the topic. These strategies were culturally responsive and used the learners' greatest form of prior knowledge and cultural artefact, their home language, IsiXhosa.

3.4 Chapter Summary

In this chapter, I presented and discussed the theoretical framework that underpinned the study. I started by distinguishing the terms 'theoretical framework, analytical framework and conceptual framework' before explaining my selected theoretical and analytical framework. Vygotsky's sociocultural theory, theoretical framework, and Mavhunga and Rollnick's (2013) TSPCK as the analytical framework were discussed in detail. The key tenets of the sociocultural theory used in this study were highlighted. The chapter ended with an in-depth discussion of the key tenets of the analytical framework, including aspects of the RCM of PCK.

CHAPTER FOUR: RESEARCH METHODOLOGY

> Professional learning communities provide a context for participants to work together to address common challenges and improve their practice and offer a unique opportunity for collaborative research and learning. (Vescio et al., 2008, p. 25)

4.1 Introduction

In this chapter, I discuss the research methodology employed for this study. The role of methodology in research is aptly described as follows:

> Methodology shapes and is shaped by research objectives, questions, and study design. Methodologies can prescribe choices of method, resonate with academic disciplines, and encourage or discourage the use and/or development of theory. (Carter & Little, 2007, p. 1316)

The data gathering was centred on the PLC established for this study. Hence, the epigraph, taken from Vescio et al. (2008), captures what the data gathering and analysis for the study were all about.
To explain my methodology, I first give a brief overview of research paradigms and orientation before going into detail about and justifying the use of two distinct paradigms that informed the study. Second, I discuss the research design, again as a concept first and then go on to discuss how the design employed the case study approach for this study. The research site is also discussed as well as the sampling of participants. In this study, data were gathered using semi-structured interviews, workshops, lesson observations and reflections of participants. These data-gathering methods and the data analysis that followed are described and discussed. Finally, I end with a discussion of validity and trustworthiness.

4.2 Research Paradigms

Willis (2007) explains that a paradigm is "a comprehensive belief system, world view, or framework that guides research and practice in a field" (p. 8). Tylor and Medina (2011) add that a paradigm comprises a view of the nature of reality (ontology), a related view of the nature of knowledge and how it is generated (epistemology) as well as the approach for generating this knowledge (methodology). Cohen et al. (2018) similarly contend that a paradigm is "a shared belief system, the identity of a

research community, a way of pursuing knowledge, consensus on what problems are to be investigated and how to investigate them" (p. 8). Research paradigms are classified as positivism, interpretivism, post-positivism, critical theory (ideology), constructivism and/or pragmatism. Because they are relevant to this study, I discuss the interpretivist and critical paradigms.

4.2.1 Interpretivist paradigm

In this study, the interpretive paradigm was employed together with the critical paradigm. The ontological position of the interpretive paradigm is subjectivism. According to Al-Ababneh (2020), subjectivism is the perception that reality is arbitrary and varies from individual to individual. From this perspective of reality, Cohen et al. (2018) contend that the interpretive paradigm endeavours to understand the subjective world of human experiences. These authors also posit that from an interpretive point of view, theory emerges from situations and data gathered therefrom. Interpretivism is sometimes referred to as constructivism because it emphasises the ability of an individual to construct meaning (Kivunja & Kuyini, 2017). This view is elaborated on by Creswell and Creswell (2018) who contend that social constructivism is often combined with interpretivism. This is due to the interpretivist viewpoint, which holds that reality is created by individuals and subjectively interpreted in various contexts.

The research participants, working with the researcher, drafted and enacted the lesson plans that applied pedagogic translanguaging in English and IsiXhosa to teach the concepts of Work, Energy and Power. The language they used in the translanguaging was the one most relevant to their contexts and everyday reality. Language plays a major role in moulding and shaping reality (Scotland, 2012) and affording epistemological access; hence in this study, I explored the use of two languages in the construction of scientific knowledge.

A researcher must view the world through the perceptions and experiences of the participants to appreciate the reality of a particular context from an interpretivist paradigm (Thanh & Thanh, 2015). In this study, as the researcher, I was part of a group of Grade 12 Physical Sciences teachers working to co-develop, teach and reflect on exemplar lessons on Work, Energy and Power that incorporate everyday language and home language by employing pedagogical translanguaging. Willis (2007) states that interpretivists seek research approaches that enable them to have an in-depth understanding of human beings and their environments and the part those people play in shaping that environment. The case study methodology used in this study was in line with Willis's (2007) assertion. However, the

interpretive paradigm has some shortcomings.

The shortcomings of the interpretivist paradigm include the lack of attention to the participants' history which may have shaped their present reality (Weaver & Olson, 2005). Cohen et al. (2018) add that the failure of interpretivism to address the influence of politics and ideologies on knowledge and social reality is its other drawback. In this study, the language of instruction that the teachers used in their teaching was a product of their colonial past. The critical paradigm was also used with the interpretivist paradigm because it addresses this shortcoming and seeks to emancipate learners and teachers by redressing this historical language of teaching and learning issue. I discuss the critical paradigm in the following paragraphs.

4.2.2 Critical theory paradigm

The critical theory paradigm is attributed to the critical theorists of Frankfurt, namely, Max Horkheimer, Theodore Adorno and Herbert Marcuse; it considers reality as having been shaped by social, political, cultural, economic, ethnic and gender values (Scotland, 2012). Horkheimer (1982, p. 244) contends that the "critical theory seeks human emancipation, to liberate human beings from circumstances that enslave them". This author further explains that from a critical point of view, language does not passively label already existing objects, but actively shapes and moulds reality. This view on the role of language is similar to that of the interpretive paradigm. Furthermore, language contains power relations and can be used to empower or disempower people. It therefore becomes evident that the language used in the acquisition of knowledge has a bearing on the kind and power of the knowledge acquired. This might lead to marginalism of those groups who do not have access to the language of power, which in the South African situation is English (and Afrikaans, to a lesser extent). Scotland (2012) contends that the critical paradigm seeks to address these issues of social justice and marginalisation by embracing the emancipatory function of knowledge.

Critical theory is directed at interrogating values and assumptions, exposing hegemony and injustice, challenging exciting social structures and engaging in social activities (Patton, 2017). The underlying aim of critical research is to bring about transformation. That is, researchers do not carry out transformations for participants and the participants have to play an active role (Ngcoza & Southwood, 2015). It is from this perspective that I explored the co-development of lessons with my participants to bring about transformation in the teaching of Work, Energy and Power with the use of pedagogic translanguaging. Asghar (2013) says that critical theorists do not merely explore the problem but seek

to find the means to solve the problem. The incorporation of the IsiXhosa language is envisaged as an attempt to provide better access to knowledge on Physics in general and specifically on the topic of Work, Energy, and Power which may have been restricted by the use of a second language.

Scotland (2012) points out that although the critical paradigm seeks to emancipate and empower research participants, it is problematic, as it tends to stereotype in two ways. First, participants are labelled as falling into a certain marginalised group. This might lead researchers to have preconceived ideas about the phenomenon to be researched, leading to bias as far as the gathering, analysis and interpretation of data is concerned. Secondly, it also tends to ignore the level of conscientisation of some of the participants. This is problematic as it assumes that all participants need conscientisation and need to be assisted in gaining emancipation which might not be the case.

I approached this study with this criticism in mind and tried to be as objective as possible. Researching *with* the participants rather than researching *on* the participants also helped to overcome the victim mentality assumed by the critical paradigm since it empowered them as co-knowledge creators who, if given the right platform, can play an important role towards redressing colonial injustices such as having their language relegated to a language of informal discourse only. The interpretive paradigm and the critical theory paradigm were therefore used in a complementary fashion.

Thanh and Thanh (2015) assert that researchers believe that the interpretive and critical paradigms predominantly use qualitative methods. A qualitative research approach was employed to understand the co-construction of TSPCK on Work, Energy and Power. The following section addresses the research goal, research questions and how the data to answer the questions were gathered.

4.3 Research Goal and Questions

The research goal and research questions are stated in this section.

4.3.1 Research goal

The study's main goal was to enhance Grade 12 Physical Sciences teachers' PCK through a collaborative process, enabling them to adeptly apply translanguaging strategies in English and IsiXhosa when teaching the concepts of work, energy, and Power.

4.3.2 Research questions

1. What TSPCK (including language use) on the topic of Work, Energy, and Power did Grade 12 Physical Sciences have before the intervention?
2. What could Grade 12 Physical Sciences teachers learn through:
    a. Co-analysing curriculum documents focusing on the topic of Work, Energy and Power concepts?
    b. Workshops focusing on the co-development of exemplar lessons on Work, Energy and Power that take into consideration learners' home and everyday languages?
3. What are the effects of the PLC intervention on:
    a. The quality of the participant teachers' bilingual mediation of Work, Energy and Power in their lessons?
    b. The participant teachers' TSPCK of Work, Energy and Power?
4. What are teachers' reflective insights and perspectives on the intervention's effectiveness, challenges, and outcomes?

4.4 Research Design: Case Study

This study employed a qualitative case study approach. A case study has been defined differently by different scholars. Below are two prominent definitions:

> A case study an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clear. (Yin, 2003, p. 13)

> A case study is a problem to be studied, which will reveal an in-depth understanding of a "case" or bounded system, which involves understanding an event, activity, process, or one or more individuals. (Creswell, 2003, p. 61)

Case studies are normally used in studies that involve the 'how' and the 'why' questions in which there is an in-depth examination of the case in its natural setting (Pearson et al., 2015). This description fits well with my research question, which sought to explore working with Grade 12 Physical Sciences teachers on how to incorporate everyday language and home language when mediating learning of the concepts of work and energy. Lodico et al. (2006) posit that qualitative research gives a voice to the feelings and perceptions of the participants of the study. This was done through working with the

participants to co-develop and enact lesson plans. Lodico et al. (2006, p. 269) also contend that "case study research is a form of qualitative research that endeavours to discover meaning, to investigate processes, and to gain insight into and in-depth understanding of an individual, group, or situation". Cohen et al. (2018) echo this sentiment by stating that the qualitative research approach provides intricate and detailed meanings of the contextualised behaviour of the participants. The language used by the participants in their teaching was peculiar to their context which was characterised by IsiXhosa as the home language of all the learners.

In case study research one needs to be clear about the case and the unit of analysis. Merriam (1998) argues that a case is a single entity around which there are boundaries, and it can be a person, a group of people, a programme or a specific policy. However, the terms 'case' and 'unit of analysis' are sometimes used interchangeably. To avoid ambiguity, in this study, the case was the PLC made up of the researcher working *with* Grade 12 Physical Sciences teachers drawn from schools that have learners learning Science through a second language from the same district. The unit of analysis was the co-development of teachers' PCK on how to incorporate learners' home language and everyday language in the meditation of the concepts of work, energy and Power in Grade 12.

4.5 Research Site and Sampling of Participants

This qualitative case study focused on a unique and distinct case and hence non-random purposive sampling was used (Cohen et al., 2018). Two techniques of purposive sampling namely convenience sampling and homogeneous sampling were employed. Lodico et al. (2006) explain that homogeneous sampling is the selection of individuals with similar attributes becoming the sample. This study was conceptualised while I was working as a part-time university lecturer and a full-time teacher in the Chris Hani West district. The participants sampled initially were people I had been working in the same district for many years and access to them was not difficult. I approached each of them, and they each verbally agreed to be part of the study. In the socio-cultural context of the study, it is more acceptable to have a verbal agreement first before presenting any formally written document, and therefore, the participants' words were enough to convince me of their commitment. However, these were not the participants I finally worked with.

Before obtaining ethical clearance from the university and getting to the data-gathering stage I moved to the Buffalo City Metropolitan District in the same province. The distance of about 200km between me and the participants necessitated that I look for new participants of the same profile as the original

ones. A friend I had made when studying together for my Honours degree introduced me to several teachers in the district whose profiles fit the requirements of this study. After several phone calls to set up meetings, I managed to arrange face-to-face meetings in their schools. These meetings were used to explain what the study sought to achieve, their role as participants, and to get to know them as individuals. After meeting the teachers, I then met the principals to get their letters of permission to work with the teachers and at their schools. The difficulties that I faced in the process and how I overcame them are discussed further in Chapter Eight where I reflect on the whole data-gathering process.

Like the original participants, the new ones were also IsiXhosa home language speakers and teaching Physical Sciences from Grade 10 to Grade 12 in a village or township school. By coincidence, two of the five participant teachers were people I had worked with as NSC Physical Sciences Paper 1 markers for several years. Four of the teachers were teaching Physical Sciences from Grades 10 to 12, and the fifth one was only teaching the subject at Grade 10 although she was qualified to teach up to Grade 12. These teachers were purposively chosen since they were easily accessible to me and fitted the profile as stated above. As a part-time researcher, I chose reasonably close participants (about a 30 km radius) to me as I had limited time and financial resources. The five teachers were homogeneous in the sense that they were all except one - as explained above - teaching Grade 10 to 12 Physical Sciences in rural or township schools with IsiXhosa home language learners who were learning Physical Sciences in English. The participants are described in more detail below. The pseudonyms used below were chosen by the participants.

The idea of letting participants choose their own pseudonyms was preferred to the more common practice of assigning alphabet letters and numbers or deciding on names chosen by the researcher because I wanted them to be able to identify themselves easily when they read this thesis. It was also a way of expressing to them that they were not mere participants but important co-creators of the knowledge and that I was not researching *on* them but *with* them as members of the PLC. Assigning them codes or my own pseudonyms would, in my view, undermine their value in this study. In the spirit of Ubuntu, it is unethical to fail to acknowledge people who assist you in one way or the other. In my Shona language, we have a saying '*kusatenda huroyi'* which loosely translates into the notion that being ungrateful is such an evil that is equated to witchcraft. Hiding the identities of participants would be tantamount to being ungrateful and unappreciative of their contribution to the co-creating of knowledge produced in this study. I now introduce my participants in the following paragraphs. Their information

was gathered using a short form that I titled ‘participant profile form’. It is through this form that the participants chose their own pseudonyms.

4.5.1 Participant profiles

Nimjou Mankau was a very experienced male teacher with 30 years of teaching experience who had been teaching Physical Sciences from Grade 10 to 12 Grade throughout his teaching career. He was also conceptualising his PhD study in Science education at the time of collecting data and had been an NCS Physical Sciences Paper 1 marker for many years. He was the most experienced and highly qualified member of the PLC. As a PhD candidate himself, Nimjou Mankau indicated that through his participation in the study, he expected to learn something that would be valuable for his own study. His school is referred to as School A.

The second participant, Rhadie, was the least experienced member of the PLC with four years of teaching experience. She became a teacher after initially studying for a Diploma in Analytical Chemistry followed by the Post Graduate Certificate (PGCE) in Education in Physical Sciences. She also held an Honours degree in educational psychology. She indicated that her age was in the range of 30–35 years. One of the reasons for agreeing to be part of the study was that she expected to get motivation and support for her plans to register and study for her master’s degree. She was still undecided about whether to do a degree in Science education or educational psychology. Her school is referred to as School C.

Dlamini, the third participant, was between 41 and 45 years and held a Bachelor of Science Honours in Physics and had 16 years of experience at the grade 12 level. He had previously enrolled for a Master of Education degree but did not complete it. He was not willing to disclose the reasons, but he had the intention of registering again soon. Dlamini was also an NSC Physical Sciences marker for paper 1(Physics). His school is referred to as School D.

Miss A was the fourth participant and was 34 years old. Unlike other participants, she gave her exact age. She held a master’s degree in environmental sciences and had become a teacher by doing a PGCE in Science education. She had five years of teaching experience in Physical Sciences at the Grade 12 level and three years of experience at Grade 10 and 11 levels. She confessed to being a procrastinator when it pertained to studying for her PhD. Her school is referred to as School E.

The fifth participant was Linda; she played an instrumental role in helping me identify the participants. Unlike the other four participants, Linda preferred that I use her real name instead of choosing a pseudonym. On the profile form she wrote "No pseudonym; use actual name". Her full name was Linda Abegail Tola, but I used just the first name, Linda. At first, she was not supposed to be a participant because she was not teaching Grade 12 at the time of the study. She asked to attend our workshops for her own personal development. I decided to include her in the workshops that resulted in the co-designed lesson plans. She made very important contributions in lesson preparation workshops as will be displayed in Chapter Seven where I present and analyse data from the workshops. She was aged 38 and had 15 and 13 years of experience in teaching Grade 10 and 11 Physical Sciences respectively. She also had 2 years of teaching Technical Sciences at Grade 12 level. Technical Sciences is a subject that has concepts in common with Physical Sciences. She holds a Bachelor of Science degree in Microbiology and Biochemistry, an Advanced Certificate in Education (ACE) in Science and an Honours degree in Information Technology Education. At the time of the study, she had suspended her master's in education studies for personal reasons. She mentioned that she was motivated to be part of the PLC because of the learning opportunities it presented. She also indicated that the experience might also inform her master's degree study. Initially, the Grade 12 teacher at her school had agreed and signed the consent form but pulled out of the study. This setback is also reflected on in Chapter Eight.

Table 4.1: Summary profiles of the participants

Teacher (pseudonym)	Age/Age range	Gender	Highest qualification in teaching Physical Sciences	Total number of years teaching Physical Sciences	Years teaching Grade 12
Nimjou Mankau	51 -55	Male	MEd (Science)	30	30
Rhadie	30 -35	Female	Diploma in Analytical Chemistry and PGCE	4	4
Dlamini	41 - 45	Male	BSc Hon (Physical Sciences)	16	16
Miss A	34	Female	PGCE	5	5
[9]Linda Tola (Real name)	38	Female	ACE	15	None

As the table shows, the PLC consisted of teachers whose ages ranged from 30-55 and whose qualification levels ranged from an ACE to a Master of Education degree. There was a mixture of youth and experience, which represented a diverse range of Science teachers. As stated earlier, the five teachers were from five different schools.

[9] Linda Tola decided to not choose a pseudonym but gave permission for her real name to be used in the study.

4.5.2 Types of schools in the study

Table 4.2 below gives brief details about the schools.

Table 4.2: The type of schools involved in the study

School	Teacher	Grade 12 Physical Sciences class size	School quintile	Area located
A	Nimjou Mankau	8	3	Township
B	Linda Tola	n/a	3	Township
C	Rhadie	32	3	Rural
D	Dlamini	16	3	Township
E	Miss A	79	3	Township

As seen in Table 4.2, four of the schools were in the townships and one in a village. Schools in South Africa are classified into 5 quintiles according to the poverty level of the community in which the school is located. Quintile 1 refers to the set of schools in each province that serve the bottom 20% of students in terms of economic status. Quintile 2 schools serve the next 20% of the poorest communities, and so forth while quintile 5 caters to the least poor 20%, in other words, the wealthiest of the schools (Department of Education, 2004). All five schools in the study fell into quintile 3; schools that fall within this quintile are classified as no-fee schools. These schools rely on government funding for their day-to-day running. Additionally, these schools are not allowed to charge school fees. They are only allowed to accept voluntary donations from parents. This means that the schools cannot afford any expenditure outside the minimum guidelines given by the Department of Basic Education. None of the schools had a functional, well-resourced Science laboratory. The size of the classes involved ranged from eight learners to 79 learners in one classroom.

4.6 The Phases of the Research

The study was done in five phases. Each phase had its own focus and associated data-gathering methods, and the phases are as follows:

- **Phase 1**: Establishing pedagogic practices and orientation of the teachers before the intervention phase. Data were gathered using semi-structured interviews, document analysis and the orientation workshop.
- **Phase 2:** Co-creation of TSPCK through lesson planning. Data were gathered through the workshops which focused on planning for the lessons which applied translanguaging, and which were informed by the document analysis. These created the pPCK for the topic of Work, Energy and Power.
- **Phase 3**: Enactment of the planned lessons. This phase explored the teachers' ePCK for the topic. Data were gathered through video recordings of the teachers' lessons.
- **Phase 4**: Group evaluation of the process and the PLC activities. Participant views for the evaluation were sought using questions on the PLC WhatsApp group. The questions focused on evaluating the entire process. Individual written evaluation on plans were also discussed with the PLC.

I now discuss the data-gathering methods that I used from Phase 1 to Phase 4 of the study.

4.7 Data-gathering Methods

To gather data to answer my research questions I used semi-structured interviews, document analysis, workshops with participants, reflections of participants, video recordings of lessons, and stimulated recall interviews. I now discuss each of these data-gathering techniques. Table 4.3 below summarises the data-gathering methods used, and the research questions that they sought to answer. The data-gathering methods also formed the various phases of the study as shown in Table 4.3.

Table 4.3: Research questions and related data-gathering methods

Phase	Research question	Data-gathering Method
1	1. What TSPCK (including language usage) on the topic of Work, Energy, and Power did the Grade 12 Physical Sciences teachers have before the intervention?	Semi-structured interviews
1	2. What can the Grade 12 Physical Sciences teachers learn through: a) Co-analysing curriculum documents focusing on the topic of Work, Energy and Power? b) Workshops focusing on the co-development of exemplar lessons on Work, Energy and Power that take into consideration everyday and home language?	Document analysis, Workshops
2	What could the Grade 12 Physical Sciences teachers learn through: a) Workshops focusing on the co-development of exemplar lessons on Work, Energy and Power that take into consideration everyday and home language?	Workshops
3	3. What were the effects of the PLC intervention on: a) The quality of the participant teachers' bilingual mediation of Work, Energy and Power in their lessons? b) The participant teachers' TSPCK for work and energy?	Lesson Observation (video record)
4	4. What are teachers' reflective insights and perspectives on the intervention's effectiveness, challenges, and outcomes?	Reflections

4.7.1 Semi-structured interviews

Merriam and Tisdell (2016) contend that interviewing is the best data-gathering technique when conducting an intensive case study involving a few individuals. This study was a qualitative case study involving five teachers working with the researcher. Of the five teachers, Linda was not interviewed since she was not teaching Grade 12. Different types of interviews lie on a continuum from structured to unstructured interviews. Structured interviews are characterised by rigid adherence to prepared questions. These types of interviews do not fully capture the perspective and understanding of the

participants (Merriam & Tisdell, 2016). At the other end of the continuum are unstructured interviews which are more like conversations. Their goal is to get to know the respondent in preparation for a more structured interview. Somewhere in between the two extremes, we find semi-structured interviews which were used in this study. Semi-structured interviews have the following characteristics:

- The interview guide includes a mix of more and less structured interview questions;
- all questions used flexibly;
- usually, specific data is required from all respondents;
- the largest part of the interview is guided by a list of questions or issues to be explored; and
- No predetermined wording or order (Merriam & Tisdell, 2016, p. 110).

The interviews explored the current pedagogic practices with respect to the concepts of work, energy, and Power prior to the intervention. I used an interview schedule (see Appendix E), informed by Mavunga and Rollnick's (2013) five components of teachers' TSPCK, namely learners' prior knowledge, curricular saliency, representations and what is difficult to teach. In addition, some questions aimed at exploring the participant teachers' use of LoLT and the challenges they faced with learners because of poor proficiency English. As pointed out by Merriam and Tisdell (2016) my interviewees would in some cases go beyond responding to the question and include information that would answer other questions I had not yet asked. In such a case, I would then not ask the question if it had been adequately answered.

The interviews gathered data primarily to answer research question 1 and they constituted the first phase of the study. The interview responses constituted the reported PCK on the topic of Work, Energy and Power. According to Mazibe et al. (2020), PCK refers to the knowledge that educators present both orally and in writing. In the case of this study, the reported PCK was what they presented orally during the semi-structured interviews.

The interviews were carried out using the Microsoft Teams platform and were scheduled at times convenient for the teachers who had busy schedules. The first interview was conducted between the 6th and 30th of March 2023. The interviews lasted between 27 minutes and 65 minutes. They were

recorded and downloaded for analysis. The automatically generated transcriptions were also downloaded.

4.7.2 Document analysis

Performing a systematic study or evaluation of documents, both printed and digital, is known as document analysis (Bowen, 2009). Merriam and Tisdell (2016) contend that documents that can be a source of data in qualitative research are a natural part of the research setting. Analysing relevant documents helps the researcher to have a better understanding of the setting and the context of the research participants. In this study, the documents that were analysed were the CAPS document for Physical Sciences, NSC examination diagnostic reports and learners' textbooks. Table 4.4 below shows each of the analysed documents and the reason for the analysis.

Table 4.4: Summary of data analysed from documents

Document	**Data analysed**
CAPS document	• The content that the teachers need for the teaching of Work, Energy, and Power • The prior knowledge expected to be possessed by Grade 12 teachers
NSC diagnostic reports (2017 – 2022)	• Performance of the candidates in questions on Work, Energy and Power with a specific focus on common errors and misconceptions • Probable causes of poor performance that were identified • Suggestions for teaching approaches were made
Learner textbook	• The language, representations and contexts used in the examples • Identification of what was difficult to teach

In South Africa, the energy concepts are taught in Grade 10 Physical Sciences and examined both in Grades 10 and 12. In Grade 12 the concepts learned in Grade 10 form the basis of the work-energy theorem introduced at this stage. Grade 10 concepts, therefore, are essential prior content knowledge for Grade 12 learners. The specific content is outlined in the CAPS for Physical Sciences. This document was analysed to ensure that both the researcher and the respondents were aware of the

minimum standards and parameters for the teaching of the concepts in Grades 10 and 12 and for identifying the relevant prior content knowledge. The next set of documents analysed were NSC examination diagnostic reports.

Every year the DBE publishes an examination diagnostic report that analyses the performance of candidates in every subject examined in the previous year. These reports analyse the general performance of learners in each subject and each question points out general strengths, weaknesses and common errors made by candidates; it also makes suggestions on how teachers could improve their teaching of the various topics. Analysing these reports informed the researcher and the participants on the general performance of learners on the topic in the NSC examinations which in turn may also inform teaching strategies. The textbooks used by the participants and their learners were assessed for their alignment with CAPS, the way they presented the concepts and the language and context used.

Content and thematic analysis were used to analyse the documents mentioned in the preceding paragraph. The content analysis involved organising information into categories related to the research questions (Bowen, 2009). The categories were centred on Mavhunga and Rollnick's (2013) five components of TSPCK, namely 1) learners' prior knowledge; 2) curriculum saliency; 3) what is difficult to teach; 4) representations; and 5) conceptual teaching strategies. Different documents covered different components. Data gathered from document analysis were used to answer research question 2(a) which was part of Phase 1. Data gathered from document analysis are presented in Chapter Six.

4.7.3 Workshops

The co-construction of knowledge on the mediation of Work, Energy and Power with the incorporation of everyday and home language was done using a series of workshops with the participating Grade 12 teachers. Originally, I had planned to have the workshops as face-to-face interactions, but this did not happen. The workshops were all virtual on the Microsoft Teams platform. I discuss the changes in Chapter Eight where I reflect on the data-gathering process.

Some studies that I discussed in the literature review chapter (Bantwini 2012; Ono & Ferreira, 2010; Murray, 2014) highlighted some of the flaws or shortcomings of the way workshops are used in South Africa as a method for in-service teacher development. As reported earlier, some teachers complained of not being afforded time to ask questions and share experiences and reflections after trying out what

they had learned during the workshops. Another concern identified was the excessively large class sizes of teachers attending the workshops (Bantwini, 2019). In this study, the workshop approach was used with a small group of teachers. After enacting the co-constructed lessons, participant teachers wrote their reflections.

The workshops involved the discussion of the content to be taught and an analysis of the language used to draft the lesson plans. These lesson plans were designed to apply translanguaging in the teaching of the concepts of Work, Energy and Power. The workshops and lesson plans became the planned PCK (plPCK). The PCK that the workshops focused on was specific to the topic of Work, Energy and Power and is hence referred to as the planned topic-specific pedagogic content knowledge (plTSPCK) (Mapulanga et al., 2022). After the workshops, the teachers taught the co-planned lessons in their respective schools. They video-recorded the lessons.

The video recordings captured the enacted PCK (ePCK). After the lessons they wrote down their reflections which were shared with other members of the PLC. A comparison of the plPCK and the ePCK was also done. Data gathered from workshop discussions were used to answer research question 2(b). Table 4.5 shows the original plan for the workshop and their respective foci. However, as I mentioned earlier, things did not go exactly as planned.

Table 4.5: Originally planned workshop schedule

Workshop Number	Mode	Focus
1	Face-to-face	Orientation workshop
2	Online	Introducing participants to document analysis
3	Online	Reflexive practice
4	Face-to-face	Analysing documents
5	Face-to-face	Lesson plans for week 1 of teaching
6	Face-to-face	Lesson planning for week 2 of teaching
7	Face-to-face	Lesson planning for week 3 of teaching
8	Online	Group reflection on the intervention

The orientation workshop was done online as it emerged that the participants preferred to have a virtual workshop since they were very busy with classes and extra classes. They also requested that workshops number 2 and 3 should be omitted citing lack of time as a reason. Since I was researching *with* them, I agreed and decided to embed what was to be discussed in these workshops in the lesson planning workshops. This is explained in Chapter Seven, where I present and discuss the data gathered during the workshops. Table 4.6 shows a schedule of the workshops conducted.

Table 4.6: Schedule of workshops conducted

Workshop Number	Mode	Focus
1	Online	Orientation and document analysis
2	Online	Lesson plans for week 1 of teaching
3	Online	Lesson planning for week 2 of teaching
4	Online	Lesson planning for week 3 of teaching
5	Online	Group reflection on the intervention (midway through the intervention)

The workshops were conducted between 11 April and 5 May 2023. After the lesson plans were drafted the teachers used them to teach and this constituted Phase 4 of the study. The lessons were recorded, and the data gathered are presented in Chapter Seven.

4.7.4 Lesson observation

The distinctive feature of observation is that it allows the researcher to gather first-hand data as it is generated (Cohen et al., 2018). Merriam and Tisdell (2016) state that observation takes place in the natural setting of the occurrence of the phenomenon. As the researcher, I was not able to visit each of the four classrooms taught by my research participants. I relied on video recordings of the lessons. Data were gathered using video recordings of the participants teaching in their usual classrooms. One advantage of videos is that they can overcome the possible bias of the observer's view as they can be shared and reviewed by other researchers (Cohen et al., 2018). These authors add that videos can be viewed several times, unlike a one-time live observation. The recordings were done using cell phones, either by the teachers themselves or by my research assistant. There are also a few negative aspects of using videos as an observation tool.

Although videos give thick data, they are time-consuming in terms of transcribing and analysing them. In this study, I focused on those episodes where the teacher was making reference to prior knowledge, using representations and incorporating everyday language or IsiXhosa to mediate the teaching. The other problem with using a video camera is the learners or teachers tend to look at the camera or alter

their natural behaviour to what they think the researcher expects. However, Vesterinen et al. (2010) emphasise that the tension caused by the presence of the video camera diminishes with time. To mitigate this threat the video cameras were used before the teachers were teaching the topics from which data was gathered, to ensure that the camera became a familiar part of the class. This also allowed the teachers to adjust the settings and positioning of the camera to the best possible position in the classroom. Some video-recorded lesson episodes needed further discussions with the teacher to gain deeper insights.

The recorded lesson videos were used to study how the pPCK from the PLC workshops was enacted and to what extent it made the teaching and learning of the concepts easier. Data gathered from lesson observations were used to answer research question 3. After teaching, teachers were also asked to reflect on the lessons using the spaces provided in the lesson plans. The recorded videos were deleted from the research assistant's electronic devices to ensure their security. I stored them on my external hard drive and my Microsoft OneDrive.

4.7.4 Reflections

Gutierez (2015) believes that personal reflection is the best method for capacity building among teachers. The author also mentions how professional development, which incorporates personal reflection, enhances teachers' ability to teach, which benefits students' learning. After enacting the co-constructed lessons, the participant teachers wrote their personal reflections on the lessons. These reflections were then shared with other members of the PLC. This served at least two purposes. The first purpose was to highlight strengths and other positive aspects of the lesson which needed to be reinforced, and the second was to identify weaknesses or aspects of the lesson that could be improved upon. Thirdly, the teacher also reflected on their application of translanguaging practices as guided by the lesson plan. As Gutierez (2015) further contends, group reflections bring about knowledge development through constructive utterances of opinions and feedback. As the researcher, my role was mainly to facilitate the process, moderate the discussion and take notes. Data gathered from reflections were used to answer research questions 2(b) and 4.

4.8 Data Analysis

Data gathered from the various data-gathering methods outlined in the preceding paragraphs were analysed both inductively and deductively. Inductive data analysis involves analysing data gathered

"without hypotheses or theory to be tested" (Cohen et al., 2018, p. 712). Thematic analysis was used to examine, identify and report on the most likely and notable trends in the data (Majumdar, 2022). These trends form themes. Through inductive analysis, themes are allowed to emerge as the data are gathered and analysed. By contrast, in deductive data analysis data sets are analysed by looking for themes that are predetermined or evidence to test a theory. Both deductive and inductive analysis were used as explained later.

4.8.1 Data from semi-structured interviews

The five components of TSPCK proposed by Mavhunga and Rollnick (2013) were used as predetermined themes to analyse data gathered from the semi-structured interviews intended to answer research question 1. Question 1 examines the teachers' pedagogical practices and TSPCK before the intervention. The interviews were conducted using the MS Teams platform. MS Teams transcription had a lot of mistakes and I had to replay the recordings and correct the transcription. The participants code-switched from time to time and the software would just write English words that sounded like the IsiXhosa words. Even when one uses English the programme makes many mistakes. This was caused by the African accent of the respondents. Correcting transcriptions was a very tedious and slow task. A five-minute conversation in which the interview respondent translanguaged would take more than 30 minutes to correct.

After correcting the transcriptions, I had a good sense of the participants' responses. I then organised the responses to each interview question next to the interview questions. The first five questions explored each of the five components of TSPCK. The five components served as the predetermined themes. The analysis of the responses was therefore deductive. Questions 6 to 9 explored the participants' language practices in their mediation of learning the topic of Work, Energy and Power. The last questions allowed the participants to add any other relevant information. Questions 6 to 9 were analysed inductively since there were no predetermined themes.

Once the data were organised in a table as described in the preceding paragraph, I used ChatGPT to analyse them and identify the codes within the predetermined themes (questions 1 to 5). Open AI created ChatGPT, an artificial intelligence-generated content (AIGC) model, launched on November 30, 2022, that can handle difficult language production and interpretation problems in the form of dialogues (Eysenbach, 2023; Wu et al., 2023). ChatGPT can enhance the efficiency of thematic analysis by generating initial codes and themes codes, categories, and themes, as well as direct citations

from within text that relate to the themes (Lee et al., 2023). Fong et al. (2024) add that using ChatGPT increases research efficiency and significantly reduces the time needed for data analysis. I typed the following prompt on ChatGPT:

> Respondents A to D responded to the question [I inserted the relevant question]. Responded D used English and isiXhosa. Translate the isiXhosa parts and then identify the themes from each response and quote from the responses the exact words that fall under each theme.

I then pasted the responses from the transcripts, and ChatGPT produced the themes and related quotes from the responses. These were then used as codes to create themes allowing me to compare the analysis of each respondent with the others. Although Bijker et al., (2024) note that ChatGPT is reliable in assisting with data analysis, Eysenbach (2023) points out that the chatbot is occasionally inaccurate. Hence, the analysis from ChatGPT was double-checked with the raw data and was very accurate.

4.8.2 Data from document analysis

As shown in Table 4.4, I analysed the following documents: the CAPS document, one textbook, and the NSC diagnostic reports. The data gathered were analysed thematically and the findings were shared and discussed with the members of the PLC. That data were also vital for preparing the lesson plans during the workshops. This is presented, analysed and discussed in Chapter Seven.

4.8.3 Data from workshops

As indicated in Table 4.5, five workshops were conducted and from these workshops, we discussed and produced three lesson plans for the whole topic of Work, Energy and Power. The workshops were conducted via the MS Teams platform. They were recorded and transcribed. The recordings and transcriptions were downloaded. As with the case of the interviews, the transcriptions had to be corrected. In this case, I focused on those parts that were quoted in the data analysis. Besides the product of the workshops, that is, the lesson plans, the analysis also sought to understand the types of interactions and how the participants were contributing to the co-creating of knowledge. As alluded to earlier in this chapter, the analysis also explored how the role of the MKO shifted during the workshops. The content of the lesson plans was also analysed through the lens of the TSPCK and pedagogic translanguaging.

The analysis process was done step-by-step according to the following six phases (stages) suggested

by Majumdar (2022):

- **Phase 1: Getting familiarised with the data**. This was done by reading the entire transcription from MS Teams and making any corrections that arose from the incorrect capturing of utterances because of different pronunciations of words. In some cases, participants translanguaged in English and IsiXhosa. MS Teams wrote the English words that sounded closest to the IsiXhosa. In these cases, I went back to the recordings and listened to the parts that needed correction. I noted initial ideas for coding as I went through the transcription.

- **Phase 2: Generating initial codes.** In this stage, I identified the basic elements for the raw data and labelled them with names such as 'introducing the study', 'introducing concepts' (for the orientation workshop) and so on.

- **Phase 3: Searching for themes**. In this phase, I collated related codes to form themes. For example, all codes that had to do with introducing the concept, the study and document analysis formed the theme 'introductions.'

- **Phase 4**: Reviewing themes. In this stage, I checked the generated themes and compared them to the coded extracts from the transcripts before I refined them.

- **Phase 5: Defining, Refining and (Re)naming themes**. During this phase, I concentrated on learning the significance of each theme as well as what the overarching themes were about.

- **Phase 6**: Producing a final report. Having satisfied myself that the generated themes were accurate I produced a summary of the analysis in the form of a table.

4.8.4 Data analysis from reflections

The reflections were done in two ways. First, the teachers wrote their reflections on the lesson plans as they taught the lessons. They reflected on their individual enactment of the co-planned lessons. No predetermined themes were used for analysing these reflections. Second, there was a short meeting midway through the intervention that reviewed the progress. Deductive-inductive data analysis was done. Initially, I had planned to have a face-to-face reflective workshop after the enactment of the lessons, but it did not materialise as explained earlier. I then resorted to posting reflective questions on the PLC's WhatsApp group.

4.8.5 Data analysis from lesson video recordings

The recorded lessons were viewed several times. Because of the length of the videos and the time available for the study, it was not possible to transcribe entire lessons. Only parts of the lessons were transcribed for closer analysis. Focus was placed on the episodes where the teachers were supporting learners using translanguaging strategies and some aspects of TSPCK worth highlighting. A deductive and inductive thematic analysis was also used to analysis the lessons from the data.

4.9 Validity and Trustworthiness

The validity of the research concerns the instruments used in gathering the data. It is about demonstrating that a particular data-gathering instrument measures what it is meant to measure (Cohen et al., 2018). There are two forms of validity, internal and external. Internal validity is about the extent to which the findings of a study are believable while external validity is concerned with the extent to which the findings can be applied to other situations or can be generalised (Merriam & Tisdell, 2016). Internal validity is this study is demonstrated by the evidence for all the findings. Some are presented as quotations and vignettes in chapters 6 to 8 and all the important data can be verified by examining the Appendices. Cohen et al. (2018) contend that reliability is concerned with the precision and accuracy of the whole research process. They argue that research is reliable if similar results will be produced if the study is repeated in a similar situation. However, Merriam and Tisdell (2016) caution that reliability assumes that studying human behaviour repeatedly will yield the same results. These authors point out that from a social sciences point of view, the question is not whether the findings can be replicated but whether the results are consistent with the data collected. The rigour that I exercised in the data-gathering analysis as shown in this chapter and demonstrated in chapters 5 to 8 was an attempt to strengthen reliability. The trustworthiness of research findings is a corollary of its validity and reliability. In this study reliability and validity were ensured through the use of triangulation, member checking, adequate engagement with data and peer reviews. Merriam and Tisdell (2016) explain that triangulation involves collecting data from more than one source to obtain rich descriptions of the same phenomenon. As described earlier, in this study, I used semi-structured interviews, observations (using video recording), follow- up interviews and workshop notes.

Another type of triangulation is the use of more than one theory as described in Chapter Three. Two paradigms, i.e., the interpretive paradigm and the critical theory paradigm, were used and served as different lenses with which to view and analyse the emerging findings. Member checking was done by

taking back the summarised or analysed data to the research participants to verify their accuracy. As I was conducting the study I got opportunities to present parts of it at the Southern African Association for Researchers in Mathematics Science and Technology Education (SAARMSTE) colloquia at the Walter Sisulu University Research and Innovation Day and well as at the Higher Education Learning and Teaching Association of Southern Africa (HELTASA) webinar on multilingualism in higher education. This was a safe space for me to get feedback and suggestions from fellow scholars and it served as another layer of validation.

4.10 Ethical Issues

Merriam and Tisdell (2016) note that to ensure validity and reliability in qualitative research, the research must be conducted ethically. These authors add that relational ethics, which have to do with the positionality of the researcher, should be borne in mind. This involves being aware of one's role concerning participants and treating them with respect, as people, and not just as sources of information. In this study, I ensured that I respected my participants' language, culture and values. For instance, in the IsiXhosa culture, everyone has a clan name in addition to their surnames. Clan names are not recorded in the official records but they are widely used. Calling someone by their clan name is a sign of respect that goes beyond titles such as Mr and Doctor. During my introductory meetings with my participants, I inquired about their clan names which they proudly gave me. Formal introductions of adults amongst *AmaXhosa* (native IsiXhosa-speaking people) almost always include the clan names and I did not deviate from that practice. Not only did I ask for their clan names, I also told them mine, as we have clan names in my native country, Zimbabwe. This helped to level out the power gradient, aided by the fact I was a Shona home language speaker researching the incorporation of IsiXhosa in the teaching of Science.

In applying the code of ethics, as laid down by the university, I took cultural and contextual issues into account. Bridges (2017) argues that codes of ethics that are used by some universities may not be applicable in some cultural settings and contexts, such as in Africa. He contends that "openness is secured not by the reassuring terms of contractual engagement (the consent form) but by culturally embedded relationships" (Bridges 2017, p. 306). For this study, I used the trust I built during the initial verbal engagement and the mutual respect and trust that I had purposefully attempted to build to negotiate openness and confidence *before* the presentation and signing of the formal consent forms.

4.11 Chapter Summary

In this chapter, I discussed the methodology employed in the study. The chapter opened with a discussion of the paradigms that I used in this study. I started by discussing how I used the interpretive paradigm together with the critical paradigm. The justification for the use of these two paradigms was explained and justified. After situating the study within the paradigms, I went on to discuss the case study design employed. This was followed by how I selected the participants in the case study and brief profiles showing what made them suitable for the study. After a discussion of the ethical issues, I described how the data were gathered and analysed at each of the different phases of the study. Finally, I discussed how the validity and trustworthiness of the data and findings were ensured.

CHAPTER FIVE: PRE-INTERVENTION INSIGHTS: TEACHERS' ARTICULATION OF THEIR PEDAGOGICAL CONTENT KNOWLEDGE AND DOCUMENT ANALYSIS

> Teaching is not a profession; it's a passion. It's a passion that requires a deep understanding of the subject matter, a passion that requires a deep understanding of the students, and a passion that requires a deep understanding of the art of teaching itself. (Stronge, 2007, p. 65)

5.1 Introduction

The above epigraph by Stronge (2007) captures what the data presented in the chapter sought to establish about the teachers in this study. In this chapter, I focus on the presentation of data gathered in Phase 1 of the study comprising semi-structured interviews and document analysis (see Sections 4.9.1 and 4.9.2). This phase focused on exploring the pedagogical practices of the teachers before the intervention phase and analysing documents that informed those pedagogical practices. I start by presenting data from the semi-structured interviews before moving on to document analysis. The semi-structured interviews explored the teachers' TSPCK on the topic of Work, Energy and Power.

5.2 Data from the Semi-structured Interviews

The semi-structured interview schedule (see Appendix E) had nine guiding questions and the data from these interviews primarily sought to respond to research question 1:

> What TSPCK (including language usage) on the topic of Work, Energy, and Power do Grade 12 Physical Sciences have before the intervention?

Interviews are one way that is commonly used to explore teachers' PCK (Malcolm et al., 2019). Accordingly, five of the eight questions that were asked explored the teachers' pedagogical practices *before* the intervention and were guided by Rollnick and Mavunga's (2013) five components of TSPCK which became the five main themes for the interviews. After the five questions, the sixth question focused on the language of teaching and learning and how teachers mitigated language-related learning problems. Question 7 explored the teachers' perceptions of the accessibility of the language

used in the textbooks that the learners use. The eighth question asked teachers to provide any additional information they felt might have been overlooked during the interview.

5.2.1 Theme 1: Learners' prior knowledge and misconceptions

In each interview, the wording differed slightly depending on the flow of the discussion before the actual interview started. The question aimed to explore whether the teachers could identify and articulate key concepts from earlier grades that learners must have mastered before they can successfully learn the Grade 12 level concepts of Work, Energy, and Power. The CAPS document (Department of Education, 2014) was used to identify these concepts that form the prior content knowledge that Grade 12 learners are expected to have (see Box 5.1).

Table 5.1: Expected relevant concepts from prior learning

1. Vectors and scalars
2. Basic trigonometry
3. Types of forces
4. Inclined plane and resolving forces.
5. Velocity
6. Acceleration
7. Displacement
8. Kinetic energy
9. Potential energy
10. Formulas for calculating potential and mechanical Energy, $E_k and\ E_P$ respectively.

Table 5.1 shows the key prior knowledge concepts that the teachers articulated in their responses. When comparing their responses to Box 5.1, it is evident that the teachers could not fully articulate the expected key prior knowledge concepts. On average the teachers mentioned only four of the 13 concepts.

Table 5.2: Teachers' articulation of prior knowledge relevant to the topic

Nimjou	Rhadie	Dlamini	Miss A
1. kinetic energy 2. potential energy 3. mechanical energy	1. Newton's laws of motion 2. Forces and types of forces 3. Vectors: the importance of understanding vectors, the difference between vectors and scalars.	1. Forces and Newton's second law - the net force acting on an object. 2. Conservation of mechanical 3. Free-body diagram 4. Types of forces and their application 5. parallel and perpendicular components of forces.	1. Newton's laws, particularly Newton's second law 2. Forces and types of forces, their direction 3. Angles and inclined planes

5.2.2 Theme 2: Curriculum saliency

This question explored the teachers' knowledge of the topic's key aspects (see Table 5.2).

Table 5.3: Teachers' articulation of curriculum saliency

Nimjou	Rhadie	Dlamini	Miss A
1. the significance of Mathematics 2. angle differentiation and 3. clear explanations in understanding the key concepts of Work, Energy, and Power	1. trigonometry concepts and their application to Work, Energy, and Power 2. challenges in integrating Physics and Mathematics 3. the importance of teaching trigonometric ratios	1. work done on an object 2. net work 3. kinetic energy 4. change in kinetic energy 5. work-energy theorem 6. non-conservative forces 7. power (including average power, power at an instant, and power in relation to engines).	1. new formulas 2. understanding definitions and 3. calculations 4. differentiating between various forces and angles 5. concepts such as zero work and work classifications 6. challenges of potential content gaps and the need for clarity and alignment in teaching.

As shown in Table 5.2, the teachers identified what they considered the key concepts. During the discussion, I compared their responses with the key concepts as informed by the CAPS document (DBE, 2011). The topic content is presented under four sections in the CAPS document, namely definition of work, work-energy theorem, conservation of energy, and power. The key concepts under each section are shown in Box 5.2 below.

Box 5.2: Key concepts for the topic Work, Energy, and Power

Definition of work

Definition of work done on an object by a force as: W=FΔxCosθ;
Calculating the net work done on an object; and
Positive net work done on a system.

Work-Energy theorem

net work done on an object causes a change in the object's kinetic energy;
the work-energy theorem: $W_{net} = E_{k_f} - E_{k_i}$;
Application of the work-energy theorem to objects on horizontal and inclined planes; and (Frictionless and rough surface).

Conservation of energy with non-conservative forces present

Definition of conservative and non-conservative forces and give examples;
conservation of mechanical energy only when conservative forces are present;
when non-conservative forces are present mechanical energy is not conserved, but total energy (of the system) is still conserved;

Solving conservation of energy problems (with dissipative forces present) using the equation: $W_{nc} = \Delta E_k + \Delta E_P$; and use the above equation to show that in the absence of non-conservative forces, mechanical energy is conserved.

Power

Definition of power;

Calculating of the power involved when work is done;

average power required to keep an object moving at a constant speed along a rough horizontal surface or a rough inclined plane;

Calculations using $P_{av} = F \cdot v_{av}$; *and*

calculating the minimum power required of an electric motor to pump water from a borehole of a particular depth at a particular rate using: $W_{nc} = \Delta E_k + \Delta E_P$.

Teachers' responses were not consistent with each other in what they focused on. For instance, Nimjou took a more general approach and did not name the topic concepts. Instead, he focused on broad and general areas such as applying mathematical procedures in Physics problem- solving and the differentiation of angles. In this regard, Nimjou stated: "They should know their angles. That emanating from the geometry part of Mathematics. Basically, their Mathematics should be sound". On the other hand, Rhadie, Miss A and Dlamini listed specific concepts from the topic of Work, Energy, and Power that they considered key. They expressed the following:

> First, they should understand. I think it's key, the definition of work. What is work and the equation to calculate work and then when they understand the equation and each variable, what it stands for. [Rhadie]

> One big idea is work. The concept of work done on an object. And then. Net work done on an object, the difference between work and the net work done on object. Kinetic energy and change in kinetic energy. [Dlamini]

> Overall… there are certain outcomes that…these learners need to know at the end of at the end of this topic number one, you should be able to define … these three variables which is the Work, Energy, and Power… *Ukubana lo theta lona uzaba* (that this particular angle theta will be) different… *umzekelo* (for example) for when you're calculating work for applied force, this theta is going to be different when you're calculating work done by friction work done by the normal, work done by the gravitational force. And *ihlukhaphi* (how is it different). [Miss A]

Dlamini and Miss A gave more key concepts than Nimjou and Rhadie. However, none of the four teachers identified all the topic's key concepts compared to the CAPS document in Box 5.2. Again, the teachers, on average, could not adequately articulate the key concepts of this topic. This agrees with Mazibe et al. (2020) who concluded that teachers are often unable to fully articulate their PCK.

5.2.3 Theme 3: What is difficult to teach (what learners find difficult)

This question explored the teachers' knowledge of what their learners typically find difficult to remember or comprehend. The implication was that by exploring what learners have difficulty with we can infer what the teachers might find difficult to teach. In Table 5.3 the teachers emphasised different aspects of the topic that the learners have problems with. Their responses were compared with the data gathered from NSC examination diagnostic reports. Table 5.3 shows the teachers' responses to the question.

Table 5.4: Teachers' articulation of what learners find difficult to comprehend/grasp

Nimjou	**Rhadie**	**Dlamini**	**Miss A**
1. Differentiating between forces 2. Understanding the net force: crucial for determining the work done by the net force 3. Connection of net force to Newton's second law of motion 4. Adding forces into a net force - acceleration. 5. Work done by forces including frictional forces and applied forces 6. Free-body diagrams: and their use to the determination of the net force. 7. Connection between net force, acceleration, and kinetic energy 8. Integration of concepts across different Grade levels. (prior knowledge)	1. Concept of angles and incline when it comes to gravitational force 2. Identifying and distinguishing conservative and non-conservative force 3. Choosing the appropriate equation or formula for calculating the work done by conservative and non-conservative 4. How to analyse the given statement and identify relevant values to substitute in equations (problem-solving) 5. Confusion caused by formula complexity	1. Concepts of net force and net work and applying them in various contexts. 2. Work done by non-conservative forces 3. Verbal explanations 4. Application of concepts in numerical problem-solving 5. Lack of a solid foundation in understanding the work itself. (prior knowledge)	1. Perceived ease of question papers 2. Teaching gaps from earlier grades (prior knowledge) 3. language barriers 4. grasping new terms and concepts e,g conservative and non-conservative forces 5. teaching Newton's Laws

Nimjou, Dlamini and Rhadie outlined what their learners experience difficulties with when teaching the topic. They mentioned concepts such as using net force in calculations, conservative and non-conservative forces, working with free-body diagrams and solving problems that involve objects on inclined planes.

These teachers also pointed out that the lack of prior content knowledge from earlier grades contributes to the poor mastery of related concepts at the Grade 12 level. For instance, Dlamini and Miss A said the following:

> Learners struggle with the concept of the net force and therefore struggle also with the net work done. So, they struggle with the old (prior knowledge), which is the net force and Newton's second law application. [Dlamini]

> They are well aware of *ezi* (these) equations *zo*-kinetic (for kinetic) energy and potential energy and mechanical energy. But at Grade 11… I haven't taught Grade 11 by the way, in the longest time. At Grade 11 level. Uh, we don't go too deep…. all of a sudden, they hear of zero work. What is zero work Miss? What is positive work? What do we mean by negative work? *Zizinto ezo (*those are the things) that I think they did not know at Grade 11 level. [Miss A]

In her response, Miss A pointed out that the source of the learning difficulties learners for Grade 12 learners might emanate from Grade 11 where the concepts are taught at surface level. The learners fail to grasp the Grade 12 level concepts such as positive, negative and zero work. She also highlighted that she has not taught at the Grade 11 level in a long time and therefore was unsure of the strength of her learners' prior content knowledge. She added that the difficulty level of examination questions has been lowered in recent years, and this had made the teachers' job easier since learners are now allowed to use alternative methods to solve problems.

> The examiners have made it easy for us because in the previous years they would write, use energy principles only to answer this question, but now they have made things a lot easier because I think... more specially *ilanduka* (what do you call it), *I*-group (this group), 2021–2022. *Kuya kuba bhetere* (it is getting better) because at least they are given a chance to use other formulas *kungatwa* (not being instructed that) you must use the work-energy principles only… [Miss A]

Rhadie, like Miss A, approached the learners' difficulty discussion from the same angle of examination questions:

> There are about, I think four equations that they can use. … Sometimes they do not know which equation to choose. I think it goes with they don't know how to analyse the statement to find what they are given and then use those values to choose the correct equation. [Rhadie]

According to Rhadie, the difficulty in solving numerical problems is caused by the inability to analyse the given statement and identify the variables which will indicate which formula should be chosen from the several listed under the topic of Work, Energy, and Power.

- Comparing teachers' responses to the data gathered from National Senior Certificate examination diagnostic reports (2017–2023)

When the teachers' responses were compared with findings from examination diagnostic reports (2017–2023) as part of document analysis, I came up with the sub-themes shown in Table 5.4.

Table 5.5: Relating sub-themes on what is difficult to teach to what is identified from examiners' reports

What is difficult to teach (teachers' response)	**Diagnostic reports (exam year)**
Integration of concepts across different grade levels (prior knowledge)	2017, 2018, 2019, 2023
Using net force to determine net work	2018, 2019, 2020, 2021
Drawing, labelling and interpretation of free-body diagrams	2017, 2018, 2020, 2021, 2022, 2023
Conservative and non-conservative forces – definitions and work done	2017, 2018, 2019, 2020, 2022
Choosing the appropriate equation or formula and mathematical skills	2017, 2018, 2019, 2020, 2022, 2023
Verbal explanations and definitions	
Problem-solving skills	2017, 2022, 2023

The diagnostic reports are compiled based on learners' performance at a national level. What the teachers identified as difficult for their learners was also difficult for learners across the country. Some of these findings are not unique to this study. For instance, Hlabane (2016) concluded that the reasons for poor performance in the NSC examinations can be classified into five main themes, namely 1) lack of conceptual understanding; 2) lack of higher-order thinking skills; 3) difficulties in comprehension and understanding of questions; 4) poor mathematical skills and 5) lack of proficiency in the LoLT. However, Hlabane's (2016) study did not focus on a particular topic but on Physical Sciences as a whole.

5.2.4 Theme 4: Teaching strategies for difficult concepts

The question analysed the methods teachers used to facilitate learning of difficult concepts and relevant prior knowledge. Table 5.5 shows the teachers' responses to the question on teaching strategies.

Table 5.6: Strategies used by teachers to mediate difficult concept

Nimjou	**Rhadie**	**Dlamini**	**Miss A**
1. Using free-body diagrams 2. Highlighting the connection between net force, acceleration, and kinetic energy	**1.** Emphasising understanding of trigonometric concepts and how they relate to Physics concepts. **2.** Integrating Mathematics with Physics – not view them as two separate knowledge entities. **3.** Providing a list of conservative and non-conservative forces (examples commonly countered in examination questions) **4.** Encourages memorisation of facts on conservative and non-conservative forces. **5.** Focusing on a specific equation**:** "Work net = change in kinetic energy" when choosing an equation.	1. Starting from known concepts and gradually introducing unknown concepts. 2. Revising forces, which the learners have previously learned in Grade 11, 3. Use of free-body diagrams:	1. Visual demonstrations and practical examples: 2. Encouraging independent learning: The teacher encourages learners to watch videos, even outside of class, to reinforce their understanding. eg YouTube 3. Leveraging multimedia resources: Uses videos to explain concepts and make learning more engaging.

The teachers came up with various strategies that they use to mitigate the difficulties identified earlier and these strategies include making use of free-body diagrams to identify forces acting on an object. The teachers remarked on this strategy:

> The free-body diagram is mainly exposing or showing the learners all the forces that are acting on the object. So that it is gonna be easy for the learner to be able to say this is how much net work I have because I have identified all the forces that are acting on an object. [Nimjou]

> We always, always draw free-body diagrams for them at least … they have got comfort on that…. [Dlamini].

Dlamini added that linking new concepts to prior knowledge is another strategy that can be used: "When you move them to the work done, work done by the net force we've calculated net force. So at least you … So you begin from the known to the unknown. Miss A indicated that using visual representations such as YouTube videos also aids in learning difficult concepts. She remarked:

> So one of the things that I try to do with my learners is to make them watch videos. At least let this be explained by someone else, and *babone* (let them see) like practical examples of this happening…They did not only get to hear it about it from *mna* (me) and also *lento yobabukelisa i*-video *e-classini* (and this thing of making them watch videos in class), I also encouraged them... You should also watch those videos even at your *kwindawo enihlala kuzo* (places of residence) [Miss A]

Integrating Mathematics and Physical Sciences is important as highlighted by Rhadie when she said that "they usually take Physics and Mathematics as two different subjects. They don't integrate them and so I try for them to do the trig ratios and I show them the side which one is the opposite side … is the adjacent side and everything". Furthermore, she indicated that she revised basic trigonometry concepts relevant to the current topic:

> Basically, with trigonometry, you know they should understand the, what that sine theta means. What does cos theta mean? And it goes with maths because now the angle between the two forces, which is your Fg parallel and your Fg perpendicular, they should know it's the same angle as the angle of the incline. [Rhadie]

Sometimes teachers encourage learners to memorise difficult facts as expressed by Rhadie: "I tell them, Fg is a conservative force. I make them memorise because it is too late to understand". One helpful strategy for solving numerical problems is to identify and use simpler equations instead of complex ones whenever possible. This can assist learners in their problem- solving processes. Rhadie tells them that "when they have to choose equations, they should just take that $W_{net} = \Delta E_k$ and they should leave all other equations".

Some of the teacher-suggested strategies are also highlighted in some NSC diagnostic reports under the sub-headings of "general comments" and "suggestions for improvement". Table 5.6 summarises these strategies and compares them with the diagnostic reports.

Table 5.7: Conceptual teaching strategies suggested by teachers versus diagnostic reports

Teacher-suggested strategies	**Strategies from diagnostic reports**
Using free-body diagrams to identify forces	When using Wnc = ΔU + ΔK or Wnet = ΔK, learners must draw a free-body diagram to identify the forces acting in the direction of motion to know how many forces are causing the net work to be done. (DBE, 2018; 2020; 2021 & 2022)
Building on prior knowledge	Teachers are urged to integrate Newton's laws of motion and Work, Energy, and Power so that these concepts can be reinforced. (DBE, 2017) Grade 11 work should be included in classwork, homework and tests in Grade 12 (DBE, 2018)
Leveraging technology (multimedia)	Use PhET [Physics Education Technology] simulations to assist learners in the identification of forces acting on objects (DBE, 2019, 2020, 2021)
Integrating Mathematics	Learners should be given a variety of problem-solving activities that involve mathematical knowledge pertaining to simultaneous equations, quadratic equations, binomials, factorisation, trigonometry and graphs in classwork, homework, tests, and examinations. (DBE, 2018)
Working with an easier equation ($W_{net} = \Delta E_k$ in stead of Wnc = ΔEP + ΔEK)	It would appear that the equation for the work done by non-conservative forces is not taught in all schools. (DBE, 2022)
Rote learning	*Not explicitly encouraged in the reports*

The techniques presented in Table 5.6 are a synthesis of what teachers offered. None of them proposed all or even most of the strategies in the table. The combined set of strategies can help individual teachers construct their TSPCK. This demonstrates the efficacy of a PLC as a vehicle for meeting the developmental requirements of South African teachers (Brodie & Borko, 2016). Each teacher will help and be helped by their colleagues in development "for educators, by educators, and with educators" (Ngcoza & Southwood, 2019, p. 3).

5.2.5 Theme 5: Use of representations

The question aimed to investigate the various teaching aids or representations used by the teachers, such as analogies, graphs, pictures and laboratory equipment (see Table 5.7).

Table 5.8: Representations used by teachers

Nimjou	Rhadie	Dlamini	Miss A
1. Demonstrations and experiments to aid understanding. E.g. 1: pulling a box on the floor to demonstrate the non-conservative force of friction.	1. Use of a trolley track for teaching Newton's laws. 2. Using videos.	1. Free-body diagrams 2. Use of drawings and graphs in questions 3. Demonstrations to help learners comprehend the topic.	1. Using everyday objects such as pens and pencils to create visual representations. 2. Use of videos to support practical demonstrations.

To clarify abstract concepts for their students, teachers employ several ways to represent and demonstrate these concepts. During the interview, for instance, Miss A exemplified how she used pens to depict the forces operating on an object and the angles between them. As she held two pens perpendicular to one another, she illustrated her point.

> The normal force is facing upwards. What is the angle? Because *iyazibonakelela ke ngoku* (it is clearly showing). What is the angle between the normal force and the direction of motion? So, *Mntanam* (my child), when you're calculating work done by the normal force, *u*-theta *wakho* (your angle theta) is going to be 90 (degrees). [Miss A]

Diagrams and pictures are used to represent forces and the bodies on which they are acting. Dlamini noted that "even questions come with drawings so that learners understand" in support of the importance of diagrams.

Nimjou also uses easily available resources such as cardboard boxes and pens. He explained:

> You use a demonstration where you can pull a box on the floor to demonstrate that there is a non-conservative force in the form of friction … If you show conservative force entity, you also want to show non-conservative force. … Take your pen and let it fall. [Nimjou]

When available, conventional laboratory apparatuses are also used when teaching Newton's laws of motion directly connected to the topic of Work, Energy and Power. Radhie indicated how she uses a

trolley and trolley track:

> Yes, we do have a trolley track at my school, so we use it basically, when we are doing Newton's laws Because I told them when a force … is applied on an object. The object according to the second law, the object is going to accelerate. [Rhadie]

In addition to free-body diagrams, Dlamini also uses demonstrations with physical objects including trolleys. He added: "We even have a demonstration in class to point to them that this is what is happening? Maybe some few trolleys there and there".

The representations used by teachers in the teachers are as follows:

- Free-body diagrams to represent force.
- Demonstrations using easily available everyday use objects such as boxes and pens.
- Demonstrations using conventional laboratory apparatus such as trolleys and trolley tracks.
- Audio-visual aids such as videos.

5.2.6 Summary and discussion of teachers' TSPCK on Work, Energy and Power

The discussion on the articulation of PCK by the teachers has so far centred on the five components of TSPCK and the use of representations and analogies (Mavhunga & Rollnick, 2013). To sum it up, the following can be said about the teachers' TSPCK.

Theme 1: Learners' prior knowledge – the teachers' articulation of relevant prior knowledge can be described as inadequate. Knowledge of learners' prior knowledge and misconceptions is vital because this knowledge helps teachers locate the learners' ZPDs as postulated by Vygotsky (1978). In addition, from a constructivist viewpoint, new knowledge is constructed using prior knowledge as the foundation. Thus, learning by constructing requires a change in prior information, where change can refer to the replacement, addition or alteration of existing knowledge (Cobern, 2012).

Moreover, learners' prior knowledge may include misconceptions about fundamental concepts such as 'energy, 'power' and 'force' which are often confused (Jewett, 2008; Lemmer, 2011; Mapfumo, 2016). Consequently, an awareness of such requisite prior knowledge is crucial for the teacher. The teachers' poor articulation of the relevant prior content knowledge might indicate that they neglect learners' prior knowledge when they teach.

Theme 2: Curriculum saliency – the teachers, except for Dlamini, could not adequately state the main ideas of the topic as outlined in the CAPS document. The big ideas for this topic in the CAPS document are the *definition of work, work-energy theory, conservation of energy with non-conservative forces present, and power.*

Theme 3: What is difficult to teach – teachers managed to identify the main areas of difficulty. This was adequate compared with the NSC Physical Sciences diagnostic reports on the topic in question.

Theme 4: Conceptual teaching strategies – a limited number of strategies were presented, and the strategies seem to indicate that the teachers use teacher-centred teaching methods. This is consistent with what was reported by Nyembe (2020) and is criticised for resulting in surface learning of concepts (Kolobe & Hobden, 2022) as it focused on doing enough just to prepare learners to pass examinations. None of the suggested strategies involved learners taking centre stage, either individually or collaboratively.

Theme 5: Use of representations including analogies – The teachers presented using limited representations. If teachers use a variety of representations, then abstract concepts difficult to teach can be better understood by learners.

The teachers' general articulation of the TSPCK components in the interview is similar to those in Mazibe et al.'s (2020) study when they explored the teachers' reported PCK. Mazibe et al. (2020) observed that teachers could not fully articulate the PCK. However, these scholars used interviews and a questionnaire but even then, they could not get teachers to articulate the five TSPCK components adequately. As in Mazibe et al.'s (2020) study, teachers in this study articulated other components better than others in this study. In another study, Nyembe (2022) also observed teachers lacked adequate PCK on Work, Energy, and Power.

5.2.7 Theme 6: Language of instruction in mediating learning

This part of the interview explored the language of instruction as a theme and two sub-themes were predetermined. The first sub-theme focused on how teachers typically use language in mediating learning. The second sub-theme was teachers' views of the language used in the textbooks and the contexts of the given examples. This is against the backdrop of the teachers and learners having ESL while the LoLT is English. Tables 5.7 and 5.8 below show responses given by the teachers on the two

sub-themes respectively.

5.2.7.1 Sub-theme 6.1: Teacher's use of language in mediating learning

All the teachers indicated that they did not stick to English, the official LoLT in their mediation of the topic of Work, Energy and Power. Including the learners' home language, IsiXhosa is vital for learners to make sense of the concepts. In this regard, Nimjou remarked: "If you want the concept to be clear, you have got to explain in the language that they understand clearly, the first language of theirs". In the same vein, Dlamini mentioned that he uses IsiXhosa words such as *"ukuyityala, ukuyitsala* which are your Xhosa [words] for push and pull when talking about the force".

According to the teachers' responses, translanguaging strategies such as code-switching, versioning and translation were used to mitigate the language difficulties experienced by learners and sometimes by teachers. Translations were used to translate notes and sections of the textbooks. Rhadie explained this by saying: "So we will read, maybe the text or notes that are written in English and then I would interpret that section of work... it's mostly translating content between English and IsiXhosa". Miss A gives learners notes written in English and then explains them in IsiXhosa. In her response, she also codeswitches and code-mixes quite extensively.

> You probably have prepared notes for them. Now the notes are there. *Kufuneka uzicacise nentoni?* (you have to explain them in what?) *Ngesi Xhosa* (in IsiXhosa) so that *bazokwazi ukuzi* understand*a* (they will be able to understand). *Ingaske undibone* (I wish you could see me) when I explain. I would read the question in English then analyse the question one word, word by word *ngesiXhosa* (in IsiXhosa) because *ufuna bayive* (you want them to understand). It is being pulled - *itsaliwe*. Pushed – *Iya*push*wa.* [Miss A]

The teachers keep English as the target language although they use IsiXhosa to varying extents. Dlamini explained saying: "I have some few words that I drop in there and there that I really know to express the concepts". When I asked him to quantify the amount of IsiXhosa he uses relative to English, he said: "So the percentage will be, well... 70% English and then there is a small 30% of Xhosa". As far as the learners are concerned, teachers allow them to ask questions and discuss in IsiXhosa, but written work is always in English. For instance, Rhadie pointed out:

> I allow them to ask in whatever way they are comfortable, but I only let them write in English in the books…Yes, they use English only because umm, we can have the discussion in IsiXhosa that and then when we come to a conclusion, we always write it down in English. [Rhadie]

Although they translanguaged, the teachers expressed concern about incorporating this practice into their teaching. They believed that although it enhances conceptual understanding, it may disadvantage learners during examinations where they need to answer questions in English. Miss A pointed out:

> I think, *kengoku, andiyazi* (I am not sure). *Xasizawmane sithetha IsiXhosa oko oko ndinayo into ethi ndizoba* disadvantage(a) (if we keep using IsiXhosa I have a feeling that we will put them at a disadvantage because they won't be asked in Xhosa). Unless this was formalised... *uyabona ungquzulwano* (You see, a collision), *haike* (oh yes). That won't be a problem because *naphaku* (even in the) exam. *Kuzawthethwa ungquzulwano* (they will mention a collision in IsiXhosa) [Miss A]

Teachers incorporate IsiXhosa when mediating the learning of the topic of Work, Energy, and Power for certain concepts that they typically find problematic to explain or teach. The terms/concepts that were specifically identified as problematic are work done, conservative forces, non-conservative forces, and power.

> The terms like … the non-conservative forces, the conservative forces. Alright. It's not that you're gonna find a word for conservative force or non-conservative force. [Nimjou]

In addition, teachers also lamented the inclusion of concepts in contexts which were alien to learners and could hence not explain them adequately in IsiXhosa. Hot air balloons and airbags were examples. The teachers also gave examples of concepts from other topics in mechanics such as elastic and inelastic collisions which were problematic when they tried to explain them to the learners.

5.2.7.2 Summary and discussion of teacher language usage

From the above excerpts, it could be surmised that the teachers did not stick to English, the official LoLT. Instead, they 'smuggled' IsiXhosa into the classroom (Probyn, 2001). This metaphor is used by Probyn (2001) to describe the practice of teachers incorporating the learners' home language in the classroom on the sly since the LoLT is English – this was the case with the teachers in this study. Teachers resorted to the use of IsiXhosa because in Nimjou's words: "If you want the concept to be clear, you have got to explain in the language that they understand clearly, the first language of theirs". The teachers were aware that for the learners to have a better understanding of the concepts they must use the learners' home language. This view is supported by many scholars such as Probyn (2001), Clegg and Afiska (2011) and Prinsloo et al. (2018). This practice explained by teachers can be defined as code- switching.

Code-switching is a linguistic activity in which speakers alternate between using the target language of the discourse and sometimes another language, then returning to the original (Probyn, 2015; Thara & Poornachandran, 2018). The official LoLT in this instance is English, and the teachers momentarily switch to IsiXhosa. As indicated by the educators in the excerpts, code-switching is used to improve learners' comprehension of concepts by those whose first language is not the LoLT.

Regarding students, teachers permit them to raise questions in IsiXhosa and use it during group discussions, but they need the written work to be in English. English is used for reporting and recording, whereas IsiXhosa is exclusively used for discussions. This approach is comparable to previous national and international research projects by David and Venuste (2021) and Msimanga and Lelliot (2014). In my opinion, one of the weaknesses of this strategy is that the learners have to translate their thoughts from conversations back to the LoLT. In addition, teachers may have given instructions in the students' home language, but still expect them to write in English when articulating their ideas – without providing examples of how to use the language.

Rhadie explained that translating sections of text from the textbook or teacher-prepared notes to IsiXhosa is another strategy teachers use to ameliorate the challenges posed by teaching and learning Science in a second language. This strategy was also used in David and Venuste's (2021) study, where it emerged that learners' answering of questions in Biology improved after an intervention that employed various language mitigation strategies – including translation and interpretation. However, the teachers also highlighted some scientific terms such as *conservative force*, *non-conservative forces* and *elastic and inelastic collisions* that they find difficult to translate.

Teachers faced a conundrum because, while they thought translanguaging techniques like code-switching and translation are helpful, learners are not allowed to use IsiXhosa during high-stakes exams. This is even though they and their students find it simpler to communicate in IsiXhosa. In the NSC examinations in South Africa, most learners are assessed in English as if they are monolingual speakers of this former colonial language. This brings into question the ethics, construct validity and reliability of the assessment (Heugh et al., 2017). Pedagogic translanguaging is closely related to TSPCK. The explanation of concepts needs to be in a language or languages that learners fully understand. The teachers already use a bilingual approach to teaching as seen from the language they used to respond to interview questions and their articulation of how they use language in the classroom. Table 5.8 summarises the teachers' responses to the questions on language use in the classroom.

Table 5.9: Teachers' use of languages in the classroom

Nimjou	Rhadie	Dlamini	Miss A
Importance of using learners' first language: Emphasises the importance of using the learners' first language, IsiXhosa, to explain concepts clearly even if they are not allowed to respond in IsiXhosa during assessments. **Use of scenarios and relatable examples:** Suggests using scenarios and examples from the learners' own environment or community to make the explanations more relatable and easier to understand. They emphasise the need to create scenarios in IsiXhosa that allow for clear explanations before reverting to English. **Difficult terms/concepts**: Terms like **"non-conservative forces" and "conservative forces"** **S**uggests creating scenarios and explanations in IsiXhosa to provide clarity for these terms.	**Translation from English and IsiXhosa:** Describes a practice of translating content from English and IsiXhosa during teaching. They read the English text and interpret it in IsiXhosa for better understanding. **Learners are allowed to ask questions in IsiXhosa**, but they are required to write their answers in English. **Language usage in discussions and conclusions**: Mentions that discussions during class are sometimes conducted in IsiXhosa, but when arriving at conclusions, they are always written in English. **Difficult terms/concepts**: Terms like "**work"**, and "**conservative forces", "non-conservative forces"** are easily translatable to IsiXhosa. Struggling to explain concepts like **airbags** or **hot air balloons**, as learners may not have real-life experiences with them.	**Incorporates IsiXhosa:** Mentioned using Xhosa words like "*ukuyityala*" and "*ukuyitsala*" to represent push and pull when discussing the concept of force. They estimate that approximately 70% of the lesson is conducted in English, while the remaining 30% is in Xhosa. The teacher acknowledges that certain concepts like force, direction, and change of velocity are easily translatable and can be explained in Xhosa. **Not all concepts are relevant or easily understandable in Xhosa due to the limitations of the language.** Learners lack of exposure to certain real-world examples, such as **airbags** or **hot air balloons**. **Difficult terms/concepts:** Concepts like **"work"** and "**power**", as there is a lack of well-known terms in IsiXhosa related to those concepts.	**Translation and practical example:** Mentions translating the prepared notes from English to IsiXhosa. They mention the need for simplified explanations in IsiXhosa to ensure understanding but acknowledge that the terminology may be disadvantageous if assessment questions are not provided in IsiXhosa. **Language usage in exams**: Suggests that the language used in exams (English) may not align with the use of IsiXhosa in teaching. Mentioned that if exams were formalised to include IsiXhosa, it would not be a problem. **Difficult terms/concepts:** Challenge of explaining the difference between "**elastic and inelastic collisions**" in IsiXhosa.

5.2.7.3 Sub-theme 6.2: Teachers' perceptions of the language used in textbooks

In this section, I present the data from responses given by the teachers when I asked them to give their perceptions on the textbooks that they and their learners use in terms of the level of accessibility of the language and the relevance of the examples and contexts used. The question did not require teachers to comment on a particular textbook but rather to give a general view of the textbooks they and their learners had access to. They expressed mixed views as I will show in the following paragraphs.

Nimjou did not rely on textbooks, and he preferred other sources because, in his view, the language used was too complex for the learners. Instead of textbooks, he used notes that he prepared from various sources. He explained:

> I don't have confidence in textbooks... I can have five textbooks in front of me. All written by different people… I don't trust the learners that we have…to be the kind of learners that study by themselves on (sic) a textbook because you will always find them going for the books where they have written notes, not going to the textbooks. Now remember that the notes that we do write for them are simplifying the concepts and the scenarios that we give to the…The reason that they don't like the textbook is because the English is above their pay grade. [Nimjou]

Rhadie concurred with Nimjou that her learners have trouble understanding the complex language and definitions in the textbooks and the lack of relevance between textbook content and learners' everyday lives. Like Nimjou, she used supplementary resources to make notes and glossaries to help simplify the language.

> It's difficult for learners (the language) … because when I prepare I always, like I said, try to do the glossary and I always look at the words, I'll show you all these words that the learners are having problem with. Usually they always ask about, ma'am what does this mean? And it's usually at the definitions where they are trying to make sense of the definition in their mind, but now it's all saying all these big words. But I don't encourage them using textbook a lot… I make notes, I type them out and then I print for them. [Rhadie]

In contrast, Dlamini believed the language used in the textbooks was simple enough to be understood by learners except in a few instances. He, however, concurred with Nimjou and Rhadie about the examples and contexts used in the textbooks.

> Not all of them (examples) are relevant … I remember one time I struggled to explain the concept of an airbag Uh, because learners didn't know what it does in the car, because remember some of the learners have never seen an airbag at work. So, when you talk of an airbag in a car learners struggle to get it. They struggle to understand the concept of a hot air balloon. Umm, but also the textbook tries to simplify the language. I can give them credit on that, they do try to simplify the language. So, what I would say about the examples not really relevant, but the language … it's simple enough. A learner that has average understanding of English should not be struggling to read that textbook is written easily enough in terms

of language. [Dlamini]

Miss A stated that she was satisfied with a particular textbook, *Solutions for all* that she was using with her students. She mentioned that the textbook's English language level was easily understood by her students. However, she was dissatisfied with the level of practice questions provided by the textbook. According to her, the questions were too easy compared to the ones her students had to answer in exams. Therefore, she resorted to using past exam questions to help her students practice at the required difficulty level.

> *I*English *esetshenziswa kwa*Solutions for all (the English used in) is very simplified. ... There's an exercise called 'Checkpoint.' Checkpoint 1, Checkpoint 2, Checkpoint etc … But in the exam, you will never be asked that. Instead, you might encounter a complex diagram, and there you must figure out what calculation is required first before you can arrive at the actual answer. [Miss A]

In summary, teachers' opinions on the textbooks were not unanimous. While Dlamini and Miss A were content with the textbooks' language level, Rhadie and Nimjou felt that the language employed in them was difficult for students to understand. Furthermore, Nimjou and Dlamini said some examples were irrelevant to learners' everyday contexts. These findings are comparable to Ramatlapana and Makonye (2012) where teachers indicated that the textbooks, although approved, lack enough depth and breadth to adequately address the curriculum demands. Table 5.9 summarises the teachers' opinions on the textbooks.

Table 5.10: Teachers' opinions on the textbooks

	Nimjou	**Rhadie**	**Dlamini**	**Miss A**
Textbook Description	Lacks confidence in textbooks and prefers other sources.	Lack of relevance between textbook content and learners' everyday lives eg hot air balloons.	Some examples and concepts in textbooks are not relevant to learners' contexts eg hot air balloons.	The "Solutions for All." It's described as a highly beneficial textbook with diagrams that aid in explaining concepts, clear directions, and good organisation.
Simplicity and Ease of Understanding	Language complexity and its impact on learners. Language is above the learners' level.	Difficulty in understanding complex language and definitions in the textbooks.	Language simplification attempts in textbooks, but some aspects could be improved.	The English language used in "Solutions for All" is presented in a simplified manner, making it easy for learners to comprehend.

5.2.7.4 Teachers' additional insights into their pedagogical practices

As mentioned at the beginning of the chapter, eight questions were answered by the teachers. The teachers were given the chance to share further pertinent information not asked in the interview. I have included some of the teachers' significant concerns regarding their teaching on the topic of Work, Energy, and Power below.

Nimjou emphasised the importance of understanding the connections and continuity between different topics and connected vertical projectile motions with understanding, for example, the equations of motion, work, energy, power and non-conservative forces:

> I'm the kind of a person also who understands the connection and continuity of the concept from one topic to another … and let me do an example here. When I'm dealing with vertical projectile motions. You will find that there is a connection. …. That needs for me to understand all the equations of motion. But when I understand energy, I will go to… Work, Energy, and Power where I'm going to use the understanding of non-conservative forces, slopes. [Nimjou]

His response is also related to the data presented in Sections 5.2.1 and 5.2.4 which explored the use of learners' prior knowledge and teaching strategies for difficult concepts respectively.

Rhadie added information on what she finds difficult to teach and some strategies she and her learners use to teach and learn the difficult concepts. One strategy involves linking what is currently being learnt to prior content knowledge from previous grades. She highlighted that students struggle with understanding the definitions of conservative and non-conservative forces and comprehending the concept of the independence and dependence of forces on the path taken.

> And the other thing that they struggle to define is those conservative and the non-conservative forces because now when you say that they are not independent like not independent in the path taken. … Please start talking about conservation of energy. You know those energy topics in grade. [Rhadie]

Additionally, Rhadie highlighted that when learners are motivated, they become more inquisitive and self-directed in their learning. Dlamini dwelt on the challenges of question interpretation and reading skills when dealing with examination-type questions. He expressed concern about students' ability to identify and understand the specific parts being examined in questions.

> The previous year and this year I have just. … I was interested by learners not being able to identify from the words which part is actually being examined … no learners don't actually know what they are being examined. They don't really get the questions. They don't understand the question, and even though sometimes they may know the answer, but they don't know what part

> they are being examined from the from the words that they are reading from the question. [Dlamini]

Dlamini's utterance seems to relate to Section 5.2.7 which discusses the language used in the textbook. He maintains that the language used in the examinations is also simple, but the learners have poor reading for understanding skills. He said:

> Sometimes they scan read, actually, practically scan read … The language is simple but if the learners themselves have not been reading enough. Reading for understanding, you know some are still not well developed in reading for understanding. [Dlamini]

Ms A focused on the importance of teachers' professional development and explained further. She remarked:

> I think into *ebalulekileyo* that *ootishala* [what is important is that teachers] must not stop doing is developing themselves, whether it is staff development … The department [of education] is doing so much, and also even when *i*department *isibiza* (calls us) to these workshops, *asivuyi amaxhesa amaninzi* (we are not happy most of the time) because it's taking up most of our time. *Uyabona neh* (you see right). We away from school. [Miss A]

She added that teachers must also take the initiative in their professional development. She indicated that she regularly watches Physical Sciences teaching videos on YouTube. She said, "*Mna* (me) I develop myself … I'm not even one person who watches TV. In my TV there's always YouTube. I'm always watching Physical Sciences".

The teachers elaborated on their prior statements in response to this last interview question and three new ideas emerged: 1) Making clear how concepts relate to one another when teaching (Nimjou); 2) The belief that students' reading comprehension skills were inadequate, particularly in exam-style questions (Dlamini); and 3) The requirement that teachers take the initiative to improve their pedagogical practices (Miss A). Table 5.10 summarises these ideas.

Table 5.11: Teachers' additional insights into their pedagogical practices

Nimjou	Rhadie	Dlamini	Miss A
Connecting and Building on Previous Topics • Emphasises the importance of understanding the connections and continuity between different topics. • Example of connecting vertical projectile motions with the understanding of equations of motion, work, energy, power, and non-conservative forces.	**Students' Effort and Asking Questions** • Mentions that students who are motivated and eager to learn will go the extra mile by asking questions and seeking additional guidance. • They mention that students sometimes bring question papers from previous years to discuss challenging questions.	**Challenges with Question Interpretation and Reading Skills** • Expresses concern about students' ability to identify and understand the specific parts being examined in questions. • They observe that students may have difficulty comprehending questions and often focus solely on the given values. • Poor reading skills, lack of interaction with the question's content, and limited language skills are identified as contributing factors.	**Continuous Professional Development and Self-Improvement** • Emphasises the importance of continuous professional development for teachers. • They mention attending workshops and dedicating time to personal growth and learning. • Recommends using resources like YouTube. • Uses additional resources beyond the main textbook, including study materials guides.

5.3 Data from Document Analysis

In this section, I present and discuss data from document analysis as described in Section 4.9.2. Curriculum documents present the PCK possessed by the community of practitioners in subjects such as Physical Science, which according to the RCM is called collective PCK (cPCK) (Mavhunga, 2020). The document analysis was responding to research question 2(a):

What do Grade 12 Physical Sciences teachers learn through co-analysing curriculum documents focusing on Work, Energy, and Power concepts?

The following documents were analysed and discussed in the PLC workshops: the CAPS document; NSC diagnostic reports from 2017 to 2022 and the Grade 12 Physical Science textbook (Solution for all). The document analysis was guided by Mavhunga and Rollnick's (2013) five components of TSPCK. The five components are the themes into which the data was classified: Students' prior knowledge (PK), Curriculum saliency (CS); What is difficult to teach (DT); Representations (Rep); and conceptual teaching strategies (CTS). In addition to these five themes, the context of the examples used in the textbook emerged as another theme and I coded it as Cn. Some of the data from the document analysis is presented and discussed in various sections of this thesis as indicated in Table 5.6.

5.3.1 Data from the CAPS document

We analysed the CAPS Grades 10 and 11 content to determine the relevant prior content knowledge. These two grades were chosen since they are part of the FET Phase. Physical Sciences is introduced in the South African curriculum at the Grade 10 level. The prior knowledge identified from the CAPS document is listed in Section 5.2.1. This was the basis for evaluating the level of prior knowledge articulated by the teachers. In addition, the CAPS document also specified the subject matter knowledge (SMK) on the topic of Work, Energy, and Power that the teachers are expected to possess. The prior content knowledge and the SMK of the topic of Work, Energy, and Power constituted the cPCK as postulated by Mavhunga (2020). After the CAPS document, the analysis shifted to the textbooks. One textbook, *Solution for all*, was analysed since three of the four teachers indicated that it was the main book they used with their learners.

5.3.2 Data from the textbook analysis (*Solutions for all*)

When analysing the textbook, we focused on the topic of Work, Energy and Power and noted the following.

- Relevant prior content knowledge was revised before new concepts were introduced.
- The PLC considered that some examples and contexts used were alien to the learners' environment although some related to the learners' contexts.
- There were difficult words/concepts that needed translation or explanation in IsiXhosa that were identified and listed (see Table 5.9).

- Free-body diagrams and pictures represented abstract ideas such as forces acting on an object.

The data gathered from the document analysis informed what was discussed during the lesson planning workshops. Equally important data was gathered from the NSC examination diagnostic reports for the examination years 2017 to 2023.

5.3.3 Data from the NSC examination diagnostic reports

The diagnostic reports, which detail students' exam results, are produced once a year. The reports provide a diagnostic question-by-question analysis and commentary on the subject's overall performance. The questions on Work, Energy, and Power were the focus of our diagnostic investigation. This is often question five in paper 1 of the Physical Sciences examination (Physics). The same sub-headings used in the diagnostic reports are used as themes in the analysis. The analysis results are used to pinpoint issues and make suggestions for enhancing teacher professional development programmes, educational policies and pedagogy (Villanueva, 2016)

5.3.3.1 General comments

The general comments were based on all the questions in the examination paper, but we selected comments relevant to the topic of Work, Energy, and Power. Some comments have been made more than once during this review period and the corresponding years are indicated. Comments made at least three times during the six years from 2017 to 2022 were considered perennial and are indicated in Table 5.11.

Table 5.12: General comments from NSC Physical Sciences diagnostic reports

Comment	Years Reported
• Grades 10 and 11 work is poorly understood.	2017, 2018, 2019, 2023
• Some learners still cannot work with scientific formulas correctly. • The application of mathematical principles is still a challenge for many learners. • Learners are still struggling with drawing and labelling free-body diagrams correctly.	2017, 2018, 2019, 2020, 2022 2018, 2019, 2020 2017, 2018, 2019, 2020, 2023
• Teachers should ensure that learners are able to draw free-body diagrams for such problems in classwork, homework, and tests.	2017, 2018, 2019, 2020

Source: DoE (2017–2023)

Table 5.11 demonstrates that the general comments in the diagnostic reports can be used to develop teachers' PCK. Some of these comments align with what the teachers said during the semi-structured interviews. First, the teachers' articulation of relevant prior knowledge (Section 5.2.1) was inadequate, and the same theme (prior knowledge) emerges from the diagnostic reports when the reports highlight that Grades 10 and 11 work is poorly understood. The teachers do not draw on prior knowledge when they teach; this is despite them mentioning that they observe that learners lack prior content knowledge from earlier grades.

Second, some general challenges faced by learners as suggested by teachers were also raised in the comments. One such challenge is the difficulty that learners have applying mathematical principles. Yet another one is the drawing and labelling of free-body diagrams. Concerning free-body diagrams, the report also suggests their use as a conceptual teaching strategy (see Section 5.2.4). Thirdly, the teachers also raised the challenge of using scientific formulas. Consequently, Rhadie encourages her learners to avoid the formula for work done by non-conservative forces $\boldsymbol{W_{nc} = \Delta E_k + \Delta E_p}$ and encourages them to use the work-energy theorem formula $\boldsymbol{W_{net} = \Delta E_k}$. The analysis then focused on the common errors and misconceptions in the topic of Work, Energy, and Power.

5.3.3.2 Common errors and misconceptions in the topic of Work, Energy, and Power

For this section, I focus on the common errors and misconceptions in the topic of Work, Power, and Energy. Unlike in the previous section (general comments), the frequency of comments was not used to determine what was important. All comments were considered and grouped into three categories: definitions and statements of principles/laws; conceptual understanding; and application and calculation errors. The summary is presented in Table 5.12.

Table 5.13: Common errors and misconceptions

Errors or misconceptions	**Year(s) Reported**	**Category**
• Inability to define conservative force and misuse of terms (using 'force' instead of 'work') • Omission of keywords in the definition of non-conservative force. • Omission of keywords 'total' and 'isolated' in stating the principle of conservation of mechanical energy.	2019 2018,2020,2022 2021	Definitions and statements of principles/laws
• Misapplication of the conservation of mechanical energy. • Inability to differentiate between conservative and non-conservative forces. • Misconception about the scalar nature of work done. • Incorrect interpretation of the work-energy theorem. • Inappropriate use of equations of motion.	2017 2018, 2020, 2022, 2023 2019	Conceptual Understanding
• Incorrect equation usage. • Incorrect calculation of ΔK using the wrong formula. • Writing incorrect labels, showing both weight and its components, or not drawing the normal force perpendicular to the surface. • Failure to identify non-conservative forces, copying incorrect formulas, and swapping initial and final velocities in calculations.	2017, 2023 2020 2022 2022	Application and Calculation Errors

The errors in stating or defining concepts and scientific laws/principles are quite frequent as indicated in Table 5.12. Errors in these lower-order simple recall questions may indicate that learners lack understanding of the concepts or the language to use when the memorised words

are forgotten. The omission of words in these definitions and laws may also indicate that teachers use rote learning because if the learners had conceptual understanding, they could use their own words for the definition or law/principle.

The lack of conceptual understanding is explicit when, for example, learners fail to differentiate between conservative and non-conservative forces. One of the teachers in this study reported that she encourages rote learning of concepts difficult to teach, such as conservative and non-conservative forces (see Section 5.2.4). This rote learning may assist learners in scoring marks during examinations but comes at the cost of poor conceptual understanding. This finding also emerged from a study by Kolobe and Hobden (2022), who concluded that Physical Sciences chemistry teachers in Grade 12 prioritise students' performance in the NSC examination rather than their comprehension of concepts. In addition, facts such as the work-energy theorem are memorised but when it comes to their application in problem-solving learners fall short.

One of the most crucial skills for the NSC Physical Sciences curriculum is drawing free-body diagrams. This ability applies to the mechanics section of the Physics component of Physical Sciences, including electrostatics, and is not restricted to Work, Energy, and Power concepts. Furthermore, candidates often make computational mistakes that stem from misidentifying the forces acting on the objects under consideration. The teachers bemoaned the inadequate mathematical abilities of their students throughout the interviews (Section 5.2.2) and they also brought up this point. In addition, as Dlamini noted during the interview, low reading comprehension might cause the inability to recognise the proper formula from the provided statements.

5.3.3.3 Suggestions for improvement

Based on the five components of TSPCK proposed by Mavunga and Rollnick (2013), the diagnostic reports' improvement recommendations are related to CTS. The recommendations provided in the diagnostic reports for the assessment period of 2017–2023 are compiled in Table 5.13. Where appropriate, related strategies have been categorised into sub-themes.

Table 5.14: Suggestions for improvement (CTS)

Sub-themes	Suggestion (conceptual teaching strategies)	Year(s)
5. . Integration of Concepts	• Teachers are urged to integrate Newton's laws of motion, and Work, Energy, and Power for reinforcement.	2017
6. Problem-Solving Approach	• A systems approach can be used when solving a two-body problem using energy principles. • When using Wnc = ΔU + ΔK or Wnet = ΔK, learners must draw a force diagram to identify forces acting in the direction of motion.	2017 2018, 2019,2021, 2022
3. Understanding Conservative and Non-conservative Forces	• Carefully selected examples and assessment tasks must be used to facilitate the understanding of why certain forces are classified as conservative or non-conservative. • Emphasise that frictional force is not the only non-conservative force; an applied force is also a non-conservative force.	2018, 2019, 2020 2022
4. Calculation and Equation Emphasis	• When calculating ΔK, learners should use ½ m($v_f^2 - v_i^2$) instead of ½ m$(v_f - v_i)^2$. • Learners should know that work done by a force is always equal to a change in energy, e. g., Wnet = ΔK, Wnc = ΔU + ΔK, Wg = -ΔU. • Emphasise that Δ implies final – initial. • Clearly explain to learners the difference between Wnet (total work done by all forces) and Wnc (work done by non-conservative forces).	2018 2019,2020, 2021,2022 2019, 2020 2022
5. Visualisation and Simulation	• Use PhET simulations to assist learners in identifying forces acting on objects.	2019, 2020, 2021,2022
6. Work-Energy Theorem Awareness	• Many learners use the work-energy theorem to calculate the work done by non-conservative forces. • Emphasise the equation for the work done by non-conservative forces. • Teachers must emphasise that the 'loss' in energy is negative and that work done by a frictional force is negative work done.	2022 2023

Six sub-themes emerged from analysing the 'suggestions for improvement' section in the diagnostic reports. They are 1. problem-solving approach; 2. understanding conservative and non-conservative forces; 3. calculation and equation emphasis; 4. visualisation and simulation; 5. work-energy theorem awareness; 6. visualisation and simulation. They fall under CTS following Mavhunga and Rollnick's (2013) five TSPCK components (see Table 5.14).

Table 5.15: Data from document analysis

Document title /type	Author(s)	Reason for analysis	Keys issues identified	Applicable TSPCK components
CAPS Document	Department of Basic Education (2011)	• Curriculum requirements for work and energy concepts • Key concepts • Identifying prior content knowledge from earlier grades	See Section 5.2.1 for PK. See Section 5.2.2 for CS	1. Students Prior Knowledge (Required) (PK) 2. Curriculum Saliency (CS)
Textbook - Solutions for All	Du Plessis et al. (2013)	• To identify the key concepts • Areas/sections/concepts that are difficult to teach. • Terms or words that are confusing / have a different meaning in everyday language. • Identifying requisite prior content knowledge	• Introduction: picture of a skier "*The photograph on this page shows a skier moving down a slope. Energy transfer takes place as he moves down the slope"* (p.165) (Rep, Cn) • Revises Prior Knowledge on kinetic energy; potential energy, mechanical energy and, conservation of mechanical energy (p.166 -167) – (PK) • Short exercise before new material (PK) • Positive work, Negative work, zero work (DT) • Force and Free-Body diagrams used (PK, Rep) • Man pulling a block of ice (PK, R, C) – Block of ice example can be out of learners' context • Trigonometry (PK) • Resolving forces (PK, DT)	1. Representations (Rep) 2. What is difficult to teach (DT) 3. Students' Prior knowledge (PK)

			• Falling apple, pushing a car, remote-controlled car - Familia context (Cn) • Vector/Scalars – (PK) • Net work (CS) vs common word network • Adding forces algebraically (PK, DT) • Skier example on the exercise – Unfamiliar Context (Cn) • Net positive work done, and net negative work done – (DT) • *Gymnast on a trampoline* – Unfamiliar (Cn) • Conservative and non-conservative forces – (DT) • Formula for Wnc – many variables involved (DT) • Science around us section – Bow and arrow example – context, IK – (Cn) • Force, Power and Energy concepts – language (DT)	
National Senior Certificate examination diagnostic Reports	Department of Basic Education	• Performance trends on the topic over five years • Common errors made by candidates. • Recommendations for teaching the topic	**See Table 2.1**	1. What is difficult to teach 2. Conceptual teaching strategies 3. Representations 4. Prior Knowledge

5.4 Chapter Summary

In this chapter, I presented data gathered from phase one of the study. The data from the semi-structured interviews and document analysis explored the teachers' pedagogical practices, and we gained a better understanding of the topic in question, Work, Energy and Power. Mavhunga and Rollnick' (2013) TSPCK was used as the lens to analyse the teachers' pedagogical practices and the documents. In addition to the five components of TSPCK, the semi-structured interviews also explored the language usage of the teachers and the language usage in the textbooks. The CAPS document, which is the official document that details the content to be studied, was analysed to get a clear understanding of the content to be taught at the Grade 12 level and the prior content knowledge the Grade 12 learners are expected to have before learning the topic in Grade 12. The national trends in learners' performances in the recent past specific to the topic in question, common errors and suggestions on how to teach the topic were found in the NSC diagnostic reports for the period 2017 to 2023.

The data gathered in this phase sought to answer research questions 1 and 2(a) and formed the basis for lesson preparations done in collaboration with the teachers in phase 2 of the study. The data presented in this chapter will be analysed and discussed in Chapter Nine. In the next chapter, I present data gathered from phase two of the study.

CHAPTER SIX: CAPACITY-BUILDING WORKSHOPS

> Although the perception that terminology is an intractable obstacle to the use of African languages in high-function domains has been dismissed as scarecrow tactics employed to justify inertia or the status quo, it remains pervasive and can perhaps be addressed to some extent by a closer examination of how a language progresses to become a medium for expressing previously unattested knowledge units or structures. (Antia & Ianna, 2016, p. 63)

6.1 Introduction

In the previous chapter, I presented data gathered during phase one of the study. Phase one was the pre-intervention phase of the study. Phases 2 and 3 comprised the intervention and in this chapter, I present and discuss data gathered from phase 2. This phase comprised workshops held with the teachers. It is during these workshops that the co-construction of knowledge on the teaching of the topic of Work, Energy, and Power took place. During the workshops, the role of the MKO as expounded by Vygotsky (1978), shifted continuously between myself and the participants with whom I had formed a PLC. The epigraph above succinctly captures the goal of the workshops, which was to capacitate teachers to use learners' home language as a resource for knowledge construction. The PLC members and I created lessons that used the learners' home language as linguistic capital for knowledge production rather than attempting to create new terms for scientific concepts.

As outlined in Section 4.9.3, the workshops, except for the last one, were conducted on MS Teams and the recordings and transcriptions were downloaded for analysis. I thus present data from the orientation workshop, followed by data from the lesson planning workshops. The data presented in this chapter sought to answer research questions 2 (b) and 3(a):

1. What can the Grade12 Physical Sciences teachers learn through:

    b. Capacity-building workshops focusing on the co-development of exemplar lessons on Work, Energy and Power that consider learners' home and everyday language?

2. What are the effects of the PLC intervention on:
    a. The quality of the participant teachers' bilingual mediation of the learning of Work, Energy, and Power in their lessons?
    b. The participant teachers' TSPCK of Work, Energy, and Power

6.2 Data Presentation from the Orientation Workshop

The first workshop was meant to orient the participants and set the tone for the approach used in the co-construction of knowledge within the PLC.

6.2.1 Purpose of the workshop

This workshop was conducted on the MS Teams platform which was recorded. In addition, I also made notes as the workshop progressed. The workshop had the following objectives:

1. Outline the steps of the data-gathering process and agree on time frames with the participants.

2. Introduce key concepts of the research to the participants.

6.2.2 Generation of themes from the workshop recording

The thematic data analysis was deductive because the coding process was driven by my preconceived purpose for the workshop as listed above (Majumdar, 2022). As noted earlier, the orientation workshop was conducted on the MS Teams platform. The video recording and transcription were downloaded for analysis. The analysis process was done step-by-step according to the six following phases (stages) suggested by Majumdar (2022) (see Section 4.11.3)

Table 6.1: Themes that emerged from the workshop

Code Names	Themes
A1. Introducing the study A2. Introducing study focus A3. Introducing the PLC idea A4. Introducing the concepts in the study A4. Introducing research activities	A. Building a foundation for the Professional Learning Community
B1. Explaining research activities B2. Clarifying roles	B. Navigating Research Processes and Team Dynamics
C1. Soliciting participants' views on time frames C2. Participant suggestions for activity schedule C3. Participant views on the teaching plan	C. Collaborative Planning with Participant Input
D1. Alternative views on the teaching plan D2. Alternative views on types of research activities	D. Exploring Diverse Perspectives
E1. Challenges on available teaching time E2. Challenges of assessment requirements	E. Navigating Constraints

The conversations from the workshop brought out the following issues that I present as themes summarised in Table 6.1

6.2.3 Building a foundation for the professional learning community

The participant teachers and I formed a PLC as explained in Chapter Four. The orientation workshop was the first group engagement of the PLC and I had to introduce the study, the idea of the PLC, the focus of the study, concepts, or terms to be used such as translanguaging, and others.

The introductory part served to build a foundation for the PLC. The above is evident from the extracts below:

> This group is called a professional learning community, in other words, we are a community of practice, and we are learning with each other, and we are learning from each other. [Researcher]

> Just to give a brief background of what is going to happen … I'm sure we agree that this topic is one of those challenging topics… Now we realise that most of the research is researching on the learners, learners' mistakes, learners' attitudes, learners' this, learners' that. How about the teachers...if you focus on the teachers now, we are focusing on something that we can do to try and improve the teaching of those mistakes that have been identified, right? [Researcher]

> So, I am trying to work on what is called the pedagogic translanguaging, we will unpack it. Now what we're going to do is this group, we are going to develop what we're calling topic-specific pedagogical content knowledge. [Researcher]

6.2.4 Navigating research processes and team dynamics

After the introductory stage, the workshop progressed to a discussion on the research process to be followed and team dynamics. In this part of the workshop, I outlined the research process which included the suggested workshops that were to follow the current one, the lesson plans, and their enactment and recording thereof. In addition, the role of Linda, a non-grade Grade 12 teaching participant was highlighted.

The extract below gives evidence of the above:

> Now, so the first activity we have done. I've had interviews with four of you. … Right then, after we have taught, we are going to also have probably another session where we reflect.

> I'll give you some notebooks where you write the reflections which I will collect so that I can analyse the reflections. In addition, we can also have a group reflection where we now sum up.

> Linda is not teaching Grade 12 Physical Sciences, but she's a Physical Sciences person, so I asked her to be part of these discussions. [Researcher]

6.2.5 Collaborative planning with participant input

The PLC was all about collaboration and co-creating of knowledge. For this to be achieved the voices and opinions of the participants were taken into consideration from the planning and setting up of the schedule of activities and throughout the study. This is evidenced by the extracts below:

> I think that can be manageable other than having a lesson plan for every lesson. What do you think on that one? [Researcher]
>
> And I support the lesson plans for. Yes, for … yes for each, week … Umm, something I just remembered. Maybe I don't know, since usually the exams are written before the week that is set in the ATP [Annual Teaching Plan] instead of maybe planning for three weeks you should push it back. Maybe 2 weeks and half. [Rhadie]
>
> If we … if we do agree on that. I would suggest that he will start with acids and bases. Then it means that you will be starting with the Work, Energy and Power after five weeks. Yeah, that is what it will entail. So what's the take of other people on what I'm just presented here? [Nimjoh]
>
> Me. I would like to start with rates of reaction. Because in acids and bases there are things that involve rates and reactions and there are things like … your K of an acid. So I am not sure how are going to negotiate this? Because that's the trouble with me. I don't foresee a situation where we start with the acids and bases. Then we come to rates because if you want to talk about Kc and acids. We must have touched rates of reactions, chemical equilibrium, which is energy change? [Dlamini]

The excerpt above suggests that the PLC was involved in collaboration. The participants were given a voice in the planning process. One of the most important components of successful teacher development is collaboration (Darling-Hammond et al., 2017). According to Bantwini (2019), professional development as implemented in many teacher development workshops in South Africa typically lacks this collaboration component. In our PLC, we created a space for collaboration, an important aspect of teacher professional development (Yang, 2020).

6.2.6 Exploring diverse perspectives

In keeping with the approach of conducting research with the participants rather than research on them, diverse views from the participants were encouraged and discussed before an agreement was reached. In the orientation workshop, the following extract showcases examples of that approach.

> I am kindly asking that we don't start with this topic (Work, Energy and Power). We start with another topic. [Researcher]
>
> I would suggest that he will start with acids and bases... if you do chemistry … do chemistry and finish it. Then you come with mechanics. So, if we start with the acids and bases then it means that we will have to come with it. The chemical change is the rate and extent of reactions together with equilibrium. So, all three of these topics will have to be done first. [Nimjoh]
>
> Umm. Though mine is a bit different… Me. I would like to start with rates of reaction because, in acids and bases, there are things that involve rates of reactions.[Dlamini]

> I think maybe if we all decide not to start with the work energy and power and then we know that we are going to start with some chemistry topics then since this thing, this study is not about the chemistry topics the teacher can start with whatever topic that they feel they are comfortable with. One can start with his acids and bases. [Rhadie]

> Thank you very much, Miss. I think you took both ideas and synthesised them properly… I think that will work. And if you think starting with rates of reaction is better than starting with acids and bases then it's fine. [Researcher]

From the above extracts, I suggested that we should change the order of teaching to give ourselves time to plan for teaching the topic the research was focusing on. Nimjou suggested that we start by teaching acids and bases while Dlamini preferred starting with rates and the extent of reactions and he gave his justification. Rhadie believed we could leave it to the individual teachers as long as we started with chemistry. The group came to an agreement which I reinforced.

Teachers had the platform to present alternative views and the course of action was negotiated. This chance to air alternative views and negotiate how things would be done is often lacking when navigating constraints in the workshops conducted for teachers (Bantwini, 2019).

6.2.7 Navigating constraints

As we planned for our subsequent workshops and decided on the order of teaching the topics in order to accommodate the co-planned lessons on Work, Energy and Power it emerged that time and the pressure of completing assessment tasks were constraints faced by the teachers. The extracts below show some instances where constraints were raised and how we navigated through them.

> Let's face reality; the reality is that as math and Science teachers, there's never enough time. We smuggle time through afternoon classes and morning classes… the planning is usually three weeks, but we know that we don't have the three weeks. [Dlamini]

> Yeah, I'm adding to that. I was also looking at this assessment plan that the exams are actually starting on the 29th of May and then on that Friday from the 29th of May, they're writing maths. So it means that week it will be hard to get kids because their maths teachers will be busy with them. So let's try to finish whatever we're gonna do on Work, Energy and Power at least before the 29th [Rhadie]

> Because of the two weeks that is going to be swallowed by the examination, sort of the assessment and planning, it means that we need to do something with the other topics to teach them as early as possible and as fast as possible… Meaning that we use the afternoon classes. Also, the Saturday

classes and probably the Sunday classes are gonna be there … on the 27th and the 28th. [Nimjou]

One major constraint the participant teachers faced in their practice was inadequate time to teach the curriculum. In the above extracts, the discussion was about agreeing on when the topic in question would be taught after all the lesson plans had been done. Teachers lamented the lack of teaching time and indicated that the mid-year examination took two weeks and they had to resort to extra classes in the afternoon and over weekends. This finding is supported by studies which reviewed the CAPS, such as Matsepe and Maluleka (2020), where teachers commented that the CAPS did not give them enough time to complete the prescribed curriculum.

In their study, Ramatlapana and Makonye (2012) commented that the CAPS curriculum was too prescriptive and restricted teacher autonomy regarding the pacing and scheduling of assessment tasks. In another study, Grussendorff et al. (2014) pointed out the rigid nature of the CAPS, in terms of time allocation and prescribed assessment tasks. These authors add that the rigid nature was meant to give clear guidance to teachers who were assumed to be ill-prepared to teach Physical Sciences.

6.3 Lesson Preparation Workshops

Owing to the hectic schedules of the participants, the co-planning of lessons was carried out over three workshops that lasted between 30 minutes and two and a half hours. The information gleaned from document analysis and the conclusions drawn from the orientation workshops influenced the focus and nature of the discussion and the content of the lesson plans.

6.3.1 A summary of sub-themes and themes from the workshops

We held three workshops focused on discussing lessons and developing the teachers' PCK. The discussion involved interrogating the documents I had compiled to summarise the Physical Sciences NSC examinations diagnostic reports from 2017–2022 as presented and discussed in Section 5.5.3. Table 6.2 summarises the key issues discussed and the outcomes of the workshops. These issues became the sub-themes which I then grouped into themes as shown in the table below.

Table 6.2: Lesson planning workshops summary

Sub-theme	Workshop Number	Aligned TSPCK Component	Themes
General comments from diagnostic reports	1		Emphasis on diagnostic reports
Importance of studying the diagnostic reports	1, 3		
Lesson plan template introduced and discussed	1, 2		Collaborative lesson plan development
Co-planning teaching schedule	2		
Discussing lesson plan structure	2		
Addition of section on misconceptions into lesson plans	3	Prior knowledge including misconceptions (PKM)	
Misconceptions and their sources	2		Misconceptions and strategies to deal with them
How to avoid and deal with misconceptions caused by other teachers	2	PKM Conceptual teaching strategies	
Identifies words/terms that need to be the focus of translanguaging	3	Conceptual teaching strategies	Difficult terms and translanguaging strategies
Explanation of how bilingualism will be employed	1		
Unpacking the concept translanguaging	2		
Translation discussion (Google translates)	2		
Consideration of township learners and dialects	2	Knowledge of learners and their contexts (Shulman, 1987; Mazibe et al., 2020)	
Code-meshing and complexities	2		

These workshops followed the orientation workshop which discussed document analysis and the concepts of bilingualism and translanguaging among other things. In the following sections, I present the six themes that emerged from the three workshops. Excerpts from the workshops are included to support the discussion of the six themes. In the section below, I will use LPW1, LPW2 and LPW3 to refer to lesson planning workshops 1, 2 and 3 respectively.

6.3.2 Emphasis on diagnostic reports

To begin with, I emphasised the importance of studying the NSC diagnostic reports as a valuable resource for developing the TSPCK for the topic in question and all others in Physical Sciences. I highlighted the aspects of TSPCK that could be developed by studying these reports. The excerpt below illustrates this theme:

> What I looked at in these diagnostic reports… I looked at the general comments… I was focusing on those that also have something to do with Work, Energy, and Power. Then I zeroed in on the Work, Energy, and Power… I looked at common errors and misconceptions. And I looked at suggestions for improvement. I think this is important to go through before we plan our lessons… So after studying this where we are clear where the common areas, the misconceptions and what examiners are advising us to do are. I think we are in a better place now to plan. [Researcher] – LPW1.

6.3.3 Collaborative lesson plan development

The five teachers who worked on this study and I made up the PLC. I was conducting research with them rather than on them. Throughout the process, there was a collaborative effort in this respect. We collaborated to create lesson plans using pedagogical translanguaging that focused on the concepts of power, work, and energy.

The opinions and suggestions of the teachers were always valued. We determined as a group how many lesson plans to develop. In the excerpt below, Dlamini justified the three recommended lesson plans for the topic before he agreed on how many lessons to develop:

> So, we will have three comprehensive lesson plans. Can I have your take on the number of lesson plans that we can come up with? [Researcher] – LPW1

> Well, I think three will be proper. …. The definition of work and just basically work... separately from the work-energy theorem. And then maybe it should show them combined with … conservation of mechanical energy. And then the part of the non-conservative work and the conservative work done, yeah, I think three lesson plans would be fine. [Dlamini] – LPW1

After we agreed on the number of lessons, as the researcher and the PLC leader I took the liberty to design an initial draft of the lesson plan. I presented this at the workshop, explained the various sections and invited the teachers for their input. This initial draft formed the basis for all subsequent discussions. Figures 6.1 and 6.2 are screenshots from the second workshop which was held using MS Teams (LPW2) when I was presenting the initial draft of the lesson plan.

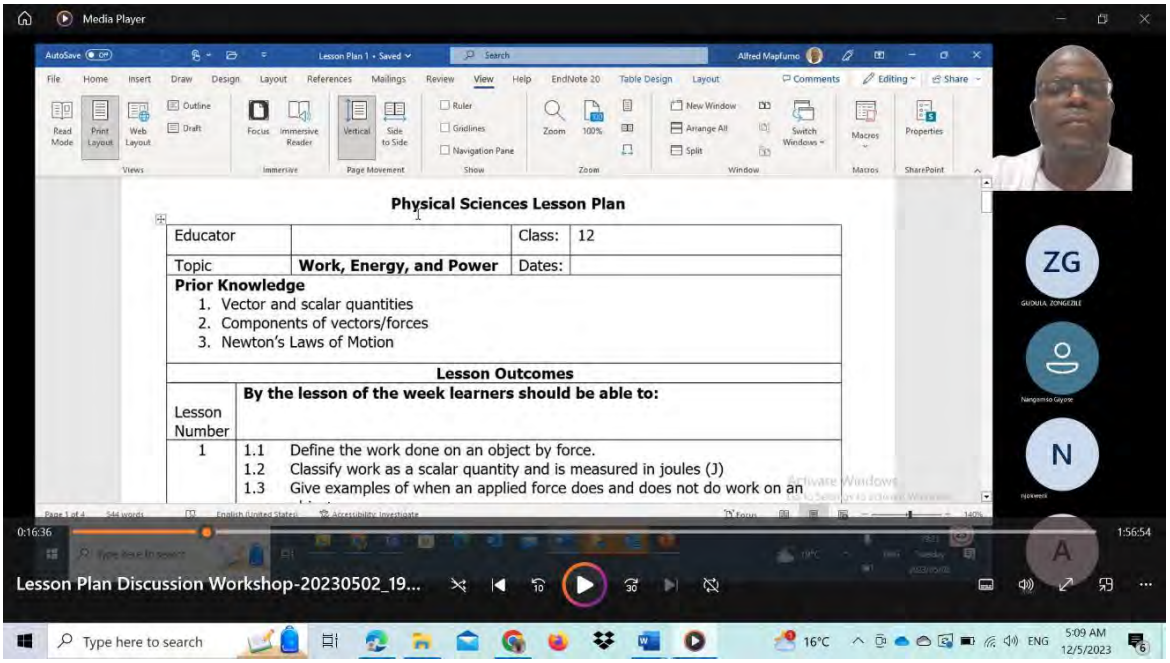


Figure 6.1: Presentation of Lesson Plan Draft - Screenshot 1

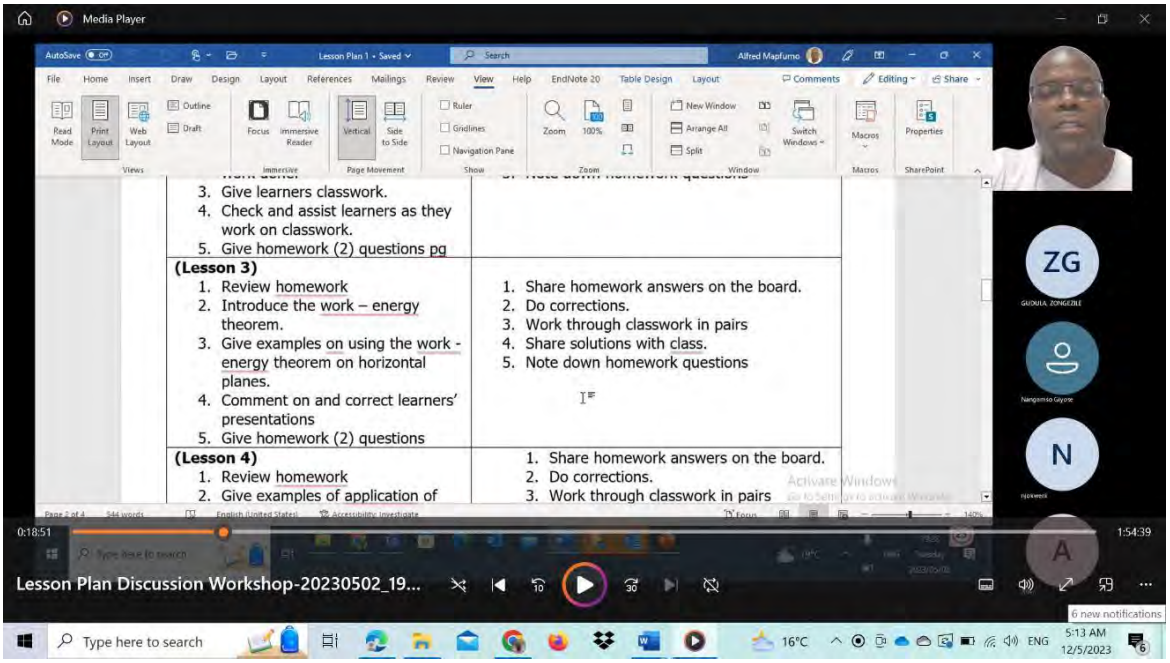


Figure 6.2: Presentation of Lesson Plan Draft - Screenshot 2

In the excerpt below, Linda suggested we should add misconceptions identified from the

diagnostic reports into the lesson plan. The suggestion was accepted by the group and misconceptions were included (see Appendix D).

> After all the planning … OK, I don't know whether it should be after or maybe before just after the lesson outcomes. …. We list the misconceptions there… such that as the teacher teaches … the teacher matches the lesson outcome with the misconception that is based on the lesson income. Or maybe the lesson outcomes could be in a table form together with the misconceptions. [Linda] – LPW2.

One of the most important things a PLC needs to create its PCK successfully is collaboration (Darling-Hammond et al., 2017). Teachers had the opportunity to fully comprehend and accept the PCK features that the workshops concentrated on through cooperation and voicing their thoughts. This was not like typical workshops where there were many teachers in one room, with no opportunities to engage with the presenter and with the phenomenon under discussion (Bantwini, 2019).

6.3.4 Misconceptions and strategies to deal with them

Linda's suggestion to include misconceptions in the lesson plan resulted in a discussion of them. The discussion centred on how misconceptions could develop when learners attended other tuition and revision programmes, such as the one referred to as 'Jenn' where they are taught by other teachers. In Nimjou's words:

> Oh, on avoiding the misconceptions, the learners are going to do them as they're going to Jenn. They're going to the Saturday classes with others or going to wherever. … This emphasis on misconception should be done when you're doing the revision for the end of the year, because when they are doing their own studying and their own discussions in their own places with other learners from other schools. [Nimjou] – LPW2.

Dlamini responded to the above sentiment expressed by Nimjou by suggesting how to deal with the identified misconceptions:

> I'm of the same view that we emphasise the correct physics and actually be preventative of the errors by repeating the correct physics … how if we are aware of the misconception that learners think work is a vector quantity, we keep on repeating to them that work is a scalar quantity… will become aware of the misconceptions if we keep on repeating them. We give them exercises in such a way that, for example, they would say with vertical projectile motion learners think every time initial velocity is 0. [Dlamini] – LPW2.

Dlamini's suggestion adds weight to the importance of studying the diagnostic reports as it helps teachers anticipate some common misconceptions and emphasise the 'correct physics', as he referred to it. This will negate the effect of other teachers as pointed out by Nimjou earlier. During

the workshops, the PLC also identified some difficult terms and how to use translanguaging strategies to enhance learners' comprehension of them.

6.3.5 Difficult terms and translanguaging strategies

I reminded everyone about the key issues of translanguaging before our discussion. After that, there was a short PowerPoint presentation where we discussed compiling the glossary of concepts to be included in the lesson plans. Collaboration was displayed during the discussion of terms that needed to be translated and the glossary of IsiXhosa terms needing to be compiled.

6.3.5.1 Discussions leading to the compilation of the glossary of concepts

Dlamini displayed interest in how IsiXhosa would be used in teaching the difficult terms and concepts:

> Hey, can you please go to the … where we have the interpretation, I honestly liked it. Uh, where do we interpret these concepts? I have been teaching displacement and as a teacher myself and I say I should have used one of those phrases. I've never used those phrases. I'm saying this … that these are accessible phrases. [Dlamini] – LPW2.

The above utterance from Dlamini was made after I had presented a list of terms identified from the diagnostic report as poorly understood. Figure 6.3 shows a screenshot of the lesson plan with some of the terms with my initial translation that I had obtained from Google Translate. This screenshot was taken during LPW2.

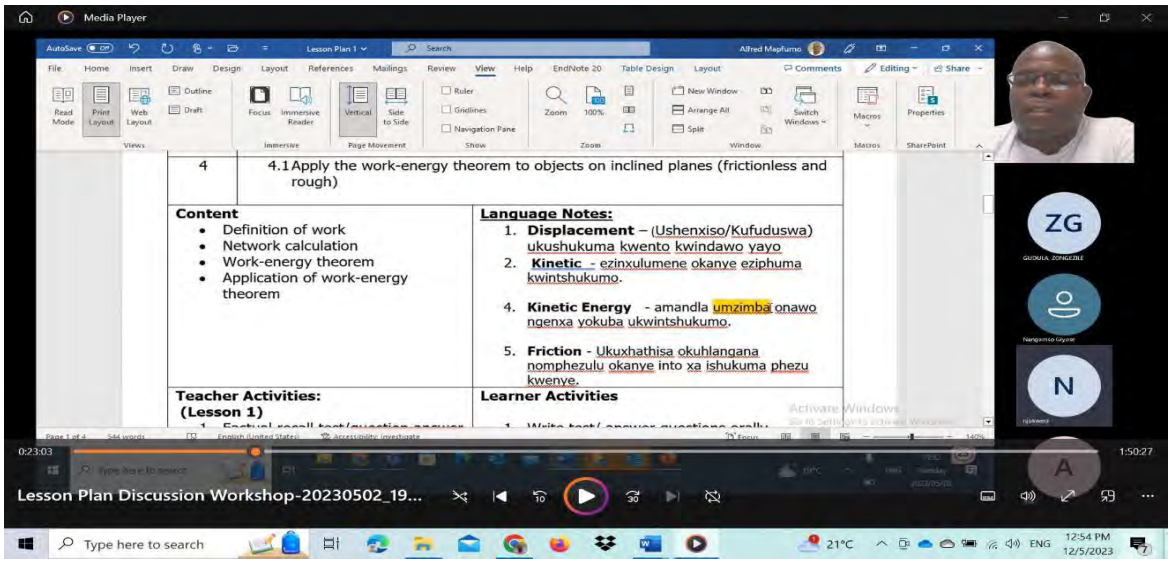


Figure 6.3: Screenshot showing the initial IsiXhosa glossary (LPW2)

The teachers studied the glossary and decided to change and rephrase some of the words. The discussion continued about the translation of terms that would be used in lesson plans 2 and 3. There was a robust discussion with teachers giving different views. The excerpts below are examples of the contributions from the PLC members:

> Because I yeah, I think movement - *intshukumo*. Yes, *umzimba* (body), not a really..... It has too many meanings. Actually, I would say into (object) instead of an object it will say into (object). … It simply means a lot of things in Xhosa. Yeah, but I think *i*-friction - *ukuxhathisa*. Yeah, I think those are the right words that can give a correct interpretation. [Dlamini] – LPW2

> OK, on displacement, can you please go back to displacement? The Xhosa definition of displacement isn't specific on the straight line. Whereas the English displacement is specifically *ukuba* (that) a straight-line path. [Linda] – LPW2

> The difference between conserving something and saving something … isn't it that when you conserve something you are keeping it as it is … there is no change at all, whereas when you are saving something, for example, if you speak of [Linda] – LPW2

I typed the changes in a red font as the conversations went on. Figure 6.4 shows how the lesson plan looked at the end of the workshop. A glossary of eight terms was compiled and Linda was tasked to clean it up and share it with the other members of the PLC.

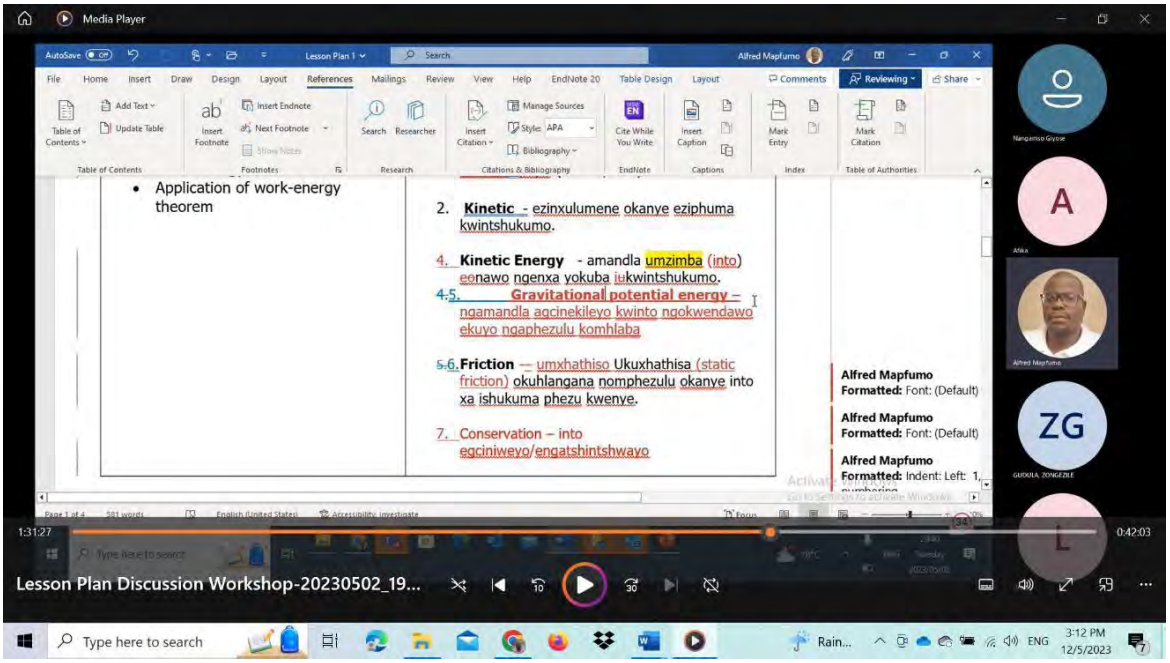


Figure 6.4: Screenshot showing the developing IsiXhosa glossary (LPW2)

6.3.5.2 Consideration of the home language of the township learners

During the deliberations, the teachers were sensitive to the IsiXhosa language complexities as far as their learners were concerned. It emerged that IsiXhosa used in the townships was not too formal hence some words needed to be avoided. Miss A pointed out that the IsiXhosa words such as *ukushenxa* and *ukufuduswa w*ould be too difficult for learners in her school context:

> …*ukushenxa, andiqondi ukuba abantwana bayayazi ithetha ukuthini loo nto leyo* (I do not think the learners know what *ukushenxa* means). So, what I usually do rather, I say *ukususa* (to be displaced) rather *kunoba ndithi ukufuduswa okanye ukushenxa* (instead of *ukufuduswa* or *ukushenxa*). These are good terms but we also want to include *abantwana abakhulele elokishini* (learners who grew up in the township). [Miss A] – LPW2.

On the same issue of looking for simple IsiXhosa words, Dlamini added that "the language that is the spoken language now and the language that, the book language is different…". Apparently, Dlamini was referring to formal IsiXhosa as the book language. This discussion indicates the complexities of using formal/standardised translations and dictionaries such as *Isichazi-Magama SeMathematika neNzululwazi Ibanga 4–9* (The South African National Lexicography Units, 2019) as they do not consider the various versions and dialects of the language spoken by people from different parts of the IsiXhosa-speaking provinces, as reiterated by scholars such as McKinney and Tyler (2019) and Majola (2024). Herein lies the value of working with small groups of teachers to develop contextually relevant teaching material.

6.3.5.3 The challenge with code-meshing in the study

The teachers expressed fears about the code-meshing strategy because learners may end up using it in their final and externally marked Grade 12 examinations. Only English and Afrikaans are acceptable languages for assessments in South Africa, hence the teachers feared that should they use code-meshing they might be penalised. Nimjou expressed these fears as follows:

> As these are the … of translanguaging. Are we compelled to use all of them? If you say you want us to use all of them? There might be a problem with the 4th one (code-meshing). Remember that we are preparing these kids for examination It will be a big problem because they will think that it is acceptable. Remember that they are not going to write to us. They're going to write to the Department of Education. And be marked externally… it's not going to be acceptable when they are marking there. [Nimjou] – LPW2.

After Nimjou expressed his worries, I asked the other members for suggestions on using code-meshing which learners cannot use in assessments. Linda enquired as to whether translanguaging would still occur if code-meshing were omitted. This prompted me to go back over the PowerPoint presentation and make it clear that translanguaging would take place as long as we were using two languages to make sense of the scientific concepts. Linda then suggested the following:

> OK, since our colleague has made us aware of the misconception (challenge) in the exam… could we then say for the purposes of this study, we have eliminated code-meshing and then we explain why? [Linda]- LPW2.

I expressed my disappointment about not exploring code-meshing as a strategy for bilingual assessment. This upholds the myth that Indigenous African languages are inferior if they are limited to spoken language and not written language (Choi, 2021). Rhadie then suggested:

> Or maybe we can allow them to code-mesh when they are taking notes. We allow them to write their notes both in English and IsiXhosa. I mean, does it have to be an exercise? [Rhadie] – LPW2.

Rhadie's idea was adopted as a compromise to explore the use of code-meshing.

6.3.6 Glossary of concepts for Work, Energy, and Power

After the workshop that discussed the glossary of concepts as outlined in section 6.3.4.1 the teachers were given more terms to translate after these workshops. Their translations were then sent by WhatsApp or email to me. The final glossary is given in Table 6.3.

Table 6.3: Glossary of terms for Work, Energy, and Power

	Scientific concepts	Participants' translation/glossary
1	**Displacement**	(Umlinganiselo woshenxiso/wokufuduswa). Umlinganiselo wokusuka kwento endaweni isiya kwenye, ukuqala apho isuka khona ukuya apho iphele khona ngomgca othe ngqo.
2	**Kinetic**	Ezinxulumene okanye eziphuma kwintshukumo
3	• **Energy** • **Ability to do work**	• Amandla • Amandla obunakho
4	**Kinetic energy**	Amandla into enawo ngenxa yokuba ikwintshukumo.
5	• **Force** • **Push or pull on a body**	• Amandla • Amandla otsalo okanye utyhalo
6	**Positive Work**	Umsebenzi oncedisana namandla otsalo okanye utyhalo
7	**Negative work**	Umsebenzi ophikisana namandla otsalo okanye utyhalo
8	**Gravitational force**	Amandla otsalo ngumhlaba
9	**Gravitational potential energy**	Ngamandla agcinekileyo kwinto ngokwendawo ekuyo ngaphezulu komhlaba
10	**To conserve**	Ukugcina into injengoba ibinjalo (ikwimo ebikuyo) ekuqaleni nangona isebenza/isetyenziswa.
11	**Conservative force**	Umsebenzi owenziwe ngalamandla uxhomekeke kwisiqalo nesiphelo sendlela ehanjiweyo, hay kumgama wayo.
12	**Non-conservative force**	Amandla okutsala okanye ukutyhala angagciniyo
13	**Dissipative force**	Amandla okutsala okanye okutsala achithwayo
14	**Non-dissipative force**	Amandla okutsala okanye okutsala angachithwayo
15	• **Power** • **Rate of doing work**	• Amandla • Ubungakanani bamandla okwenza

As noted earlier, there are different dialects of IsiXhosa and the standardised version is based on one dialect (Strom, 2019). The glossary of concepts we compiled with the participants was based on the IsiXhosa version familiar to the learners who lived in the township as highlighted by Dlamini and Miss A. For instance, she pointed out: *"Ukushenxa, andiqondi ukuba abantwana bayayazi ithetha ukuthini lonto leyo"* (I do not think the learners know what *ukushenxa* means). Hence, the *"isigingqi /IsiXhosa sengingqi"* (the language of the local area) was considered in the choice of terms used (Bylund, 2014; McKinney & Tyler, 2019).

6.4 Chapter Summary

In this chapter, I presented and discussed data from the PLC workshops. The first workshop focused on orientating the teachers and setting the tone for planning and enacting the co- planned lessons. The three workshops that followed the orientation workshop focused on discussing how to prepare lessons that apply pedagogical translanguaging when teaching Work, Energy and Power concepts. From the deliberations, we managed to develop a lesson plan format that included relevant prior content knowledge and a glossary of concepts translated from English to IsiXhosa. These terms were identified from the teachers' articulation of what is difficult to teach (see Section 5.2.3) as evidenced in the NSC Physical Sciences examination reports for the years 2017–2022 (see Section 5.5.3).

Furthermore, data presented in this chapter demonstrates that working in a PLC gives teachers opportunities to engage with each other and with the topic being discussed – this develops their PCK in more meaningful ways than when they are in large groups with limited opportunities for engagement. This finding responds to Bantwini (2019) who concludes that the way in which in-service teacher professional development is currently being done in South Africa is ineffective.
The discussions on document analysis helped to develop the teachers' TSPCK components i.e. prior knowledge and misconception (textbook, CAPS document and diagnostic reports); CTS and representation (diagnostic reports); and what is difficult to teach (diagnostic reports). The language of teaching and learning was identified as one of the causes of poor performance in Science and hence the application of a bilingual approach in the planning of lessons (Msimanga & Erduran, 2018; Msimanga & Lelliott, 2014; Probyn, 2015).

With respect to bilingual teaching and learning the developed lesson plans demonstrated how teachers could apply pedagogical translanguaging using techniques that included code-switching, translation and IsiXhosa glossaries for difficult words and concepts on the topic of Work, Energy and Power at the Grade 12 level. However, teachers indicated that they were reluctant to explore code-meshing in assessments for fear that their learners might do the same in the final matric examinations where they would not be credited for answering in English and IsiXhosa. The workshops, which constituted the main activities of the PLC, uncovered the characteristics that conformed with those of an effective PLC for teacher profession development proposed by Hammond et al. (2017). These characteristics include a focus on content (Work, Energy and Power); active learning; supporting collaboration; the modelling of effective practices (pedagogic translanguaging); provision of expert support and offering opportunities for feedback and reflection). These characteristics are reported as typically missing in professional development programmes (Bantwini, 2014; Murray, 2014; Ono & Ferreira, 2010).

CHAPTER SEVEN: ENACTMENT OF THE LESSONS AND REFLECTIONS

> Translanguaging is not just about language, but about the deployment of linguistic and cultural resources to make meaning. (Wei, 2018 p. 17)

7.1 Introduction

The semi-structured interviews, document analysis and planning workshops were intended to develop the teachers' PCK. In this chapter, I thus present the enactment of the pedagogic translanguaging that was planned. From the lesson planning workshops, we produced three lesson plans intended to cover a week of teaching each (see Appendix E). However, owing to several factors which included teachers being behind in their teaching schedule and the pressure to complete the prescribed section of the curriculum by the time learners wrote their mid-year examinations, only two teachers – Rhadie and Nimjou – managed to have their lessons recorded for analysis. From the recorded lessons, I managed to obtain some valuable data that I analysed for translanguaging techniques and TSPCK.

According to the epigraph (Wei, 2018), the aim of pedagogical translanguaging is to bring about conceptual understanding using the available languages as resources for meaning- making. Effective teaching is therefore not only about having the PCK but also about having the right language *for* the students. Hence, in this chapter, I present and discuss the lessons enacted by the two teachers and their reflections on the lessons and the entire intervention. The chapter attempts to answer the following questions:

- What are the effects of the PLC intervention on:
    a. The quality of the participant teachers' bilingual mediation of the learning of Work, Energy, and Power in their lessons?
    b. The participant teachers' TSPCK for Work, Energy, and Power?
- How do reflections influence (or not) Grade 12 Physical Sciences teachers' pedagogical insights and enactment of the topic of Work, Energy and Power after the intervention?

7.2 Rhadie's Lesson Enactment

One lesson, which was 40 minutes long, was recorded for Rhadie. This was the introductory lesson for the topic. The definition of work, the 'work done' equation on a horizontal and inclined plane, was covered. She also differentiated between positive, negative and zero work done on an object. She drew force and free-body diagrams to show the forces acting on the object as she explained. Rhadie also used an example question to reinforce what she had explained and show how net work done on the object is calculated. After that example, she used a scenario of two colliding objects to develop the work-energy theorem. The lesson ended with the revision of the principle of conservation of mechanical energy. During the lesson presentation, Rhadie applied various pedagogical translanguaging techniques, as exemplified in vignettes 1 and 2. I now elaborate on these techniques below.

7.2.1 Pedagogic translanguaging techniques used by Rhadie

The following vignettes show instances of several educational translanguaging strategies that Rhadie employed, viz. *code-mixing, code-switching*, and *translation*. Notably, versioning was typically combined with *code-mixing*. All quotes in IsiXhosa will be italicised while those in English will not.

7.2.1.1 Code-mixing

In her lesson, Rhadie demonstrated the forces at work on a body moving along a rough, inclined plane. When responding to the teacher, the learners (LNS) usually spoke in unison. As described in Section 4.7, the school was a poor rural school which was not well-resourced.

Box 7.1: Showing Rhadie's Vignette 1

Rhadie*:* We have different types of forces, right, that act on an object. It is moving down. *Inoba zeziphi i*-forces (What could be the forces) that are acting on this block? This is my motion, and (as she draws a free-body diagram) *sizoba* (we draw a) *i*-free-body diagram. *Nithi zeziphi i*-forces (you say which forces) that are acting on the block?

LNS: Friction

Rhadie: *I*-friction*, inoba injani i*-direction *ye*-friction*? Kalok i*box *iyehla* so *i*-friction *yona ibheka ngaphi* (the box is going down, so in which direction will friction face?)
LNS:Phezulu

Rhadie*: Phezulu* (Upwards)*.*Why *isiya phezulu* (Why does it go upwards?)
LNS It opposes motion.

Rhadie: It's opposing motion. *Yeyiphi enye i*-force *ekhona?* (Which other force is present?)
LNS*...Yi*-force of gravity (It is the force of gravity*). Injonga ngaphi i*-force of gravity? (Where does force of gravity face?)

Rhadie: So, force of gravity *inobani? Ino* perpendicular *no* parallel (It has perpendicular and parallel force). There is the parallel component, Fg parallel and the perpendicular component, Fg perpendicular. *Zeziphi ezinye i*-force? (What are the other forces?)

LNS: Normal force

Rhadie: *Ime njani i*-normal *force?* (How is the normal force oriented?).
LNS: *I*-perpendicular *kwi*-surface (It is perpendicular to the surface)

Rhadie: And then *ijongephi yona? Injonge ezantsi?* (Where is it facing? Is it facing downwards?)
LNS: Noooo…*i*-opposite *i*-Fg perpendicular. (It is opposite to Fg perpendicular)

Rhadie: It's pointing upwards*. Siyavana neh?* (Are we together, right).

This vignette shows that Rhadie code-mixed most of the time. Her code-mixing was within a sentence, where English and IsiXhosa words formed part of the same sentence, for example, "So force of gravity *inobani*? *Ino* perpendicular *no* parallel".

In some cases, short English phrases/sentences are followed by short IsiXhosa phrases/sentences. For instance, when she said, "It's opposing motion. *Yeyiphi enye i*-force *ekhona*?" In addition, the IsiXhosa noun prefixes '*i*-' (singular) and '*ii*-' were also used with English nouns during the code-mixing, for example, *i*-force (the force), *ii*-forces (the forces), *i*-gravity (the gravity), *i*-friction (the friction). This addition of the prefix *i*- is usually done for scientific terms that cannot be changed

into isiXhosa.

On close analysis, the prefixes represent the English article preposition, ‘the’ as indicated in the brackets. These terms are terms that the learners already understand and might be using in everyday life. In some cases, the prefix i- is used to mean ‘it is’, for instance, in “*i*-opposite*”* and *“i*-perpendicular*”* (‘it is opposite’ and ‘it is perpendicular’). It could be summed up that the way Rhadie code-mixed did not show any preference for or prominence of the official LoLT, which is English. Instead, she used IsiXhosa and English as one cohesive language system (Cenoz & Gorter, 2021) to mediate the learning of Science concepts. This reflected her enacted PCK (ePCK) was in coherence with the collaboratively planned PCK (plPCK).

7.2.1.2 Code-switching

Vignette 2 in Box 7.2 below is an example of an episode where Rhadie used code-switching to mediate learning by switching from English to IsiXhosa and vice versa. The teacher was solving a problem that involved applying the work formula on a body where several forces were acting. This problem was being solved collaboratively with the teacher as the more knowledgeable other (Vygotsky, 1978). Rhadie collaboratively drew the free-body diagram together with the class.

Box 7.2: Rhadie's Vignette 2

Rhadie*: Besithe i*-friction *izojonga ngaphi yona?* (In which direction did we say friction faces?)
LNS: (Some said down, some said top)

Rhadie: *Izojonga ezantsi* (it will face downwards) because it opposes motion. So there is *i*-friction *engubani? 20N.* So *umbuzo wokuqala* (So the first question). Draw a free-body diagram, not just any free-body diagram, of all the forces acting on the car. *Sifuna ukubona zonke ezi* forces that are acting on the car (We want to see all the forces that are acting on the car). *Ukhona umntu obawela ukusizobela?* (Is there anyone willing to draw or us?)
(A learner comes forward to draw the free-body diagram on the board and mumbles the names of the force as he goes)

Rhadie: *Ukhona umntu obawela uku-edishaa okanye siyayivumelana? Siyayivuma neh?* (Is there anyone willing to add anything or do we agree with it? So, we agree?). Remember friction can change direction depending on the motion, but Fg parallel is always down the slope.

Rhadie*: Then u*-number *2*. Calculate the net work done on the object (she writes this on the board). *Xa sithetha ngegama elithi* net *senzantoni kanene?* (When we talk about the term, net, what do we do by the way?)
LNS: We add

Rhadie: *Siya edisha, siyadibanisa, senza i*-sum*. Siyavana neh? Sokutsho ke ngoku*.(We add , we put together, we do the sum) Let us calculate the net work done. That means *kufenaka siqale sibone zeziphi i*-forces *ezenza i-work nezingenzi i-* work*. Zeziphi ezisebenzayo nezingasebenziyo. Iyasebenza i*-force*? Iyasebenza i*-normal force*?* (We must first identify the forces that are doing work and those that are not doing work. Is Normal Force doing work?)

As proposed by Vygotsky (1978), this is the kind of collaboration in a social setting that results in individual learning. Similar to Vignette 1, Rhadie allowed learners to use their full linguistic repertoire, which comprised mainly English and IsiXhosa, to ask and answer questions (Cenoz & Gorter, 2021).

Code-switching involves temporarily abandoning the official language of instruction, which in this case is English, for a language that is well understood by the learners which in this case is IsiXhosa (Probyn, 2015). This practice still maintains English as the superior language and the learners' home language as the subordinate language that is only used when the teacher deems English to be inadequate to mediate learning. However, as can be seen from Vignette 2, Rhadie's use of code-switching seems to differ from how it is described in the literature (Probyn, 2015; Thara & Poornachandran, 2018). In contrast, Rhadie used it more purposefully to mediate conceptual

understanding and control classroom discourse (Ferguson, 2003), rather than treating IsiXhosa as a subordinate language.

7.2.1.3 Versioning

During code-mixing and code-switching practices, Rhadie incorporated versioning of English words. For instance, in Vignette 2, she says "*siyaedisha, siyadibanisa, senza i*-sum" (We, we combine, we find the sum). The verb 'add' is versioned to *'**ed**isha'* by adding the suffix -*sha*. English words are adapted to IsiXhosa orthography, which requires the substitution of 'a' with 'e' in 'add' and the suffixing of 'add' with '-*isha'*, which happens in the versioning of many English verbs into IsiXhosa.

In this case, Rhadie used a bilingual approach of repeating terms for the concept of 'the sum of all forces' to emphasise this important concept concerning the topic of Work, Energy, and Power and for the mechanics section of the Physics curriculum. The importance of the concepts is also indicated in the Physical Sciences diagnostic reports analysed and discussed in section 5.5.3.2 (DoE, 2021).

The mathematical concept of addition is maintained, and by versioning it into *edisha,* it fits well into the linguistic flow of the bilingual sentence (Bylund, 2014). In another instance, she said *"Sizo maltiplay-a i*-force *yethu nalo* Δx*"'* (we will multiply our force by that Δx). In this case, she added the suffix -*a* while maintaining the verb 'multiply' (spelt – *maltiplay* in line with IsiXhosa orthography). In another instance, Rhadie illustrated how to apply the work formula to a force acting at an angle to the direction of motion. She explained, *"Besithe xa sine* force *eme ngolohlobo senzanjani? Siya rizolv**a***" (we will resolve into components). The term 'resolve' is versioned to '*rizolva'*.

The three examples above show how versioning can be used for incorporating mathematical or scientific concepts like *add*, *multiply*, and *resolve* into an IsiXhosa sentence without having to use Indigenous translation equivalents or coin new ones. This versioning using words borrowed from English terms whose meanings are understood helps in cases where there are no easily accessible indigenous language terms. It also mitigates the problem of a lack of IsiXhosa terms for scientific ones (Antia & Ianna, 2016). This approach may be useful when students already understand the ideas represented by English words, such as the resolution of forces acting at an angle, the notions

of components, and addition and multiplication operations in Mathematics. Rhadie was able to incorporate English words into the IsiXhosa language more easily by using the versioning technique (Sefotho et al., 2023).

As stated earlier, another form of versioning was through the addition of the prefix *i-* to nouns and verbs. The addition of the prefix *i-* created loan words for nouns and is a form of lexical borrowing (Bylund, 2014). This was done even in cases where the IsiXhosa term was easily accessible. For example, in IsiXhosa the concept addition is *ukudibanisa*. This finding is consistent with that of Bylund (2014) although he studied the use of loan words in everyday, informal conversations. When loan words were used, the stem of the English word was maintained but a prefix/suffix was added to make the sentence flow and sound natural.

During the lesson presentation, Rhadie used more IsiXhosa than English when explaining concepts. However, her chalkboard summaries were always in English. Moreover, she allowed her learners to freely use their home language to ask or answer questions. Figure 7.1 shows an example of Rhadie's chalkboard summary in English.

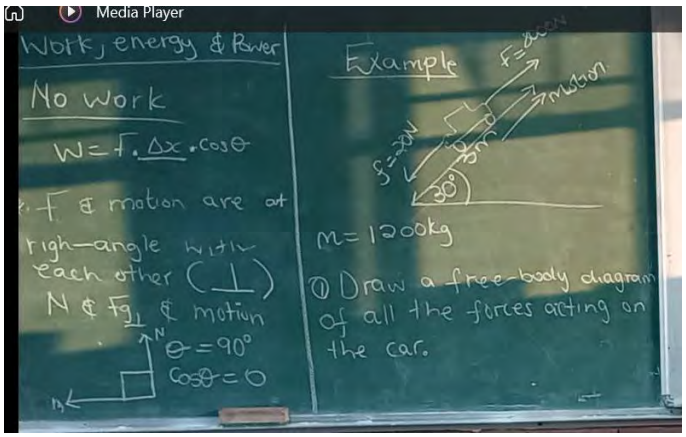


Figure 7.1: An example of Rhadie's chalkboard summary in English

7.3 Nimjou's Lesson Enactment

Nimjou was able to capture two lessons he gave on the topic of Power, Work, and Energy on video. These lessons were analysed to determine how pedagogical translanguaging and TSPCK components were implemented. Lesson 1 was the introductory lesson for the topic, and it lasted

for about 50 minutes. During the lesson, the teacher introduced the definition of 'work done' and the corresponding formula used in calculations. He also introduced the idea of work done on an inclined plane and indicated that the force and force components that act on a body on an inclined plane when a force is applied to it.

In terms of language usage, Nimjou used mostly English in the first 35 minutes of the lesson, and there was almost no learner involvement. However, in the last 15 minutes, he switched to isiXhosa when he was soliciting learner participation purposely. At some point, he asked a question in English, and one learner replied in a code-mixed manner:

> Nimjou: Why are these two (answers) different for the same scenario?
>
> Learner: "Tishala, for le yesibini… okukuqala uyipushile, which means you applied i-force. Kuko i-force eektayo kula 1 metre. Kule yesibini uthe wayiyeka on the second metre, so asikwazi ukufaka le second metre because akuko force eektayo (Teacher, for the second one… First, you pushed it, which means you applied a force. There is a force acting for the one metre. For the second one, you let is go for the second metre. So we cannot include the second metre because the is no force acting).

The code-switching started when he repeated, in summary form, the key points he had explained in English. Vignette 1 and Vignette 2 were extracted from the last 15 minutes of the lesson.

7.3.1 Pedagogic translanguaging techniques used by Nimjou

Nimjou taught the lesson on Work, Energy, and Power using more English compared to Rhadie. His two self-recorded lessons were analysed, and the results showed that he mostly employed code-mixing and code-switching to translanguage to a lesser extent. In addition, references were made to the glossary of concepts produced in the workshop sessions on lesson preparation (see Section 6.3). Moreover, Nimjou allowed his students to ask and respond to questions in IsiXhosa during his teaching, thereby drawing on their full linguistic repertoires as a resource, rather than as a constraint for the construction of knowledge (Burkholder & Palaez, 2000; Cenoz & Gorter, 2021). That is, he allowed his learners to answer or clarify in IsiXhosa. The vignettes that follow demonstrate his translanguaging techniques.

7.3.1.1 Code-mixing and versioning

Vignette 1 was taken from the first recorded lesson; the teacher was explaining the forces acting on a body that is moving along an inclined plane. In this example, he described the components of a force acting on a body not parallel to the direction of motion.

Box 7.3: Showing Nimjou's Vignette 1

Nimjou: Fortunately, we have the knowledge of what, of the components of forces, horizontal and vertical forces, *neh.* So, I am bringing back to you that understanding of component forces. Now things that I have brought into the scenario here are what? (he pauses)

Learners: Free-body diagrams, the component forces.

Nimjou: So that's your two things that I have brought to this scenario. So that we understand *into yokubana kwenzeka ntoni na kwintoni? Kwi*-work done on an object (On the work done on an object). So, when *ufaka amandla neh,* (when you apply a force) (He makes a pushing gesture), that is *utshiliza, u*push*a* (when you push) in other words. You must know that this object is gonna move in a certain direction. If it is not moving in the direction of the force, there must be another force that follows. *Uyayibona neh* (You see it right*)?* So, *sithi kengoku, utshilo kengoku wathi* (So we say, he said it that) when work is done*, umsebenzi wenzekile neh* (work is done right)*, Niyayibona* (you see that*)*? But *xa wenzekile umsebenzi* (When work is done) like *ukuhlamba izitya* (washing dishes)*.* Do we see any motion there? And a displacement?

Learners: No.

Nimjou: So, it means that *xa usenza umsebenzi ngokwe nzululwazi* (when you do work scientifically*),* scientifically, *uyayibona neh* (you see, right), it means that you must apply a force. *Tshiliza okanye utsale* (push or you pull).

In box 7.3 Nimjou introduced the idea of work done by a force acting at an angle to the direction of motion in English. He began by drawing on using the learners' prior everyday knowledge (Kuhlane, 2011) about washing dishes, "*ukuhlamba izitya"*, as a resource to construct the scientific concept of work done by a force. This reference to learners' prior everyday knowledge helped distinguish between the everyday meaning of the word 'work' from the scientific concept 'work done' (Dega & Govender, 2016).

Nimjou then code-mixed when he emphasised the idea that a force must be applied for work to be done: "So when *ufaka amamdla*, *neh,* that is *uyatshiliza, uya*push*a* in other words". Here he seems to be cognisant of the problematic term, *amandla* which refers to energy, force, or power in IsiXhosa. He seemed to purposely use the words '*uyatshiliza, uyapusha*' to distinguish the

amandla (force) from energy and power (Irmak et al., 2023; Lemmer, 2011; Mapfumo, 2016). To further emphasise the point, he used the borrowed (versioned) word *'uya*push*a'* which means 'you push'. The term *uya*push*a* is versioned from the word 'push' by adding a prefix, *uya-* and a suffix -*a* to the verb push. In this excerpt, Nimjou also applied code-mixing to emphasise key points by translating and repeating parts of a sentence.

Nimjou said: "*Xa usenza umsebenzi ngokwe nzululwazi*, scientifically, *uyayibona neh*, it means that you must apply a force*. Tshiliza okanye utsale".* By translating a few words from what he said in English into IsiXhosa – that is, "apply a force – *tshiliza okanye utsale*" – he is emphasising that for work to be done scientifically, a force must be applied. This strategy also avoids the confusion that can be brought about by using the word *amandla* for force without a qualifier which distinguishes it from energy and power. So, it can be concluded from the above vignette, that applying a force was explained as *tshiliza, okanye tsala* in IsiXhosa.

In Vignette 2, which was taken from lesson 1 (like Vignette 1), Nimjou is still discussing the issue of force being applied and work being done as a result. Again, the issue of the three concepts of energy, force, and power, all translated as *amandla* in IsiXhosa crops up. This vignette also exemplifies how the teacher drew on the learners' linguistic repertoires in his mediation of learning. Three different learners coded LN1, LN2 and LN3 took part in the discussion.

Box 7.4: Showing Nimjou's Vignette 2

Nimjou: Iinto ke endiyifunayo yeyokubana uthi xa usenza, ucinga neh (what I want is that when you do, when you think), when you are thinking. Ucinga ngamandla, uyabona (when you think about energy, you see). You must know that kukho into kuthiwa (there is something called…) wena uthe ngamandla mos i-force (you said force is amandla, right?)

LN1: Ewe (Yes)

Nimjou: But i-energy? Uzophinda uthi esiXhoseni ngamandla neh? (How about energy? You will say in IsiXhosa, it is also energy, right?)

LN1: Yhooo…(Exclamation)

Nimjou: So i-force ngamandla otshilizo (so force is pushing), okanye ngamandla okuthini, okutsala (or its pulling). I-energy? You gonna think about it. Uzothini ngesiXhosa (What will you say in IsiXhosa)?
LN1: Yhooo ayinaso, ayinaso… (Oh, there is no term for it)

Nimjou: Sukuthi ayinaso, uvele uthi ayinaso ungakacingi. Qala ucinge kuqala (Do not say there is no term for it before you think. Think about it first). Think about it.

(There followed a brief indistinct discussion with another learner)

LN1: I-energy ngamandla onawo onokuwasebenzisa… (Energy is amandla that you possess and can use).

Ninjou: Uthi ngamandla onawo onokuwasebenzisa? (You say it is amandla that you possess and can use?)

LN2: Ayiyo potential energy leyo tishala? (Is that not potential energy, teacher?)
Nimjou: Leyo (that), it sounds like potential energy xa usithi amandla onawo onokuwasebenzisa (when you say the energy that you possess and can use)

LN2: Ewe … because agciniwe, a-stored (Yes because it is stored),

Nimjou: But ke ngoku, generally, energy yintoni? (But now, what is energy in general?)

LN3: Ngamandla (It is amandla)

Nimjou: Ngamandla qha?(Amandla only?) Umm, power?

LN3: Ngamandla (It is amandla)

Nimjou: Ngamandla i-power (power is also amandla)? So, there is some confusion there neh …We need to come up with a way uzakuthi now, i-energy ngamandla atheni neh, and then i-power ngamandla atheni (We need to have a way of differentiating energy and power). So, due to the understanding of the concept ekuthwa yintoni, yi – energy ne-concept ekuthiwa yintoni, i-power. But okwangoku sise kwintoni, kwi – work that is done (for now we are still dealing with work done). So, sithini ke ngoku? Sigqithe neh (So, what should we do now? We can move on, right?)

In Vignette 2 above, Nimjou picked up the *amandla* discussion building on the force definition – "*amandla okutshiliza okanye ukutsala"* – by soliciting learners' ideas on the explanation of energy in IsiXhosa. For instance, he asked the question: *"Uzothini ngesiXhosa?"* which led to a contribution by LN1. He further used IsiXhosa to probe and encourage learners to share their thoughts when he added, "*Sukuthi ayinaso, uvele uthi ayinaso ungakacingi*". The teacher gave learners a platform to draw on their home language as a means of getting epistemological access by asking questions in IsiXhosa. As suggested by Ferguson (2003), this translanguaging technique of reverting to learners' home language encourages learners to engage more with the concepts being learned.

7.3.1.1 Code-switching and drawing on learners' linguistic repertoires

Vignette 3 extracted from Nimjou's second lesson. The lesson began by asking learners about the key concepts discussed in the previous lesson. The teacher specifically asked the learners to explain the key concepts from the previous lesson in isiXhosa. After the recap questions and answer session, Nimjou explained the different work done by forces such as gravitational force, friction and forces at an angle to the direction of motion. The discussion led to the concept of net force and energy transfer when work is done on an object. The teacher used English until he got to a point where he asked the learners to describe their understanding of the concept of energy. The discussion that ensued is presented in section 7.3.2. The lesson ended with an explanation of the relationship between mechanical energy transfer and change in kinetic energy.

In Vignette 3, I use the codes LN1, LN2 and so on, although the learners may or may not be the same as in Vignette 2. Since the camera was focused on the teacher, learner voices were low and as a result, it was difficult to distinguish them. The codes LN1 and so on only serve to indicate that different learners were taking part in the conversation.

Box 7.5: Nimjou's Vignette 3

Nimjou: You must remember, what did we end up having as a formula?

LNS: $\boldsymbol{W = F\Delta x cos\theta}$ [as the teacher writes it on the board]

Nimjou: Exactly. Whether you are doing it in English or IsiXhosa you have got to come up with that [he points at the equation on the board]. What is work in IsiXhosa?

LN1: *Ngumsebenzi?*
Nimjou: Ok, work *ngumsebemzi.* Fine. But when do you say work is done?

LN2: *Kukusebenzisa amandla ukuhambisa into. Noba i*-distance *engakanani na,* for *ithutyana ukusuke* from *kwindawo ihleli kuyo* to *enye indawo* (It is using a force to move an object over a distance, for a moment from, one point to another).

Nimjou: *Ukusebenzisa amandla,* OK *ukwenza* into *ihambe ukusuka ku*-point A *iyotsho ku*-point B, OK. *Utsho ngolohlobo*? (To use energy, OK to make an object move from point A to point B. Ok, you mean it that way)?

LN2: Yes

Nimjou: So, you are incorporating *ezi zinto* that is, *u*-F, *i*-force *sasithe yintoni*? *Ngamandla neh, owafakayo kulonto kuze imuve, neh, okanye ihambe* and then this is the distance. That is a *ukusukela kulendawo uyisa kwenye* (What did we say it is? It is *amandla* that you apply to an object to make it move, and then this is the distance. That is from one point to another).
But *ke ngoku* (but then) what about this one [pointing at $cos\theta$ at the board]?

[After a brief and indistinct learners' discussion]

LN3: *Ngamandla tishala, la ubuwasebenzisa, aye kwelicala uphushela kulo* (It is *amandla* (force) teacher, the one you used, in the direction in which you pushed).

Nimjou: So, in other words, *kuba ufaka amandla kule* object *ngokuthi uyityale okanye uyitsale izohamba le* object. *Ihamba ibheka kwelicala uwatyalela ngakuwo amandla* (If you apply a force by pushing or pulling the object will move. It will move in the direction of the force)

LN3: Yes…

Nimjou: So, this part, cos θ *icaza lonto*… (cos θ indicates that)

Nimjou introduced the lesson by asking a question about the formula in English. After learners had given him the formula, which he wrote on the board, he specifically asked them to explain the concept of work done in IsiXhosa. By so doing, he once again provided a platform for learners to

draw on their home language as a resource for epistemological access (Ferguson, 2003; Liu & Fang, 2022). The first learner to respond, LN1, gave an everyday term for work, *umsebenzi,* and the teacher probed the learner further to give more detail while still using English. LN2 gave a correct explanation of the concept of work done in IsiXhosa. At this point, Nimjou switched to IsiXhosa and reinforced the explanation given by LN2.

Although both Nimjou and LN2 switched to IsiXhosa, they included English prepositions like 'for', 'from' and 'to'. In their IsiXhosa sentences, both Nimjou and the learners used versioned words such as '*u***push***e'* (you push). The versioned word, '*u***push***e'* is formed from the English word 'push' (a verb) by adding the prefix *u-* and the suffix *-she* to the word 'push'. This is despite having an easily accessible IsiXhosa word '*utyale'* which means 'you push'. However, when Nimjou reinforced the learner's answer he used the words "*uyityale akanye uyitsale"* (you push or pull) instead of '*u***push***e'*.

7.3.2 Which *amandla* is it then?

The difficulty in differentiating the concepts of force, energy or power in IsiXhosa emerged from Nimjou's engagement with his learners. This challenge has also emerged in previous studies conducted in different parts of the world (e.g. Dega & Govender, 2016; Irmak et al., 2023; Mapfumo, 2016). In the study by Mapfumo (2016), it emerged that the confusion stemmed from the fact that in IsiXhosa, the home language of the learners, the same word – *amandla* – was used to refer to all the three concepts (of force, energy and power). This was also the case within this present study.

This confusion was anticipated as it had been discussed in the lesson preparation workshops and definitions were listed in the glossary of concepts (see Section 6.3.6). From Vignette 1 Nimjou referred to force by saying, "When *ufaka amandla neh,* that is *utshiliza, upusha"* He relates force to pushing. In the same excerpt, he also said, "You must apply a force. *Tshiliza okanye utsale* (push or pull)". He further reinforced this by stating: that "*i*-force *ngamandla otshilizo* (pushing), *okanye* (or) *ngamandla okuthini? Okutsala* (pulling)". This made it clear that a force is about a push or pull, i.e. *'tshiliza okanye utsale'*. Furthermore, in Vignette 2 he asked a learner, "But *i*-energy*? Uzophinda uthi esiXhoseni ngamandla neh?"* (How about energy? You will say in IsiXhosa it is also energy, right?).

In this instance, Nimjou purposely used IsiXhosa to surface the complexity of the term *amandla* when used in Physics by bringing up the concept of energy. From the discussion that ensued, energy was then referred to as *amandla onawo onokuwasebenzisa* (*amandla* that you possess and can use) and one learner added that "'*agciniwe, a*-stored*''* (it is stored). This suggests that energy can be stored (potential energy) and these statements differentiate it from a force. The teacher went further to flag the concept of power. However, it was not part of the current lesson when he said, "We need to come up with a way *uzakuthi* now, *i*-energy *ngamandla atheni neh,* and then *i*-power *ngamandla atheni"* (We need to have a way of differentiating energy and power).

The preceding paragraphs give evidence of how Nimjou drew on his learners' linguistic repertoires to navigate the problem of differentiating between the three concepts of energy, force, and power. It can, therefore, be concluded that the three concepts can be described and differentiated by using the word *amandla* with a different qualifier for each concept. That is, force is *amandla okutshiliza okanye okutsala* while energy (potential) can be *amandla agciniweyo onokuwasebenzisa*. In a lesson that employs pedagogical translanguaging, these explanations can be used when the terms are introduced and then be used as part of code-mixed sentences, as suggested by Antia and Ianna (2016).

7.4 Comparing Rhadie's and Nimjou's Application of Pedagogical Translanguaging

As evidenced in the vignettes presented so far in this chapter, both Rhadie and Nimjou implemented pedagogical translanguaging techniques in their mediation of learning of the topic of Work, Energy, and Power. I now compare their application of pedagogical translanguaging.

7.4.1 How did they code-mix, including versioned words?

The most commonly used translanguaging technique for Rhadie was code-mixing, and in the case of Nimjou, he code-mixed less frequently and generally appeared to use more English words than Rhadie. Versioning was typically incorporated into the code-mixing by both teachers. However, Nimjou tended to use more English words in sentences than Rhadie.

7.4.2 How did they code-switch, including versioned words?

In terms of frequency, code-switching was the second most used pedagogical translanguaging technique used by Rhadie. For Nimjou, code-switching was the most frequently used technique. Notably, during their code-switching episodes both teachers also used versioned words such as *i*-friction*, ukuedisha* (Rhadie) and *i*-energy*, i*-force (Nimjou). This application of code-switching is consistent with the assertion that language boundaries are continuously being blurred in everyday language use and that the classrooms in bi/multilingual societies such as the one in this study are heteroglossic rather than monoglossic environments (McKinney & Tyler, 2019).

7.4.3 Reference to concept glossary

In the presentation and discussion of pedagogical translanguaging strategies by the two teachers, I did not specifically refer to the use of the concept glossary before this point. This was because the teachers only referred to the glossary once or twice throughout their lessons. In the case of Rhadie, she referred to negative work as "*umsebenzi ongalunganga"* and positive work as *"umsebenzi olungileyo".* However, according to the concept glossary (see section 6.3.6) that we produced during the lesson planning workshops the concepts were described as follows:

> Positive Work: *Umsebenzi oncedisana namandla otsalo okanye utyhalo*
> Negative work: *Umsebenzi ophikisana namandla otsalo okanye utyhalo*

Rhadie's translations of the two concepts – positive work and negative work – were however incorrect and this may be an indication that she may not have consulted the glossary before teaching the lesson. Nimjou, on the other hand, might have referred to the glossary when he discussed the concepts of energy and force. For instance, Nimjou said *"i-* force *ngamandla otshilizo* (pushing), *okanye* (or) *ngamandla okuthini? Okutsala* (pulling) when he was differentiating 'force' from 'energy'. According to the concept glossary developed by the PLC:

> Energy (Ability to do work): *Amandla (Amandla obunakho); and*
> Force (Push or pull on a body): *Amandla (Amandla otsalo okanye utyhalo/utshilizo).*

Nimjou's translation was consistent with the glossary. In this instance, Nimjou displayed ePCK which was consistent with the plPCK while this was not the case with Rhadie.

7.4.4 How did they encourage learners to make use of their linguistic repertoire?

Nimjou seemed to intentionally encourage his learners to draw on their home language as a linguistic resource for learning Science when he said: "But *i*-energy*? Uzophinda uthi esiXhoseni ngamandla neh?"* (How about energy? Will say it in IsiXhosa - it is also energy, right?). When the learner seemed not to be able to respond he further probed and made specific reference to IsiXhosa by saying, "*I*-energy*?* You gonna think about it. *Uzothini ngesiXhosa* (What will you say in IsiXhosa)". This seemed to inspire confidence in the learner to engage more with the different meanings of the noun *amandla* when used in Science discourse.

However, as was already mentioned, Rhadie seemed to lean more towards using isiXhosa in her language. As a result, I was unable to identify any specific instances in which she promoted the use of isiXhosa because it seemed to be the overall goal of her teaching style.

7.5 Topic-Specific Pedagogic Content Knowledge Components Evident During the Lesson Enactment

In this study, Mavhunga and Rollnick's (2013) TSPCK was adopted as the analytical framework. As such, the workshops that were conducted (see Sections 6.2 and 6.3) were meant to develop aspects of the teachers' TSPCK on the topic of Work, Energy, and Power. These workshops culminated in the drafting of lesson plans that focused on the application of topic-specific pedagogical translanguaging in mediating the topic of Work, Energy, and Power. In accordance with the RCM of PCK, the deliberations that took place during the workshops aimed to transform the collective PCK (cPCK) for the topic into a group-planned PCK (plPCK) on the topic.

Sources of information for the cPCK were the CAPS document (DBE, 2011), the chief markers' reports (DoE, 2018), the *Solutions for all* textbooks and our shared knowledge of translanguaging. The lesson plans co-developed by the PLC were supposed to guide teaching the topic of Work, Energy, and Power using pedagogical translanguaging. In the next section, I present and discuss evidence of the teachers' ePCK compared to the plPCK.

7.6 Rhadie's ePCK Compared to plPCK

The following TSPCK components were evident in Rhadie's enacted lesson: prior knowledge; application of various CTS; what is difficult to teach; and use of representations. It must be noted

that these components were used in the context of pedagogical translanguaging. The lesson was, however, largely teacher centred.

7.6.1 Drawing on learners' prior knowledge

This vignette captures the moment when Rhadie used an example of a moving object colliding with a stationary one to explain the change in kinetic energy, part of the work-energy theorem.

Box 7.6: Rhadie's Vignette 3

Rhadie: In both A and B we are going to notice a change in kinetic energy. *Siyayazi lena i*-change *is kinetic energy (of A) ikowuswe yi-force i-applayiwe ngu-B* (We know the change in kinetic energy (of A) is caused by the force applied by B. What is causing the change *kwi-kinetic energy* ku-B? (she pauses). *Sithe* (we said) the change in kinetic energy *ku-A* is caused by the force applied *ngu*-B. But what is causing the change in kinetic energy *ku*-B?
LNS: (Indistinct mumbling)
Rhadie*: I*-velocity *itshintshwe yintoni? Kutheni izo-slowa* down?
LNS: *Yi*-force
Rhadie: *Isukaphi le*-force*?* (Where is this force from?)
LNS: ku-A
Rhadie: *Isuka ku-A*, remember *u*-third law. *Uthini u*-third law (It comes from A. Remember the third law. What does the third law say?)
LNS: (Indistinct mumbling) When object A applies a force on object B, object B simultaneously applies a force on object A…
Rhadie: *Yho, ngaske iphume ngolweSihlanu kule veki ezayo. Uthini u*-third law? (I hope it appears (in the examination) on Friday next week.
LNS: When object A applies a force on object B, object B simultaneously applies a force on object A in the opposite direction.
Rhadie: When object A applies a force on object B, object B simultaneously applies an equal but opposite force on object A.

In Vignette 3 above, Rhadie linked the work-energy theorem to collisions taught earlier under the topic of Linear Momentum and Impulse. She also asked the learners to state Newton's third law of motion. The learners (in unison) stated the law but omitted the idea of the forces applied by the bodies on each other being equal in magnitude. She then restated the law and included the important missing word (equal). By drawing on the learners' prior knowledge, she was able to

explain why the kinetic energies of the two colliding objects changed when they collided. This observation was corroborated by her earlier claim. During the pre-intervention interviews, she indicated that one of her teaching strategies was to link Grade 12 content to content from earlier grades (see Section 5.4.4). Various examination diagnostic reports (DoE, 2017; 2018) also recommend that teachers should employ this strategy.

After the learners had stated Newton's third law of motion Rhadie excitedly remarked, "*Yho, ngaske iphume ngoLwesihlanu kule veki ezayo".* Definitions and statements of physical laws constitute 18 out of the 150 marks allocated to paper 1 (Physics) of the Physical Science examination. Her emphasis on the missing words, 'equal to' responds to one of the common errors identified in the examination reports (see Section 5.5.3.2).

The recorded lesson taught by Rhadie was the first lesson on the topic. The planned PCK was summarised in the lesson plans that were co-developed by members of the Community of Practice (CoP) (Mapulanga et al., 2022). Furthermore, in Vignette 1, Rhadie used questioning to tap into the prior knowledge of the learners when she asked about the forces acting on the block that is on an inclined plane, their directions and the components of gravitational force. These concepts are covered in Grade 11 and hence constitute part of the learners' prior content knowledge.
The lesson, according to the planning, was supposed to be drawn from lesson plan 1 (see Appendix D). Vignettes 7.1 and 7.4 exemplify where Rhadie's ePCK aligns with plPCK. However, when compared to the prior knowledge highlighted in lesson plan 1, Rhadie did not explore the learners' knowledge of vectors and scalars.

7.6.2 Conceptual teaching strategies

Rhadie's lesson was largely teacher-centred as there was not much in terms of learner participation, which was mostly through chorus answers. Her main strategy seemed to be drawing on learners' linguistic repertoire by applying pedagogical translanguaging as presented and discussed earlier in this chapter.

7.6.3 What is difficult to teach

Rhadie's explanation of the concept of positive and negative work was inadequate. She performed the mathematical portion, proving that the work formula, $W=F\Delta x\cos\theta$ has a negative result when the angle of 180˚ was substituted. This, however, could have led to a misconception that the

negative sign indicates the direction. She did not, however, provide a conceptual explanation based on physics. Box 7.6 shows what transpired.

Box 7.6: Rhadie's Vignette 4

Rhadie: Negative work is the opposite of positive work. *Xa sisithi* opposite *inoba i*-force *yethu ne* motion *injani i*-direction *yayo*? (When we say it's 'opposite' how the direction of our force is compared to the motion?)
LNS: Opposite
Rhadie: Opposite. *Enye ijonge e*-left*, enye ijonge e*-right. So *kweza* forces *zethu yeyiphi eyenza i*-negative work*?* (One is facing to the left and the other to the right. So, which of our forces is doing negative work?)
LNS: Friction
Rhadie: (she points at the free-body diagram) *Siyayibona, apha i*-friction*.Yona ijonge pezulu but i*-motion *ijongephi*?(We see the friction here, it is facing upwards but in which direction is the motion?)
LNS: Ezantsi (Downwards)
She writes summary notes on the board and draws a diagram showing friction towards the right and motion towards the left.

Rhadie: Then what is our angle (between the direction of force and motion)?
LNS: 180
Rhadie: Yes, *u*-theta is equal to 180 degrees. Therefore, cos theta is equal to negative 1. So *apha sithe*, (Here we said) [pointing at the heading 'negative work' on the board] *ngumsebenzi ongalunganga, apha ngumsebenzi olungileyo* (It's work that is not good and here it's work that is good) [pointing at the heading 'positive work']
LNS: (Some laughter)
Rhadie: *Sitsho neh* (That is what we say, right)
LN1: *Hai, ayi*-sound-*I* (No, it does not sound right)
Rhadie: *Ayi*- sound -*i neh*? (It does sound right)
LN2: *Lena ayenzi umsebenzi, lena yenza umsebenzi* (one does work and the other does not do work)
Rhadie*: Hayi ziyawenza zoyi* two *umsebenzi* (No. Both do work)
LN3: *Qha omnye ulungile, onye awalunganga* (It's just that one is good work, and the other is bad work)
LN2: *Awna mandla lo uza apha*? (Is the one facing this side weaker?)
Rhadie: *Hayi unamandla omibini*. It's just that *onmye* (the other) it's negative work and the other one it's positive work. *Sizothetha kengoku nge*-force *enegenzi umsebenzi* (We will now talk about a force that does not do work)

According to the textbook, *Solutions for all*, "Whenever positive work is done on an object by a force, energy is transferred to that object" and "whenever negative work is done by a force on an object, energy is removed from that object and transferred to other forms of energy" (du Plessis et al., 2013, pp. 169-170). To begin with, Rhadie mentioned that "'negative work is the opposite of positive work". She then went on to illustrate that the force that does negative work will be in a direction opposite to the direction of motion; she used arrows to indicate that the angle between

the two directions is 180˚. The substitution of cos 180˚ for the equation $W = F\Delta x cos\theta$ led to a negative answer and she concluded that the work was negative. This could have created the misconception that work is a vector. This type of misconception was identified in one of the diagnostic reports (DoE, 2021).

She then tried to explain it conceptually using IsiXhosa when she said: "*Apha sithe*, *ngumsebenzi ongalunganga, apha ngumsebenzi olungileyo"'* to which the learners laughed. This statement referred to positive work as 'good' and negative work as 'bad'. This did not make sense to the learners judging from the remarks they made. This statement also seemed to bring about confusion as another learner remarked that one performed work while the other did not do any work (apparently referring to the applied force and frictional force respectively). Yet another learner asked if one was weaker and the other stronger (apparently referring to the two works). The teacher responded by saying that both were strong and cut short the discussion.

The above provides evidence that for Rhadie, the concept of positive and negative work was difficult to teach. The explanation quoted from du Plessis et al. (2013) is the one that I used to compare Rhadie's explanation and concluded that she found it difficult to teach. If this observation is compared to what Rhadie expressed during the pre-intervention interview it is evident that she could not identify it as one of the difficult areas for her to teach.

This is a case of the reported PCK being different from the enacted PCK (Mazibe et al., 2020). During the lesson preparation workshops, a glossary of concepts was compiled, and the terms 'positive work' and 'negative work' were part of that glossary (See Section 6.3.6). Positive work was defined as *"umsebenzi oncedisana namandla otsalo okanye utyhalo"*, while negative work was defined as "*umsebenzi ophikisana namandla otsalo okanye utyhalo"*. Rhadie could have referred to the glossary during her lesson. This also shows that, in this case, the plPCK did not translate into the ePCK.

7.6.4 Use of representations including analogies

In Figure 7.5 and Vignette 5, Rhadie explains the concept of zero work done when the applied force is not large enough.

Figure 7.2: [10]Rhadie's demonstration of zero work done

[10] Rhadie gave consent for her photograph to be used stating that she is proud to be part of our PLC.

Box 7.7: Rhadie's Vignette 5

Rhadie: Now, *xasith*i (when we say) no work is done, *i*-force *yona* (the force) has been applied. *Siyavana neh* (We are together right). The force has been applied. Now remember the equation for work it is (as she writes on the board) $W = F\Delta x\cos\theta$. Now if there is no change in displacement that means a force has been applied (She pushes on the table as shown in Figure 7.5). *Ndiyapusha* (I am pushing), I am applying a force, *niyabona neh* (you see right)? But *letafile ayi-muvi* (this table is not moving). So, I did no…

LNS: Work

Rhadie: Because there is no change in…

LNS: Position

Rhadie: So, no work is done.

In the case shown above, Rhadie used the table to show that even if she was applying force the table did not move. This demonstration showed the learners that work is only done when the point of application of a force moves in the direction of the force. Rhadie made use of the table as an easily accessible teaching resource to enhance conceptual understanding as advocated by African scholars such as Asheela et al. (2021) and Shinana et al. (2021).

Free-body diagrams were also used throughout the lesson to represent forces as can be seen in Figure 7.5. This was an important strategy considering the comments from NSC diagnostic reports (see Section 5.5.3.1) which we highlighted in one of the workshops where we analysed these reports. For instance, one diagnostic report encouraged "the importance of drawing free-body diagrams for each object correctly and their usefulness in problem-solving must be emphasised" (DoE, 2023 p. 225). The use of free-body diagrams was another example of plPCK that became ePCK.

7.7 Nimjou's ePCK Compared to plPCK

Nimjou's enacted lessons demonstrated the following TSPCK components: prior knowledge; use of representations; application of diverse CTS; and what is difficult to teach. It is important to remember that these elements were applied in the context of pedagogical translanguaging.

7.7.1 Drawing on learners' prior knowledge

Evident in the two recorded lessons is the fact that not much reference was made to the learners' prior knowledge. This is despite the lesson plan (see Appendix D) clearly listing the relevant prior content knowledge. The only time Nimjoue made use of learners' prior knowledge was at the start of the second lesson when he asked about the learners' understanding of the concept of work in IsiXhosa (see Vignette 4). This proved to be valuable as it led to an important class discussion on *amandla* (see Section 7.3.2).

7.7.2 Use of representations including analogies

Simple drawings and free-body diagrams were used to represent forces in both lessons. He also used a motion trolley and a book to demonstrate the existence of gravitational force components on a body placed on an inclined plane. Figure 7.3 shows one of the simple drawings and related free-body diagrams that Nimjou used.

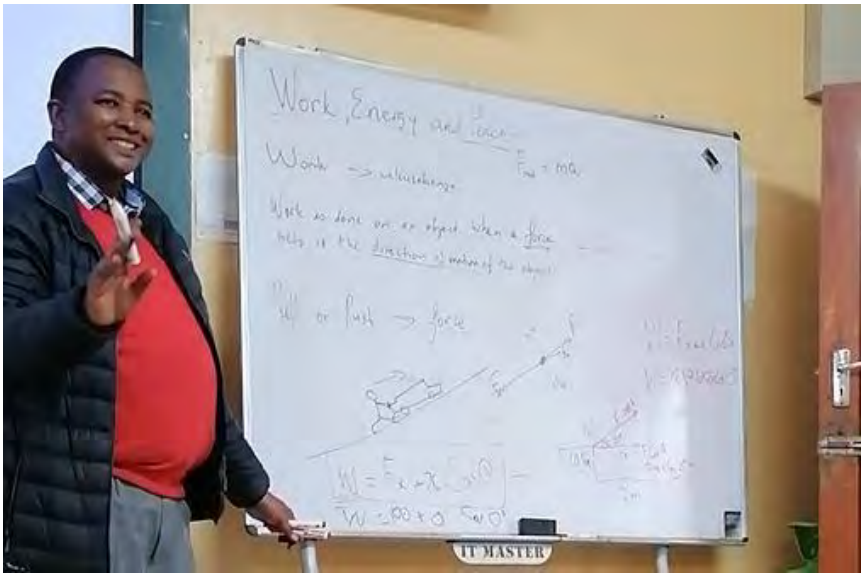


Figure 7.3: [9]Nimjou using free-body diagrams to represent forces

The importance of free-body diagrams was highlighted in the diagnostic reports (see Section 5.5.3.1) and in the lesson preparation workshops. In addition to drawing free-body diagrams, he also gave learners opportunities to draw free-body diagrams as suggested in the diagnostic reports (DoE, 2020). This was important since the diagnostic reports also noted that learners struggled to

draw and label free-body diagrams correctly (DoE, 2020). Figure 7.3 shows one learner drawing a free-body diagram on the board.

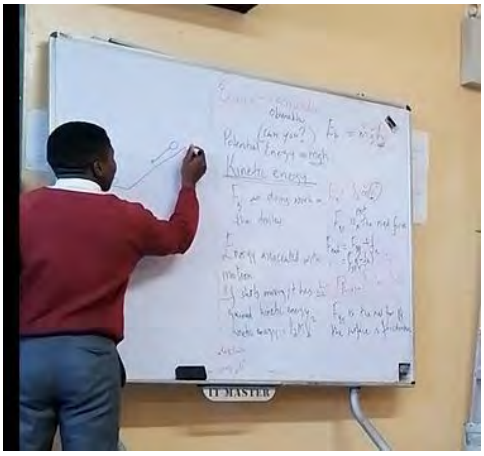


Figure 7.4: A learner drawing a free-body diagram on the board

[9]Nimjou gave consent for his photographs to be used

Figure 7.5 shows Nimjou using a motion trolley to show the effect of gravitational force on a stationary object placed on an inclined plane. Despite not having a full set of motion apparatus, Nimjou demonstrated forces by using accessible resources in his classroom (Asheela et al., 2021).

Figure 7.5: Nimjou's demonstration of the effect of gravitational force on an object on an inclined plane

7.7.3 Conceptual Teaching Strategies

Numerical problems where a body is on an incline and a force is applied at an angle to the direction of motion can be challenging to solve. Two angles are presented in this situation: the angle of inclination and the angle between the direction of motion and the applied force. Nimjou's plan to mitigate this complexity can be found in excerpt 2:

> So now it's wise to know that when we are dealing with Work, Energy, and Power, alright …what you will be considering is to use theta for *i*-direction when we are naming our angles. That is the direction of the force and the direction of the motion and other angles you give other names. You can call it x, beta or alpha. So that you can be able to differentiate because there are situations like this where we're gonna break down. Now you see that breakdown comes when we are dealing with net work.

Nimjou's strategy was to allocate different symbols to different angles which is not the way the textbook used in this study represents them. The same symbol θ is usually used for both angles in the textbook.

7.7.4 What is difficult to teach?

Teaching the distinction between force, power, and energy is challenging. Nimjou skillfully handled this situation by using a series of questions to draw on the understanding of the learners (see Nimjou's Vignette 3). This highlighted the differences between these terms, addressed in Section 7.3.2.

7.8 Transknowledging

Translanguaging leads to transknowledging when knowledge is developed by applying both Indigenous and Western epistemologies (Stroud & Kerfoot, 2020). As captured in the epigraph at the beginning of this chapter, the fundamental reason why people use languages in education is for knowledge conveyance (Heugh, 2021). In the case of bilingual education such as the one in this study, there is the conveyance of knowledge across the two-language system. This is transknowledging and it was accomplished by using IsiXhosa and English in a complementary manner during the mediation of learning. For instance, Nimjou tapped into the learners' everyday knowledge about doing work when he gave an example of washing dishes. He used this example from the learners' everyday context to build the concept of work done in Physics. Moreover, he used IsiXhosa, *ukuhlamba izitya* (washing dishes), which brought into play the cultural practices that are embedded in the learners' home language.

From a sociocultural perspective, cultural artefacts – including language, customs, and beliefs – have an impact on development (Verenika, 2013). In this regard, a glossary of terminology used to allow access to Westernised Science knowledge in IsiXhosa was created during the lesson preparation workshops. Verenika (2013) has argued that language is a cultural artefact and that culture is identified and acknowledged through language use. Incorporating learners' home language brings aspects of their culture to the learning of Science.

7.9 Teachers' Reflections on the Enactment of Pedagogic Translanguaging

The co-planned lessons were reflected upon by the two teachers who recorded their classes. I scheduled a meeting on MS Teams to check on the teachers' progress in terms of teaching at some point after the lesson plans were prepared. Rhadie said she had begun teaching on this topic. She responded as follows when I inquired if the students had been able to write notes using the code-

meshing technique:

> Yes, we wrote notes on the board but as for the IsiXhosa, we only talked but I didn't make them write. Especially the definitions because I was afraid that when it came to exams, they might write the IsiXhosa definitions. [Rhadie]

Rhadie was restricted in the use of code-meshing by the policy that only caters for English and Afrikaans as the only languages that are accepted for assessment. This fear was initially raised by Nimjou during the lesson planning phase (see Section 6.3.5.3). However, as a compromise, Rhadie had promised to encourage code-meshing for learners' personal notes. Apparently, she later decided against this. This limited the benefits of using translanguaging for the learners who still struggle to respond to examination questions although they may have had a good grasp of the concepts that were discussed using a bilingual approach.

This finding is consistent with other studies such as Probyn (2015), where written work remained in English despite class discussions and teacher talk about being bilingual. A point to note is that the practice of not crediting learners who code-mesh in examinations maintains the status quo which regards English as a superior language to IsiXhosa and other Indigenous languages (Choi, 2021). If learners could have had been afforded a chance to code-mesh when taking down notes and in assessments, this study could have been richer and perhaps able to provide evidence of the effectiveness of pedagogical translanguaging. The lesson plans had spaces for teachers to reflect on the lessons. These are some extracts:

> **What went well:**
>
> The learners felt comfortable when they were allowed to ask questions in a language, they were comfortable speaking. When they were discussing, I saw that they were able to make sense of the topic better when it was translated into IsiXhosa. [Rhadie]
>
> When it came to Work, Energy and Power, they were amazed by the lack of distinction between energy and power in their own language, IsiXhosa. [Nimjou]
>
> **Challenges faced:**
>
> Some of the words did not make sense when translated [to IsiXhosa] and a lot of time was used in trying to find an appropriate word [in IsiXhosa]. [Rhadie]
>
> During the lesson there was a challenge of finding an IsiXhosa word for the word friction but in the end *'uburhabaxa'* was understood to be a suitable word. [Nimjou]

Additionally, Nimjou's learners demonstrated their frustration towards at not being able to code-mesh during examinations despite being taught bilingually. He wrote:

> They were happy with the teacher code-switching because it is the teacher who always does it. Insisting on the inclusion of IsiXhosa was seen as the waste of time and energy by the learners since they needed assistance in strengthening their English vocabulary. Learners would ask the reason I ask for an IsiXhosa word for a certain concept whereas it is not going to be examined in their own language. [Nimjou]

This finding suggests that for the full benefits of translanguaging to be realised, code-meshing should also be permitted in high-stakes assessments such as the NSC examinations. Through asking questions and in group discussions Rhadie's learners were able to engage more with the teacher, each other and most importantly, with the content. These engagements would have been difficult and less fruitful had they been restricted to using English only. The use of their full language repertoire hence improved their epistemological access. From this study and other studies, it is quite clear that South African classroom discourse was bilingual (Charamba & Zano, 2019; Msimanga & Lelliot, 2014; Probyn, 2015). It then follows that restricting assessment to English becomes problematic for learners who may consequently lack the proficiency to express the idea that they developed in a heteroglossic environment in a monoglossic way (McKinney & Tyler, 2019).

Both Rhadie and Nimjou indicated that the process of translating scientific terms proved to be challenging and time-consuming. Herein lies the value of PLCs made up of small groups of teachers who can help each other on professional development issues such as how to explain or translate scientific concepts into IsiXhosa. This challenge faced by Rhadie suggests that she did not use the glossary of concepts produced by the PLC for some terms that needed to be explained in IsiXhosa were not included in the glossary.

7.10 Teachers' Reflections on the Professional Learning Community

According to the teachers' assessment of the PLC, it was successful in creating an environment of peer support and shared learning through collaborative discussions, observation and insight sharing, encouraging leadership, conceptual learning and practice reflection. These components improved the members' professional development and increased their efficacy as teachers.

7.10.1 Collaborative learning and sharing experiences

The members of the PLC highlighted the importance of group discussions in facilitating shared learning and reflecting on their practices as one of the major things they found useful. For example, concerning collaboration, Nimjou had this to say:

> So, we could share those ideas and the way in which members of this group, the PLC, were talking about this approach before they had actually undertaken the activity of teaching the class and observe what was happening in the class [Nimjou].

When referring to the value of shared reflections Nimjou added:

> We could see that there are commonalities between the way things were happening in the classrooms. For instance, when speaking of power and energy in IsiXhosa the learners had some common understanding of those terms [Nimjou].

7.10.2 Improvement of TSPCK

The teachers also highlighted that PLC workshops improved their comprehension of concepts and their ability to articulate and explain them, especially when translating them into IsiXhosa. This suggests that the PLC adopted pedagogical translanguaging strategies to help members' language development in addition to their content understanding, increasing their efficacy as teachers. In this regard, Rhadie said: "The discussions helped us learn about the concepts and how to present them and how to explain things. Especially when we were translating some words into IsiXhosa". Adding her voice to this notion Miss A remarked:

> *Inintsi ke* guys into *siyifundileyo… kukujonga indlela abantu abazi tacklisha ngayo i*problems*, namagama abhetele unocacisa ngawo ebantwaneni. Abantwana sibatitsha i*Physics yes*iXhosa* sometimes. *Kubeko amagama ufuna ukuwacacisa, ukba,* no this is what I mean. I think in terms of *ukuba* well articulate *kwabantwana,* vocabulary-wise *mna* I benefited a lot from that.
>
> (There is a lot that we learnt. As for me, I think the last meeting I attended, we were looking at how we tackle certain problems and better terms that we can use to explain to the learners. We teach our learners Physics in IsiXhosa sometimes. Then there will be some terms you need to explain in IsiXhosa. I think in terms of being well articulate to the learners, vocabulary-wise, I benefited a lot from that).

In support, Rhadie highlighted a specific aspect of the content that was discussed and that she benefited from. She also added that CTS were discussed. In her own words:

> Remember we are talking about Work, Energy, and Power and these discussions about conservation of energy. I remember Nimjou explaining what conservation means and all that

> stuff. Those discussions did help clear things to me … the discussions helped us learn about the concepts and how to present and how to explain things. Especially when we were translating some words into IsiXhosa. There was also debate and sometimes we make those mistakes ourselves in class not thinking of the meaning [Rhadie].

Rhadie further pointed out that the PLC workshops afforded the members opportunities to realise their classroom mistakes and learn from them. The reflections from the teachers indicated the benefits of the PLC formed by a small group of teachers as opposed to once-off workshops centrally organised by Department of Education district offices (Bantwini, 2012)

7.10.3 Supportive leadership

Nimjou acknowledged the supportive leadership within the PLC, noting that the leader provided guidance on what to observe (from the lessons) but encouraged members to draw their own conclusions. This approach empowered members to take ownership of their learning while still benefiting from the leader's expertise and guidance. He had this to say:

> We had a good time being encouraged to tackle the topic of Work, Energy, and Power so that we can come back and share what we have seen and what we have observed. This is how the support was going on. The leader of this group very much supportive and he had some ideas of what was needed to be observed and also gave us the clear indication of what needs to be on the very important list (glossary) but didn't give us what the results should be. We clearly understood what we needed to do and then you were so clear and giving us opportunities to express [Nimjou].

Chapter Six presented and discussed observations from the PLC meetings, which are further supported by the teacher reflections I included in this chapter. In other words, in line with reports from various research in South African studies, including Bantwini (2012), Bantwini (2019), Murray (2014) and Ono and Ferreira (2012), the PLC addressed the majority of the inadequacies of professional development programmes. In addition, the PLC had most of the characteristics of effective professional teacher development as postulated by Darling-Hammond et al. (2017). There was a focus on content, collaboration between the teachers, coaching from myself and other members and opportunities for feedback and reflections which ultimately were meant to develop the teachers' PCK as suggested by Jan et al. (2012).

7.10.4 Using MS Teams as a meeting platform: Affordances and challenges

Owing to the participant teachers' busy schedule we had to change the original plan from face-to-face workshops to online workshops using the MS Teams platform. Reflecting on this experience, teachers mentioned there were affordances and challenges. I now present the teachers' reflections.

7.10.4.1 Affordances

By and large, members of the PLC found the use of the MS Teams for the workshops convenient and accessible. They had this to say:

> I was able to join meetings anywhere; I even had one while on the road. [Rhadie]
>
> MS Teams was an advantage because we could be able to meet while we are physically in our own places and then we could discuss as if we are in the same place. [Nimjou]
>
> Advantage is that we could have a presenter that could present and make us talk and a meeting as if we are visual (face-to-face). [Dlamini]

From the above teachers' statements, it is evident that the platform enabled the workshops to be conducted without having face-to-face meetings in a venue. However, the use of MS Teams also presented some challenges.

7.10.4.2 Challenges

Participants raised a few challenges that they encountered. Below are their comments.

> Network was a challenge. [Rhadie]
>
> Another disadvantage could be that we could not share the same material (textbooks) that we would sometimes refer to when we were explaining concepts. [Linda]
>
> Due to unforeseen circumstances of load shedding, there was an ever-changing schedule for us. And then network was a problem. At some point, we could join the meeting later than we were expected to join. [Nimjou]
>
> The problem with MS Teams was that we did not have a tool to write (collaborate) so that we underline our things. It was all verbal. [Dlamini]

Linda agreed with Rhadie after she highlighted the network issues, and she also mentioned the difficulty in sharing the documents that would serve as the basis for the conversations. Dlamini concurred, pointing out that another difficulty was the absence of collaborative tools that allowed participants to jot down their suggestions. Nimjou lamented the difficulties brought on by load

shedding, which led to a constantly changing meeting schedule.

7.11 Chapter Summary

Data from the intervention's enactment phase were presented and discussed in this chapter, along with reflections on the PLC's activities and the application of pedagogical translanguaging. The lesson's enactment had two main points of emphasis. One was the enactment of pedagogical translanguaging as well as how the ePCK compared with the plPCK. Regarding participants' reflections on the PLC activities, I first considered the workshops a professional development process. The second was that I considered using MS Teams, an online platform, as an alternative to the traditional in-person workshops. Both Rhadie and Nimjou applied code-mixing, code-switching and versioning successfully to mediate the construction of knowledge on the topic of Work, Energy and Power. Compared to Rhadie, Nimjou used more English than Rhadie.

This shows that there is no standard ratio of the two languages, but it all depends on the learners' context concerning their mastery of the two languages in question. Both teachers reverted to IsiXhosa to draw learners into engaging with each other and the concepts being addressed. Learners were allowed to ask answers to questions in IsiXhosa. Notably, Nimjou had a fruitful engagement with the learners in IsiXhosa which resulted in distinguishing energy and force concepts in IsiXhosa. Not all the plPCK translated into ePCK for either teacher. For instance, although the lesson plans explicitly highlighted the misconceptions identified during lesson preparation, both teachers did not refer to them while teaching. However, both teachers displayed some aspects of PCK that were discussed during the lesson preparation workshops. Of note was the abandonment of allowing learners to mix English and IsiXhosa in the notes that they wrote owing to fears that they might use the practice in the examination and get penalised.

The TSPCK components that were evident in both teachers' lessons were prior knowledge; use of representations and what is difficult to teach. Through the purposeful and planned use of IsiXhosa alongside English in this study there was knowledge production. This knowledge production was from translanguaging that resulted in the transknowledging between English, the official LoLT and IsiXhosa, the home language for the teachers and the learners in the study. The chapter ended with reflections from the teachers. From these reflections, it emerged that the teachers benefited from the PLC as a vehicle for professional development. The MS Teams platform was lauded as a flexible and convenient enabler for the PLC activities which led to

teacher professional development which focused mainly on the preparation and application of TSPCK to pedagogical translanguaging. However, connectivity and load shedding were challenges faced when using MS Teams for PLC workshops.

CHAPTER EIGHT: REFLECTIONS ON THE RESEARCH JOURNEY: EXPLORING INSIGHTS AND LESSONS LEARNED

> The word itself, 'research', is probably one of the dirtiest words in the Indigenous world's vocabulary. … It appals us that the West can desire, extract and claim ownership of our ways of knowing, our imagery, the things we create and produce, and then simultaneously reject the people who created and developed those ideas and seek to deny them further opportunities to be creators. (Smith, 1999, p. 1)

8.1 Introduction

The above epigraph shows how Indigenous peoples view research as a result of Western methodologies. In this study, I attempted to depart from the extractive research method where researchers extract knowledge from participants and give them little or no acknowledgement as the real owners of such knowledge. Therefore, as explained earlier, my position is that I was not conducting research *on* the participants, but I was researching *with* them (Ngcoza & Southwood, 2015). Together we co-created knowledge and learned with and from each other. The journey was sometimes bumpy, but the overall experience was fulfilling.

The research process was like riding on a bus whose route you thought you knew well and had prepared for, only to find that all you know is the final, desired destination. The bus took me through some rough, bumpy roads and new and exciting places and gave me new travel partners – but eventually, I arrived at my destination. The change in the originally planned research site and participants led to an unknown route along my journey. It was like starting afresh since I had to establish new relationships with participants from schools who I did not know. I had to use Google Maps to locate their schools. The data collection methods evolved along the journey. This chapter traces the journey taken, it narrates the ups and downs, the frustrations, the unexpected breakthroughs and the shifts in the originally planned course of action during the data-gathering process. Most importantly, I share my triumphs and new insights about research with a group of busy but committed participants.

8.2 Decision to Change the Originally Planned Research Site and Participants

As noted in Section 4.4, the final research site and participants were not the original ones. I was working on my research proposal when I took up a new job offer as an academic staff developer at a university where I have been working part-time for about two years. That was in March 2022. I had to relocate from a small rural town where I had lived for more than 14 years to a coastal city I hardly knew. The only places I knew previously in this city were the beach closest to the central business district, two of the several shopping malls, and a few government offices that I had visited before. I also had a friend who lived in a township on the city outskirts that I had visited before.

My research proposal was approved by the Education Higher Degrees Committee in October 2022. I had to get the gatekeepers' letters before I could get my ethics certificate from the Ethics Committee. This is when the complexity of the research site and participants came to the fore. At that time, I still relied on Google Maps to find my way around the city and was adjusting to the new job and forming working relations with my new colleagues. My initial plan was to continue with the same participants about 200km away. I had already negotiated verbally with six teachers from the district that I had moved from to take part in my research, and they had agreed. The negotiations were easy since these were people that I had worked with in the same school cluster for over 10 years. In terms of positionality, I was an insider (Holmes, 2020). For instance, I was a cluster leader and often assisted them with preparation and carrying out experiments for their classes. We met at meetings, workshops and even social events since we all lived in the same small rural town. Over the years we developed cordial working relations and were friendly on social media platforms. I formed a WhatsApp group for the PLC I had established with these six participants (see Section 2.5.4).

The new city fell under a different district as demarcated by the Department of Education. Notwithstanding, I tried to stay in touch with the participants and this is when the signs of trouble started to emerge. The first sign was the lack of response to what was posted on the WhatsApp group. That did not deter me, as I thought people were probably busy and it was a temporary glitch. The reality of the situation became evident after the research proposal was approved. I had to get gatekeeper letters from the district director and the school principals and signed consent letters from the participant teachers. I realised that I had to physically go to the district office and the schools to meet the principals and teachers before I could get the gatekeepers' letters.

The schools were in rural villages with poor roads, geographically spread over a radius of about 30km. The district office was in a town at least 30km from the school that was nearest to it (considering my selected schools for the study). That is when I decided to be flexible and reconsider my research site and participants.

Understandably, Grade 12 teachers are usually very busy, especially closer to the final examinations which typically start towards the end of October. There was not much I could do about finding new participants until the new academic year in January 2023. The last quarter of 2022 was a period of waiting and wondering if I would be able to carry out this study since I had not yet found new participants to work with. However, I relentlessly worked on my first four chapters derived from my research proposal and would recommend this to other PhD scholars. During this period, I also presented my research proposal at the SAARMSTE Eastern Cape Chapter colloquia to get feedback on my study and indeed I did. This turned out to be a form of validation and ensured the trustworthiness (see Section 4.11) of my study as certain blind spots I would have not seen surfaced.

8.3 Negotiating the New Research Site and Participants

Once the new academic year started in January 2023, I set out to try and identify teachers whose school profiles matched my proposed study. Identification was the easiest part of the task. Getting to know the participants and getting them to agree to take part in the study was where the real task was and the thought of it was so frustrating. Not only was I looking for individuals, but I was also looking to build a 'web of development' (Ngcoza & Southwood, 2019) and this web of development was to be my PLC. Luckily, the friend from the township I mentioned above came to my rescue. She was born and grew up in this city and was also a Science teacher in one of the largest townships in South Africa located in the city. It was through her selfless and committed assistance that I managed to break through and get new research participants.

She was part of a project that involved teachers from different schools in the district. They were offering extra weekend classes to learners under the auspices of a certain non-governmental organisation. She suggested some teachers who were teaching in the schools in the townships around the city. After she had spoken to some teachers and shared their cell phone numbers with me, I had to talk to them individually. Each call felt very odd, and I had to introduce myself and indicate that I was the PhD scholar they had been told about and that I would like to come to their

school and speak to them and then to their principal. Before getting permission to conduct the study in the schools I had to get the gatekeeper's letter from the district director before I could go to the respective schools.

So, in my initial conversations with the teachers, I could not set a date for meeting them and their respective principals in their schools since I did not have permission from the district office. All I could do was try and establish some type of relationship and indicate that I would make the call again 'soon' to discuss the way forward. This process was necessary as it was all about building relationships with the research participants before the start of the study. This helped to decrease the 'outsider' effect once the study commenced (McKenzie, 2019). Although I had not yet received formal, written consent from these teachers I was satisfied by the verbal agreements we had made. From the perspective of African communities, word of mouth and verbal agreements are more important than signed agreements (Seehawer, 2018).

By sheer coincidence, two of the teachers were people I had known for many years from marking the Physical Sciences Matric examinations. We used to meet every November/December at the various marking centres in the Eastern Cape Province and would work together for up to 14 days at a time. Asking these two to participate in my study and discussing my aims felt less awkward. Getting in touch with the first five teachers in the new district took me over a week. This occurred in late January 2023.

During the initial phone calls, I briefly introduced myself and the study. The calls ended with a request to visit the teachers in person at their school. The purpose of the visit was to meet the participants in person, explain my study in detail and answer any questions they may have. This process took about two weeks because I had to make appointments which did not disrupt the teachers' work and my own since I was a part-time scholar as noted earlier. Sometimes appointments had to be rescheduled at the last moment due to meetings called at short notice or some other work commitments.

After meeting the five potential participants, I then approached the district director's office for the gatekeeper's letter since my application had to specify the schools that would be involved. A brief search on Google gave me the name of the district director and the office address. To my surprise and contrary to the stories I had heard this was not a difficult task as it took only two visits to get

the letter. On my first visit, I could not find the district director, but his secretary asked me to leave my application which she would forward to him as soon as he was back in the office. Just over a week later I got an email from the district director's secretary asking for my research topic even though the research topic was in my initial letter. A few days later my research supervisor received a phone call from the district director's office informing me that my gatekeeper's letter was ready. This gatekeeper's letter was issued in February 2023. I then called those teachers again to book appointments with them and their principals. From these meetings, I got gatekeepers' letters and written consent from the school principals and the teachers respectively.

8.4 The Dropping Out of Two Participants – It Never Rains but It Pours!

Not all the five participants who initially agreed to take part in the study did so. Two of the initial five participants from the Buffalo City Metropolitan District pulled out before I could collect data other than their profiles. These two were Mr Y and Miss V (pseudonyms) and they dropped out for different reasons.

8.4.1 Mr Y's dropout story

Mr Y had the lowest level of qualification in the group. He held a Secondary Teacher's Diploma and had 10 years of experience teaching Grades 11 and 12 Physical Sciences. Before accepting to be part of the study he inquired about the benefits of the study to himself or his school. He asked if I was not going to donate some materials or apparatus to the school. I explained that I was just a PhD scholar and had no financial means to make donations to the school. He looked disappointed. However, I explained the benefits to his professional development that came from being a member of the PLC (see Section 2.5.2). I also emphasised that this study wanted to explore ways of improving township learners' access to Science concepts and their attainment levels.

On accepting to be part of the PLC, Mr Y indicated he was looking forward to developing the lesson plans with the help of the PLC. He stated that he always struggled to draft lesson plans needed by the Department of Basic Education (DBE) district officials when they visited him. This was an important aspect of the research process as reciprocity is important from an Ubuntu perspective (Seehawer, 2018). The fact that there appeared to be mutual benefits from the study gave me confidence in his anticipated participation.

In our first face-to-face meeting, I explained to him that the next step was to get permission to carry out the study from the Department of Education before we could commence. After getting the gatekeeper's letter from the district director's office, I returned for him to sign the letter of consent that formalised his agreement to be part of the study. I then gave him a detailed explanation of his role in the study, and we set a date and time for the pre-intervention interview. I gave him the option of a face-to-face interview or an MS Teams one and he chose the online one.

A day before the interview, I tried calling him to remind him but without success. I, however, set up the MS Teams meeting and shared the link with him using his email. He did not log in and efforts to contact him on the phone also proved futile. After another visit to his school and another assurance of his availability on the agreed date, I set up another meeting. Again, he did not join the meeting and his phone went unanswered even after several attempts. This is when I realised that he had decided to withdraw but for some reason, he could not tell me. This was frustrating, to say the least. The thought of finding a replacement was on its own emotionally draining. I, however, accepted that he might have withdrawn although I kept wondering what the reason could have been. Possibly he did not appreciate the co-learning space that the study presented as a personal and professional benefit. I decided to wait for him to call since he was not taking my calls. After a week of waiting, I accepted that I had lost him as a participant.

8.4.2 Ms V's dropout story

Ms V was the second participant to pull out. She had preferred that I use her real name because she felt that this study was very important and came at the right time and she would want her contribution to be recorded. However, I am not using her real name since she pulled out of the study before she contributed to the study other than supplying her demographic information. Ms V was quick to point out, in our first meeting, that the Eastern Cape Department of Education was setting question papers in the trial examinations that were written both in English and IsiXhosa. This, in her view, made the study very important and timeous.

Ms V was a head of department (HoD) at the same school where she matriculated. She mentioned that she was leading some of the teachers who taught her during her days as a high school learner. She also indicated that her older colleagues challenged her to prove her worth as their HoD. This motivated her to pursue her studies by registering for a Master of Education in Science at another university. However, she did not have the financial resources to make her dream come true. From

the first meeting, I was hopeful and looked forward to working with Ms V, but it was not to be. Just like Mr Y and all the other participants, I had to first seek the gatekeeper's letter from the district director and the school principal before setting up the date for the pre-intervention interview.

As with Mr Y, she opted to have the interview online but noted that she was busy and asked me to call in a week to arrange the interview. I called as agreed but she said she was busy and asked me to call the following day. I did call the following day and my call went unanswered. I sent WhatsApp messages, and she replied that she was busy, but we eventually agreed on a date and time for the interview. I set up the meeting on MS Teams. She did not join the meeting on the agreed-upon day, despite a reminder via WhatsApp the day before. I tried calling her about five minutes into the scheduled meeting, but she never answered. This was when the reality of having yet another participant drop out dawned on me.

I decided to wait a few days before I called her again so she would not feel I was pressuring her. When I eventually called, she apologised for not continuing her participation in the study due to her busy work schedule. She, however, gave me a phone number for another teacher she had spoken to who had agreed to replace her. When I called that teacher, it turned out that he was not teaching Physical Sciences at the Grade 12 level. Although he was willing to be part of the study, I could not include him.

Of the original five participants, I was now left with only three. I discussed this problem with Linda who had introduced me to the teachers who had dropped out and she suggested another teacher in the same district. This new participant was Ms A who readily agreed to be part of the study and became the fourth participant.

8.4.3 Linda joins the Professional Learning Community (PLC)

Before I started the data-gathering process, I decided to add Linda to the PLC. As I narrated in Chapter Four, Linda was not teaching Physical Sciences at the Grade 12 level at the time. However, the contribution she had made up to that point beginning with negotiating with the teachers to take part in the study was immense. On reflection, I realised that she had a great interest in the study and that she would benefit from the PLC workshops as a Science teacher. She gladly welcomed the idea and became one of the PLC members. She participated in the workshops

including the orientation and reflective workshops. Linda worked at the same school as Mr Y, and her profile is in Chapter Four. As I was solving the participant problem, another problem emerged – I was falling behind schedule.

8.5 Constraints of the Annual Teaching Plan (ATP)

This interventionist study's timing was originally carefully planned so that the teaching of the topic on which the research focused fit in with the teachers' ATP. This was meant to reduce any disruption to the teachers' daily work. The CAPS document, which guides the curriculum delivery, is very prescriptive concerning the sequencing and the time spent on the various sections of the syllabus. While this may assist teachers to realise the salient concepts in the curriculum (Mavhunga & Rollnick, 2013) it has been criticised by some scholars such as Du Toit and Gaotlhobogwe (2017). The critics point out that too much content is set to be covered in short spaces of time. This leads to teachers rushing through the curriculum to finish in time for examinations and other formal assessments. The teachers in this study shared their district's ATP with me.

The ATP showed the content to be taught every week of the term up to the district's common mid-year examinations. As I indicated in the previous paragraph, it was very prescriptive and did not allow room for any disruptions. All the teachers in the PLC had to conduct extra classes to keep pace with the ATP. In addition to putting a strain on the teachers, the CAPS reduces their autonomy and results in ineffective teaching – this was revealed in a study by Ramatlapana and Makonye (2012). The extra classes, which were typically conducted early in the morning (before the normal school starting time), in the afternoon (after normal classes) or over the weekend were the major reasons why the teachers were not available for any face-to-face engagements.

Due to delays caused by the assembling of the PLC and the subsequent delays with the interviews, the following phases were also delayed. I begged the teachers to rearrange the order of topics to be taught in the second term so that Work, Energy and Power would be taught last instead of being the first as planned according to the ATP and they kindly agreed. The shift was within the same period and did not have a major effect on the preparation for the mandatory assessment tasks for the term. Such a shift, however, led to some unanticipated problems that I will reflect on later in this chapter.

8.6 The First Phase of the Data-gathering Process

As I noted earlier, the data-gathering process was like a bus journey whose route kept changing. Phase 1 of the data-gathering journey started with the semi-structured individual interviews I held with the four teachers to explore their TSPCK (Mavhunga & Rollnick, 2013). This phase was the pre-intervention part of the study. All the teachers preferred to interview via the MS Teams platform, as this was the same platform used by the DBE and they were familiar with it.

8.6.1 Semi-structured interviews

The interviews with Nimjou, Dlamini and Ms A were done in the evenings after 18:00. As mentioned before, the teachers conducted afternoon classes and evenings were the best time for the interviews. The interviews lasted between 27 minutes and one hour and five minutes. This was despite the interviewees being asked the same questions, although the phrasing was different.

8.6.2 The taxi rank[10] interview with Rhadie

We had set a time for the semi-structured interview at 15:00 on a school day with Rhadie. She had expected to be home by then in a township about 7km from the village where she was teaching. When I called her at around 14:45 to give her a last-minute reminder she indicated that she was still at the taxi rank and sitting in a minibus. The minibus would only leave the taxi[11] rank once it was full. I thought it was one of those postponements I was fast getting accustomed to. To my surprise, she said we could go ahead with the interview while she was sitting in the minibus waiting for more passengers to fill it up. Her fear was that by the time she got home, there would be no electricity (load shedding) and there would not be any connectivity as a result. Halfway through the interview, the taxi left the rank, and we continued. We only finished just before she got out of the taxi. The commitment she displayed was priceless and herein lies the importance of Ubuntu in research (Ogunniyi, 2018; Seehawer, 2023).

8.6.3 The Second Phase of Data Gathering: The Workshops

Originally, I had planned to have face-to-face workshops but for the reasons given earlier in this chapter, it was more practical to have the workshops online and after working hours. This was a good thing as they could make themselves available and participate fully in the discussions. The

[11] The term 'taxi rank' is used in South Africa to refer to a public transport station. Public transport is usually in the form of small minibuses that have a carrying capacity of up to 15 passengers.

workshops typically started at 18:00. Although they were planned for one hour, they often went on longer due to the robust discussions, especially when we were discussing translations into IsiXhosa of some difficult scientific terms such as ‘conservative forces’ and ‘non-conservative forces’.

It turned out that people who grew up in different places in the Eastern Cape had different IsiXhosa words for certain concepts. For instance, ‘displacement’ was translated into *umlinganiselo woshenxiso* or *umlinganiso wokufuduswa*. This is referred to as *isingingqi* (the IsiXhosa version of a particular area) (Bylund, 2014). This was very interesting, as it also meant that even in their classrooms it would be the same with the learners. These discussions strengthened the use of this language for all PLC members, especially me, as IsiXhosa is my fourth language.

8.7 The Third Phase of Data Gathering: Lesson Observations

I was fortunate enough to have a research assistant. He was a young man from the same township as three of the schools in the study. He graduated with a bachelor’s degree in human resources management but was still seeking employment during the study. I introduced him to the participants, and together we negotiated the dates and times when teaching would take place. The original plan was to record at least two one-hour lessons from each of the four teachers (excluding Linda) but only two ended up having their lessons recorded. The other two teachers did not teach the topic as planned. The mid-year examination timetable became another constraint. The other teachers had to find time outside the normal teaching and learning time to teach the topic of Work, Energy and Power but did not record those lessons.

My assistant travelled to Rhadie’s school and recorded the lessons using his cell phone. The recording was then copied onto a USB flash drive that I provided. The flash drive was the type that can be used on a cell phone. I then met him and copied the video recordings to my computer. Consistent with ethical protocols (see Section 4.10.4), the recordings on his phone and the flash drive were deleted to ensure they did not land in unauthorised hands. Nimjou chose to do his own recording and then share it with the research assistant. Dlamini and Ms A did not communicate with the research assistant when they decided to deviate from the agreed plan. Lesson observations are often viewed negatively by teachers. This could be because of their experience with lesson observations done by their HoDs and district officials which are used for performance evaluation purposes where scores are attached to the teachers’ classroom performances. Edgington (2014)

suggests that lesson observations can reduce a teacher's effectiveness because of the emotional conflict between performative behaviour and authentic teaching. This can make them uncomfortable when their lessons are observed, even if it is not for performance appraisal purposes.

8.8 The Fourth Phase Evaluation of the Lesson and the Research Process

The initial plan was to have one final workshop – a group reflection on the entire process from the pre-intervention to the intervention itself. This however did not materialise due to the unavailability of the participants. I wanted us to meet in person and talk over lunch or a barbeque. After several failed attempts to set up the meeting, I abandoned the idea and tried a virtual meeting with MS Teams, which also proved futile. In hindsight, I think the participants were tired of the process, but because of Ubuntu, they could not spell it out. I then resorted to posting questions on the WhatsApp group and the participants responded with voice notes. This could be considered a lost opportunity since the voice notes were second best compared to the face-to-face engagement in a relaxed atmosphere that I had unsuccessfully tried to create.

8.9 Lessons Learnt and Issues Other Researchers Could Consider

I learned a few lessons from the data-gathering process that I had not envisaged when I planned this study. The main ones are outlined in the following paragraphs.

8.9.1 Working with teachers teaching Grade 12 (exit level)

The teachers I worked with in this study were very busy, nonetheless, they agreed to participate. As outlined in their profiles in Chapter Four, they were all planning to further their studies in the education field but could not do so for different reasons. For instance, Nimjou had registered for his PhD but had to suspend his studies after his supervisor left the university he had registered with.

For the workshops to succeed we had to be very flexible regarding the times for interviews or workshops. As stated earlier, the workshops were typically in the evenings. The teachers conducted morning and/or afternoon classes for their Grade 12 classes. In addition, the teachers were also involved in another programme where they taught Physical Sciences classes from Grades 10 to 12. These classes were run and sponsored by a non-governmental organisation with

the full support of the Department of Education. This programme was important to the teachers. It brought learners from various schools together and different centres in the townships. Besides having their learners receive extra support in Physical Sciences, which was a poorly performed subject, they also received some extra income. It was a real sacrifice for the teachers to be part of the study and I am greatly humbled by it.

From this experience, I learned that as a researcher working with Grade 12 Physical Sciences teachers one needs to be available after hours (including public holidays and weekends) to accommodate the availability of the teachers. In addition, the researcher also needs to plan activities that can be done either face-to-face or virtually. If the study could have been done with teachers other than Grade 12, that would have been an option to consider.

8.9.2 Leveraging technology to effectively gather data and communicate with busy participants

After my participants indicated they would not be available for face-to-face workshops, I felt devastated as I had planned for face-to-face interviews and workshops. The thought of having virtual engagements was not part of the plan. However, it turned out that effective use of available technologies saved the data-gathering process that I thought would collapse. I made use of WhatsApp, emails and MS Teams. WhatsApp's popularity and its ability to seamlessly combine written, audio and video communication make it an invaluable tool for qualitative research (Bueno-Roldan & Röder, 2022).

These days almost everyone has a WhatsApp account, and my participants were no exception. I formed a WhatsApp group for our PLC and would post suggested dates and times for meetings, and share documents, meeting links and reminders. In some cases, one or two of the respondents did not see the message e.g. a reminder for meetings. As time went by, I began to communicate more on a one-on-one basis with participants instead of posting on the group. These personalised messages proved to be more effective judging from the response rate compared to the group messages.

Since all the workshops lasted about one hour (there were some exceptions as mentioned earlier) some of the tasks would be done outside the meetings and shared using email. I will use an example to illustrate the use of emails in the data generation process. As a PLC, we discussed the

format of the lesson plans and then I drafted the first draft alone. I emailed that draft to the participants a few days before the next workshop so that they could prepare their input before the workshop. After the lesson planning workshop, I asked one of the participants to compile the changes – these were mostly translations of terms the PLC identified as difficult to understand in English as discussed – and update the lesson plan. She then emailed the updated lesson plans.

As previously stated, the semi-structured interviews and all the workshops were done using the MS Teams platform. I was sceptical before I used this platform for data gathering. I had been using it to teach and attend other work-related meetings before I did a trial run with Linda. We had a five-minute discussion, and I used the record and transcribe feature to capture the discussion. After fumbling through the application, I finally managed to locate these features. By the time I did the first interview, I was somewhat confident in using the application. One skill an interviewer conducting a semi-structured interview needs is the ability to simultaneously capture all the answers and stay focused on the direction the interview is taking. The record and transcribe feature of MS Teams made it much easier as I could focus on listening and asking follow-up questions when needed without having to worry about taking notes.

However, the use of MS Teams was not without its challenges. When I looked at the transcriptions, I noticed that this AI transcribed some text incorrectly. Because our accent is heavily influenced by our home language, the AI hears and writes incorrect words. Another challenge is that the interviews and especially the workshops were bilingual. The IsiXhosa parts were transcribed into English words that sounded like them, and the sentences made no sense. I had to play the recordings and check the transcriptions. This process of correcting the transcriptions was very time-consuming. For example, for Ms A's semi-structured interview, I took on average 45 minutes to fix a translation of five minutes from the video recording. The most time-consuming part was re-typing the parts when she used IsiXhosa. To effectively collaborate with busy participants in various geographical areas, I leveraged technology such as WhatsApp, Gmail and MS Teams and real-time messaging to bridge the gap and co-create the knowledge for this study.

8.9.3 The value of mutual respect and the spirit of Ubuntu in research

The formal widely accepted code of ethics declares that researchers should include a clause that effectively says that the participant has the right to withdraw from the study whenever they feel like it. In his PhD thesis, Mutanho (2021) contested this inclusion of the phrase "You are free to

withdraw from the study at any time you like". He asserts that from an African perspective, this sounds rude and disrespectful to the participants. It makes them feel unimportant and will not do much in terms of fostering commitment and cooperation. Informed by Mutanho's (2021) study, I discussed this with my participants and explained that I wished them to stay till the end.

In the African culture verbal agreements based on mutual respect and trust can be more binding than signed pieces of paper. As educated people, with a minimum qualification of an honours degree, my participants clearly understood the ethical requirements and did not have an issue when I pointed out that the phrase is there because it is a requirement. The study was ethically based on the spirit of Ubuntu (Ogunniyi, 2018; Seehawer, 2023). I will now share two incidents as examples of my participants' commitment. The first is the interview with Rhadie who was on her way home from work as outlined above, and the second example was the participation of Miss V while driving.

One meeting I had with the PLC whose main objective was to check on how far they had got with enacting the lesson plans was held at 6 pm as usual. Miss A was driving but she still logged on and participated while driving. She could have used the fact that she was travelling as an excuse for not being part of the meeting. A true commitment was shown again in this case. This is the meeting where she agreed to my request to teach the topic to her Grade 11 class since she had already taught the lesson to the Grade 12 class by the time she joined the PLC as a replacement for one of the participants who dropped out.

8.10 My Support System During My PhD Journey

Studies have revealed that poor completion rates, delays and discontent are commonplace in PhD programmes worldwide (van Rooji et al., 2021). According to these scholars, this is because of inadequate support. In this PhD journey, I was very fortunate to have support from several sources. First, Walter Sisulu University made it possible by paying my tuition fees. This is particularly important because, before joining the university, I had to delay enrolling for a PhD study due to financial constraints. Second, I was enrolled in the University Capacity Development Project programme that supports university employees in acquiring their PhDs. Under the programme, there were regular writing retreats which took scholars in the programme away from work for four full days at a time to a place conducive to focus on their writing. In addition, there were experienced researchers who were appointed and played the role of mentors. The mentorship and

the time and space to write positively impacted the quality of my work and the time I took to complete this study.

Being co-supervised by a Science education specialist and a specialist in African languages, I was also one of the PhD scholars in the National Research Fund-sponsored Intellectualisation of African Languages, Multilingualism & Education project chaired by my co-supervisor. Again, I received mentorship from other experienced researchers and sponsorship for writing retreats. Moreover, in these writing retreats, I met with scholars who specialised in languages and received valuable ideas and reading materials from the language experts. This group turned out to be a CoP; through interactions with them, I became a member of the HELTASA CoP which focuses on implementing multilingualism in teaching and learning in higher education. This CoP is a platform for me to expand my knowledge of multilingualism in teaching and learning which goes beyond the scope of this study.

Being a member of SAARMSTE provided another layer of support towards successfully completing the study. At the proposal stage, I attended a SAARMSTE-hosted research school where I was attached to a mentor who read my proposal draft and gave me her insights and valuable comments and suggestions. At the Eastern Cape chapter level, I made several presentations of my work at various stages. The feedback I received from fellow PhD scholars and researchers from the four universities in the Eastern Cape Province added another layer of support to the study and became part of the validation process. The SAARMSTE hosts an annual conference in different countries across Southern Africa; my attendance and presentation at these conferences allowed me to meet and talk to some of the gurus in Science education research, some of whose work I have used in this study. This was also a great space for learning and networking with other scholars in the field. My experience gained through this PhD journey has taught me that support from the research community is among the key determinants of a positive experience for a PhD candidate (Ronkkonen et al., 2023).

8.11 Chapter Summary

The data-gathering process, from when I relocated to a new city to reflections was full of unexpected turns and previously not-thought-of solutions. In this chapter, I briefly reflected on my hectic but very interesting journey. I discussed some new insights on how to work with busy respondents and leverage available technologies to collect and organise data. Lastly, I thought

back on the network of assistance that helped me to effectively navigate and go through a journey whose path was not obvious when I set out on it. In the following chapter, I present, analyse and discuss my findings from the first phase of the study which was the pre-intervention interviews which sought to explore the participant teachers' TSPCK before the intervention.

CHAPTER NINE: SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

> Education is about conveying knowledge of the world through language in ways that are meaningful for students, and that will open doors for their lives beyond school … practices of code-mixing, code- switching and translanguaging can be used to reduce sociolinguistic inequities in classrooms, facilitate student *voice* and *agency*, and prepare students for *sustainable futures* (my emphasis). (Heugh, 2021, pp. 37-38)

9.1 Introduction

In this chapter, I present a summary of my findings. The epigraph above (Heugh, 2021) highlights the transformative and liberating effect of pedagogical translanguaging which ultimately impacts the futures of learners such as those taught by the teachers in this study. I begin by giving a brief overview of the study before I present the key findings. These key findings are presented followed by the phases of research. New insights or contributions to the literature are also highlighted under two sub-sections methodological, professional teacher development on pedagogical translanguaging and the enactment of pedagogical translanguaging. The limitations of this study are discussed before I end the chapter with recommendations based on the findings and areas for future research.

9.2 An Overview of the Study

This study was conducted in the Eastern Cape Province of South Africa and involved five Physical Sciences teachers who were teaching in township and village schools as participants. The timing of the study coincided with the implementation of the MTbBE project piloted in the Cofimvaba District of the Eastern Cape Province. In the first project phase, Mathematics, Science and Technology (MST) subjects will be taught in the first eight years of formal education (Grades R–7) using Indigenous home languages. In essence, the MTbBE project aims to include Indigenous South African language in the bilingual teaching of MST subjects from grade 4 while this study sought to prepare and enact lessons that applied pedagogical translanguaging in IsiXhosa at the Grade 12 level. To support the teachers in developing their TSPCK on translanguaging, I formed a PLC underpinned by the principles of Ubuntu comprising myself and the five teachers.

Hence, the study's main objective was to support this small group of teachers in developing their TSPCK on the topic of Work, Energy, and Power at the Grade 12 level. To achieve this goal the study sought to answer the following questions:

1. What TSPCK (including language) on the Work, Energy, and Power topic do Grade 12 Physical Sciences have before the intervention?
2. What can Grade 12 Physical Sciences teachers learn through:
    a) Co-analysing curriculum documents focusing on the Work, Energy, and Power concepts?
    b) Capacity-building workshops focusing on the co-development of exemplar lessons on the Work, Energy and Power topic that consider learners' home and everyday language?
3. What is the influence of the PLC intervention on:
    a) The quality of the participant teachers' bilingual mediation of the Work, Energy, and Power topic in their lessons?
    b) The participant teachers' TSPCK on the Work, Energy, and Power topic?
4. What are teachers' reflective insights and perspectives on the intervention's effectiveness, challenges, and outcomes?

The research journey comprised four phases. Phase 1 focused on the pre-intervention stage of the study, and it sought to gather mirror data on the teachers' pedagogical practices on the topic of Work, Energy, and Power with a bias towards language usage. Data was gathered from semi-structured interviews and the orientation workshop in Phase 1. Phase 2 focused on developing the teachers' PCK on the Work, Energy, and Power topic with a special focus on pedagogical translanguaging techniques. Data was gathered from workshops I facilitated which included the co-developed lesson plans. The third phase was the enactment of the co-planned lessons; in the final phase, Phase 4, the members of the PLC reflected on the whole journey.

9.3 Key Findings of the Study

The key findings from this study are related to:

- Exploring teachers' PCK using Mavhunga and Rollnick's (2013) five components of TSPCK as a lens and the teachers' use of languages in their mediation of learning

(research question 1).

- The benefits and challenges of using a teacher PLC for developing their PCK (research question 2).
- The enactment of co-planned lessons that employed pedagogical translanguaging (research questions 3 & 4).

These three broad areas of focus are presented per phase of the study.

9.3.1 Findings from Phase 1

Detailed data gathered from this phase is presented and discussed in Chapter Five (see Sections 5.3, 5.4 and 5.5). The semi-structured interviews were conducted using an interview schedule (see Appendix E) whose design was innovatively guided by Mavhunga and Rollnick's (2013) five TSPCK components with additional questions based on the LoLT.

9.3.1.1 Findings from the semi-structured interviews – TSPCK components

The first key finding from this phase is that teachers could not adequately articulate some aspects of their TSPCK on the Work, Energy, and Power topic. When asked about the prior content knowledge required by the learners to be in a position to construct new knowledge in the topic in question, they managed to refer to an average of four out of the 13 concepts that were compiled from analysing the CAPS.

In terms of curriculum saliency, again there was inadequate articulation of the key concepts and how they are connected from three of the teachers. Nimjou, however, highlighted the importance of bringing out the connections between topics. He referred to the connection and relatedness of concepts under vertical projectile motion, equations of linear motion, and Work, Energy, and Power topics.

The teachers, however, stated what is difficult to teach (see Section 5.2). The difficulties identified were consistent with findings from the analysis of NSC diagnostic reports (DBE 2017–2023), which are compiled using data from learners' NSC examination scripts. This is where the significance of the diagnostic report analysis resides, as it can help teachers prepare for and facilitate learning mediation.

The claim that they explore prior knowledge and use it as a platform to build new concepts seems inconsistent with their poor articulation of prior knowledge as mentioned earlier in this chapter. These strategies were also suggested in the NSC diagnostic reports as shown in Table 5.4. The analysis of the teachers' responses to the question exploring their TSPCK showed that they could not adequately articulate their TSPCK for the topic of Work, Energy, and Power. This finding is consistent with Mazibe et al. (2020) who also concluded that teachers could not adequately articulate their PCK and Nyembe (2022) who observed that teachers lacked adequate TSPCK on Work, Energy, and Power.

9.3.1.2 Findings from the semi-structured interviews – Teacher language usage and views on textbook language

The semi-structured interviews also explored the teachers' language usage and their views on the accessibility of the textbook language for their respective learners. The data revealed that these teachers did not always stick to the LoLT. This finding is consistent with Clegg and Afiska (2011) and Prinsloo et al. (2018), who support the view that learners learn concepts better when presented in their home languages.

The four teachers seemed to agree that there are instances where they must explain concepts in IsiXhosa for the learners to understand. Teachers used IsiXhosa when mediating learning by using translations, code-switching, and code-mixing. It can be said therefore that the teachers were using spontaneous translanguaging in their classrooms. This finding is consistent with Probyn (2001) who used the metaphor 'smuggling vernacular into the classroom' to refer to the practice of bringing in learners' home language into the classroom 'illegally' despite the LoLT being English. In addition, teachers allowed their learners to ask questions or give verbal responses in IsiXhosa, but all written work was in English. This finding is also consistent with Msimanga and Lelliot (2014) who reported that 90% of group discussions were carried out in IsiXhosa but were translated into English when reporting and writing.

There were mixed views about the accessibility of the English used in the learner textbooks. In this regard, Dlamini and Ms A thought the language was accessible while Nimjou and Rhadie thought otherwise. Dlamini believed it was because the learners had poor reading skills that they failed to fully comprehend the examination questions. Rhadie maintained that the textbook language was inaccessible and indicated that she resorted to translating some texts into IsiXhosa for the benefit

of her learners and Nimjou said the level of English in the textbook was “above their pay grade” (learners). This finding (in Nimjou and Rhadie’s view) is consistent with findings from scholars such as Letsoalo (1996) and Lodge (2020) who concluded that textbook language was too complex and confusing to English second language learners.

To sum up, all the teachers indicated that they incorporated IsiXhosa in their teaching although the degree to which they did so varied from teacher to teacher. There were mixed views in terms of the accessibility of the language used in textbooks and in examinations.

9.3.1.3 Findings from document analysis

Co-analysing curriculum documents such as the learner textbook, the CAPS document and the NSC diagnostic reports provided some valuable learning that contributed considerably towards the development of the teachers’ PCK.

The first document analysed was the CAPS document which details the SMK for the South African Physical Sciences curriculum from Grade 10 to Grade 12. From this document, we identify concepts related to the topic of Work, Energy, and Power. This was the prior knowledge that teachers expected learners to have when constructing new knowledge and assisting the teachers in identifying their learners’ ZPD (Vygotsky, 1978). This is also the knowledge that I expected teachers to articulate during the interviews (see Section 5.1.2). The same document also guides teachers in terms of the time they should spend on each topic and sub-topic. This is what informed our planning for the teaching of the topic in terms of time allocation.

One textbook, *Solutions for All* by du Plessis et al. (2013) was analysed as it was the one used by three of the four teachers in the CoP that were teaching Grade 12. It became clear that some of the textbook examples were from unfamiliar contexts as far as the learners’ environments were concerned. For instance, the chapter on Work, Energy, and Power began with a photo of a skier descending a mountain and yet another example is that of a man dragging a block of ice.
The next set of documents the PLC analysed was the NSC diagnostic reports for Physical Sciences for 2017–2023. As I stated earlier, these reports are compiled from a statistically representative sample drawn from all the final matric examination scripts and the content of the reports can therefore be used as a good indicator of the general performance of the candidates. The data gathered from these reports was valuable for the overall objective of the study, that is, to support

the development of the teachers' TSPCK. The focus was on the sections on the reports that dealt with questions on Work, Energy, and Power. The following were the key findings from the diagnostic reports used as resources for developing the teacher PCK in preparation for teaching. From the general comments subsection of the reports, we identified the following three aspects that informed our discussions as we prepared to teach the topic of Work, Energy and Power: 1) Grades 10 and 11 work is poorly understood hence prior knowledge needs to be explored before teaching new concepts; 2) free-body diagrams were poorly drawn and teachers were encouraged to emphasise this aspect; and 3) poor application of mathematical principles in problem-solving.

The next subsection in the diagnostic reports focused on common errors and misconceptions. One of the five components of TSPCK according to Mavhunga and Rollnick (2013) is the teachers' knowledge of relevant prior knowledge and misconceptions. The data from the documents helped us in the lesson planning stage and we made sure to discuss these common misconceptions. The teachers' poor articulation of prior knowledge mentioned earlier in this chapter (see Section 9.3.1.2) also led us to add a section where we noted the specific prior content knowledge and common misconceptions relevant to that lesson (see Appendix D). This innovation emerged from the study from a South African perspective. The identified errors and misconceptions were summarised into three categories: definitions and statements of principles/laws, conceptual understanding and application and calculation errors (the details are presented in Section 5.5.3.2). The last section of interest in the diagnostic reports analysed was on suggestions for improvements. Essentially, this section provided some CTS. The analysis of these strategies was summarised as follows: integration of concepts; problem-solving approach, understanding conservative and non-conservative forces, calculation and equation emphasis, using visualisation and simulations, and work-energy theorem awareness. These strategies were also valuable for the lesson preparation discussions.

9.3.2 Findings from Phase 2

Phase 2 of the study was the beginning of the intervention and built on findings from Phase 1. Primarily, the phase sought to answer the following research question (part b of research question 2):

1. What do Grade 12 Physical Science teachers learn through:
    c. Capacity-building workshops focusing on the co-development of exemplar

lessons on Work, Energy, and Power that consider everyday and home language?

For us to co-develop the lesson plans it was necessary to begin with an orientation workshop which focused on introducing the participants to the research process and the concept of pedagogical translanguaging. This workshop also sets the tone for the rest of the intervention. The deliberations during the workshop made it clear that I was not researching the participants, and they were co-creators of knowledge – hence we called the group a PLC because I was also a learner. This is demonstrated by the themes that I presented and discussed in Section 6.2.

The PLC's focus was to support the members in developing their PCK. In response to the criticism of teacher professional development practices made by scholars such as Bantwini (2012; 2018) and Ono and Ferreira (2010), the PLC in this study aimed to take a more interactive and consultative approach. Key themes that ensured this approach to teacher professional development were identified (see Sections 6.2.4–6.2.7). The key findings from the orientation workshop set the stage for the PLC to be "about educators, for educators, by educators, and with educators" (Ngcoza & Southwood, 2019, p. 3). The rest of the workshops were conducted based on the interactive and consultative atmosphere that had been established in the orientation workshop.

There were three workshops after the orientation one and these focused primarily on preparing for the lessons. These lesson workshops made a significant contribution towards achieving the overall objective of the study, that is, to develop/improve the teachers' TSPCK on the topic of Work, Energy, and Power. Diagnostic reports compiled from the analysis of NSC candidates' examination scripts provided valuable data as mentioned in Section 9.3.1.3. During these workshops, the findings were used to develop the teachers' PCK. This made the teacher development process relevant to the needs of the teachers and the PLC became a vehicle to support these needs (Brodie & Borko, 2016). Furthermore, this was an example of how to make use of NSC diagnostic reports as resources for professional teacher development.

The discussions on common errors and misconceptions identified in the diagnostic reports and suggestions for improvement (CTS) informed the format and content of the lesson plans. For example, we added sections highlighting the prior content knowledge relevant to the lesson and common misconceptions about the topic. This was an innovation from this study as these two

aspects (especially misconceptions) are rarely highlighted in lesson plans. As highlighted earlier, the focus was on co-construction of knowledge and co-learning. The lesson plan development process was collaborative, especially concerning the translanguaging aspect where the research participants took centre stage and the role of the MKO shifted to them. The process was as important as the product.

Studies reviewed have highlighted that in South African schools, the LoLT is a major contributing factor to poor learner performance in Science (see Msimanga & Erduran, 2018; Msimanga & Lelliott, 2014; Probyn, 2015). Consequently, there were calls to incorporate learners' home languages in teaching and learning Science (see Clegg & Afiska, 2011; Prinsloo et al., 2018). In support of this notion, Mavuru and Ramnarain (2020) pointed out that there is a research gap on how to incorporate the learners' home languages in the teaching of Science. It is this identified gap that this study sought to fill during the workshops which focused on lesson planning that applied pedagogical translanguaging as a practical approach to incorporating the learners' home language in a purposeful and planned manner.

Translanguaging has been identified as a pedagogical process that can mitigate the well-researched problem of the LoLT being a barrier to accessing powerful knowledge such as Science. Scholars such as Cenoz (2021) emphasise the aspect of purpose and preparedness in using two languages in the mediation of learning. Herein lies the value of lesson plans – from the workshops, we produced lesson plans that explicitly indicated the translanguaging strategies to be used by the teachers. This is yet another innovative aspect of the lesson plans that emanated from this study. Moreover, the lesson plans had a section titled 'Language Notes' composed of the concept glossary developed by the teachers during the lesson plan preparation workshops. The concept glossary developed by the PLC is shown in Table 6.3 in Section 6.3.6.

9.3.3 Findings from Phase 3

This phase was made up of the enactment of the lessons planned in Phase 2. The data from the recorded lesson plans was presented and analysed in Chapter Seven. The analysis focused on how the teachers demonstrated the TSPCK component (Mavhunga & Rollnick, 2013) and enacted pedagogical translanguaging. The data gathered in this phase sought to answer the following

questions:

3. What are the effects of the PLC's intervention on:

    a) The quality of the participant teachers' bilingual mediation of Work, Energy, and Power in their lessons?
    b) The participant teachers' TSPCK on Work, Energy, and Power?

The two teachers used different translanguaging techniques in their classrooms – code-switching, code-mixing, versioning and translation. In addition, reference was made to some of the terms in the concept glossary that was co-developed by the PLC. As the teachers used these techniques, they also modelled this translingual practice for the learners. Consequently, learners were motivated to interact with the teachers and with the concepts being learned. The borrowing and versioning of English terms into IsiXhosa seemed to have mitigated the problem of a lack of IsiXhosa terms for English scientific terms such as 'to resolve a force' which was to *'ukurizolva i-*force*'*. This practice (versioning) is useful when learners have developed an understanding of the concept or phenomenon in questions on resolving forces for example.

Concepts such as force and energy were part of an important class discussion in one of Nimjou's lessons. Several studies (see Dega & Govender, 2016; Irmak et al., 2023) have indicated that these concepts are often confused. In the local context, the use of the same term *'amandla'* for the three concepts has been identified as a contributing factor to the confusion between these concepts (Mapfumo, 2016). The class could distinguish between force and potential energy when teachers used learners' home language as a resource. Force was described as "*amandla okutshiliza okanye okutsala"* (a push or pull) while energy (potential) was described as "*amandla agciniweyo onokuwasebenzisa"* (store up energy).

Overall, this study attempted to demonstrate how translanguaging can be planned for and enacted in a Science lesson when learners and teachers share the same home language. This was done using several strategies such as code-switching, code-mixing and versioning and translating some texts into the learners' home language. The use of the learners' full linguistic repertoire enabled the teachers to contextualise the concepts. For example, Nimjou compared the everyday meaning of work to the physics meaning as a way of explaining the concept of 'work done' in Science. Translanguaging leads to transknowledging when knowledge is developed by applying both

Indigenous and Western epistemologies (Stroud & Kerfoot, 2020). The use of IsiXhosa and English as one hybrid language system fused the Indigenous and Western language systems. Language is a cultural artefact (Vygotsky, 1978), and through using two languages, the learning aspects of both cultures were used in knowledge construction.

After the lesson preparation workshops, the teachers went on to enact the co-planned lessons. The ePCK for the topic of Work, Energy and Power was not always the same as the plPCK. The plPCK for the study was co-planned since the development of the teachers' PCK was taken from a sociocultural perspective which views the contraction of knowledge as a social activity. Although there was co-construction of knowledge the internalisation of that knowledge differed from individual to individual. This might be one of the reasons why the enactment of the lessons was not the same. In addition, the teachers' personal knowledge of their learners may also be another determining factor in how they enacted the co-planned lessons. This finding of the lack of consistency between the plPCK and the ePCK agrees with those of Mazibe et al. (2020) who concluded that the plPCK as presented in lesson plans does not always translate into ePCK observed from teachers' lessons.

9.3.4 Findings from Phase 4

Phase four was the reflections on the intervention. The reflections were in two categories: the enactment of the lesson plans and the PLC vehicle for professional development. The data gathered in this phase sought to answer the following question:

4. What are teachers' reflective insights and perspectives on the intervention's effectiveness, challenges, and outcomes?

When reflecting on the lessons, teachers noted that allowing and encouraging learners to ask questions and answer without being restricted to using English enabled them to engage more with the teacher, each other and most importantly, with the content. However, the teachers lamented that they could not allow learners to code-mesh when writing notes as initially planned. They were worried that the learners might be penalised if they used the language practice in their final NSC exam. This restricted translanguaging practices to oral discussions. This finding is consistent with Probyn's (2015) findings about the limited use of translanguaging practices. Rhadie highlighted that they faced difficulties with the translation of terms and parts of texts from English to IsiXhosa as it was time-consuming and difficult.

The teachers also reflected on the process of lesson preparations and the activities of the PLC. They applauded the PLC for giving them opportunities to collaborate on lesson plan development and share their experiences. Moreover, the teachers appreciated the PLC for enabling them, through the deliberations, to have deeper insight into the concepts associated with the topic of Work, Energy, and Power. The way the researcher allowed the participants to be co-creators of the knowledge was also appreciated. The translingual approach was also highlighted as valuable new knowledge that they developed in the process.

9.4 New Knowledge

In this study, I focused on supporting Grade 12 teachers in developing their TSPCK on the topic of Work, Energy, and Power. This was a new perspective since similar studies usually focused on other grades and did not address teacher development, I use Mavhunga and Rollnick's (2013) five components of TSPCK as a framework. These components were used for teacher development and as an analytical lens for analysing curriculum documents such as the NSC examination diagnostic reports. In addition to the five components of prior knowledge including misconceptions, curriculum saliency, what is difficult to teach, CTS and representations including analogies, a sixth component, language of teaching and learning was added. It is my view that TSPCK is incomplete without the knowledge of the learners' language context and how to use their full language repertoires as a resource to mediate their knowledge construction. This additional new component became the focus of the lesson preparation.

The study focused on capacity building for translanguaging. Many studies recommend that teachers should tap into the learners' full language repertoires, but do not offer any guidance as to how they can do that. This study attempted to demonstrate how in-service teachers, who had never been capacitated on translingual mediation of learning before this study, can be supported to do it in a purposefully planned way. The lesson plans that were developed were innovative in several ways. First, they highlighted the misconceptions that the teachers should be aware of. Second, the lesson plans also had an English-Xhosa concept glossary, and third, they guided the teachers on the translanguaging techniques to use at various stages of the lesson.

The PLC approach to professional teacher development that was adopted was a departure from the usual approach that has been criticised as being ineffective by different scholars. For instance, the programmes were isolated from real classroom situations (Ono & Ferreira, 2010); ineffective in

addressing PCK (Bantwini, 2012); and offered in large groups that do not offer teachers opportunities for reflection (Bantwini, 2019; Murray, 2014). The PLC was a small group that addressed pertinent PCK issues informed by data and research studies. Furthermore, the PLC's teachers had a say in the content, timing, and structure of their professional development schedule. Research methods textbooks such as Cohen et al. (2018) and Creswell and Creswell (2018) give generic approaches to data-gathering methods and are written from a Western context. What they describe in terms of data-gathering methods and ethics is sometimes not applicable to African contexts and realities. After realising that my participants were busy people, I had to find innovative ways to gather my data. Instead of the textbook approaches for gathering data, I leveraged available technologies to respond to the practical realities of my participants.

Interviews were conducted using the MS Teams platform which also automatically generated the initial transcription (see Section 4.10). The same platform was used to conduct workshops with participants. ChatGPT was used to assist in the generation of initial codes and themes from transcribed data (see Section 4.11) The PLC's WhatsApp group was another innovation that I used to gather data. For instance, evaluation questions were posted on the group and participants responded with voice notes at times convenient to them. I then transcribed these voice notes and analysed them.

9.5 Limitations of the Study

This study was a case study with five IsiXhosa home language teacher participants teaching in schools where all learners were also IsiXhosa home language speakers. This is the first limitation as the results cannot be transferred to different contexts, such as where the teachers and learners do not share the same home language or where learners in the same classroom speak different languages. However, case studies are not intended to generalise findings, and some invaluable findings emerged in this study.

The second limitation was that teachers could not use or encourage learners to code-mesh either during notetaking or assessments. Since English and Afrikaans were the only two official LoLTs, teachers worried that learners might code-mesh when answering questions in their NCS Physical Sciences examination and risk being penalised.

The third limitation is related to the limited time and resources to conduct the study. I wanted to

observe and analyse more lessons together with the teachers. This would have led to adjusting the lesson plans and improvements in the translanguaging lesson planning. We could have another teaching cycle with different cohorts of learners from the same schools but with the same teachers. The fourth limitation was that because of the busy schedules of my participants, we could not meet in person for the semi-structured interviews and the capacity development workshops. Face-to-face encounters have the advantage of non-verbal communication which can be very valuable in communicating the participants' feelings and responses.'

The final limitation relates to the number of lessons that could be recorded for analysis. Out of the four grade 12 teachers in the study, I only managed to record a total of three lessons from two teachers. Had I been able to record at least one or two lessons from all the teachers, richer data could have been gathered for analysis.

9.6 Recommendations and Areas for Future Research

I make the following recommendations based on my research journey and the subsequent findings. First, launching government programmes such as the MTbBE demonstrates the South African DBE's commitment to bilingual education (Zimmermann & Ronza, 2023). However, there seems to be a top-bottom approach in that the programme did not start with teacher development, particularly after the pilot phase. Hence, I recommend that DBE roll out a programme whereby in-service teachers are grouped into PLCs like the one formed in this study. The PLC's focus should be to capacitate teachers in translanguaging techniques so they can effectively implement the MTbBE.

My second recommendation is that initial teacher education should include pedagogical translanguaging as part of the Science teaching methods courses/modules which will focus on how to use the learners' home languages as valuable prior knowledge and a resource for constructing Science knowledge.

In this study, available and accessible technologies such as WhatsApp and MS Teams were used successfully in the PLC activities. Hence, my third recommendation is that these technologies (and others) be adopted as legitimate channels for teacher professional development programmes. Furthermore, as this study demonstrated, technologically mediated teacher development programmes ought to include scheduling flexibility to reduce interference with educators' day-to-day duties.

Based on the findings from this study, I suggest some areas which need further research. To begin with, similar studies can be conducted in different contexts; for example, supporting teachers in developing their PCK on pedagogical translanguaging in classes where learners have different home languages. My second suggestion for future research is to focus on the code-meshing technique to enhance learners' bilingual approach in both formative and summative assessments. Only prior content knowledge was considered in this study when exploring teachers' TSPCK before the intervention. Consequently, my third suggestion for future research is to include learners' relevant prior everyday knowledge to Mavhunga and Rollnick's (2013) TSPCK component – prior knowledge including misconceptions or alternative conceptions. This will place research in a better position to explore how translanguaging can result in transknowledging. Building on prior everyday knowledge might enhance the knowledge exchange between IsiXhosa and English language systems and between the Indigenous and Western epistemologies (Heugh, 2021; Stroud & Kerfoot, 2020).

On reflection, I realised that this study could have been done using the Cultural Historical Activity Theory (CHAT). This view is informed by my realisation of contradictions between the different activity systems in the study, such as the PLC and the schools that the PLC members belonged to. More so, other elements of CHAT such as the historicity of the LoLT in South Africa were also present in this study. My fourth suggestion for future research is to use CHAT as the theoretical lens of studies similar to the present one.

9.7 Conclusion

In conclusion, the findings presented in this chapter shed light on how teachers articulate their PCK, how we established and PLC and co-designed lesson plans for teaching the topic of Work, Energy, and Power. The findings outline how the teacher enacted the lessons and highlight the pedagogical translanguaging techniques that they employed and other elements of TSPCK. These results contribute significantly to the existing body of knowledge in professional teacher development and pedagogical translanguaging in Science using English and IsiXhosa. Furthermore, valuable insights into how to support Grade 12 Physical Sciences teachers to develop their TSPCK (with special emphasis on pedagogical translanguaging) are offered. However, this research also opens avenues for further research on pre-service and in- service teacher development on bilingual/multilingual pedagogies and Physical Sciences, especially in contexts where the LoLT differs from the learners' home language.

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APPENDICES

Appendix A: Ethical Clearance Certificate

RHODES UNIVERSITY
Where leaders learn

Rhodes University, Education Faculty
Research Ethics Committee
PO Box 94, Makhanda, 6140, South Africa
Tel: +27 (0) 46 603 8393
Fax: +27 (0) 46 603 8028
email: e.rosenberg@ru.ac.za

https://www.ru.ac.za/researchgateway/ethics/

14 March 2023

Prof Kenneth Ngcoza

Education Department

K.Ngcoza@ru.ac.za

Dear Prof Kenneth Ngcoza and Mr Alfred Mapfumo

Re: Supporting Grade 12 Physical Sciences teachers in improving their PCK of the topic work and energy in the Eastern Cape Province

APPLICATION NUMBER: 2022-5915-7312

This letter confirms that your research ethics application has been reviewed and **APPROVED** by the Education Faculty Research Ethics Committee (EF-REC). Your permission letter(s) where applicable have been received and you are free to proceed with your study.

Approval is granted for 1 year. An annual progress report is required in order to renew approval for an additional period. You will receive an email notifying you when the progress report is due.

Should any substantive change(s) be made during the research process, that may have ethical implications, you should notify the Education Faculty REC Chair via email. This includes changes in investigators. The REC Chair will advise as to whether a new application is necessary.

Do keep this clearance letter secure and accessible throughout your study and after its completion. It will be needed when a thesis is examined and when publications are submitted to journals.

Please also submit a brief report to the REC Chair on the completion of the research. This can be done via email. The purpose of this report is to indicate whether the research was conducted successfully and whether any ethics-related matters arose that the committee should be aware of, in order to guide future studies.

Sincerely,

E Rosenberg

Prof Eureta Rosenberg

Chair: Education Faculty Research Ethics Committee

Page 1 of 1

Appendix B: Buffalo City Metropolitan District Permission Letter

Province of the
EASTERN CAPE
EDUCATION

BUFFALO CITY METRO EDUCATION DISTRICT

OFICE OF THE DISTRICT DIRECTOR

DR WB Rubusana Building,NU 1 Mdantsane,East London,5200 SOUTH AFRICA
Enquiries: **Ms N.Godlo Tel: 043 760 0 383/043 7600 701,Fax :043 7600 545 Email:**Nolusindiso.Godlo@ecdoe.gov.za
Website:www.ecdoe.gov.za

14 February 2023

Flat 29.20,
Sohco Village,
Amalinda, East London

Dear Mr Mapfumo

REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN THE BUFFALO CITY METRO EDUCATION DISTRICT

Approval is hereby granted for you, Mr Mapfuna to conduct research involving Five (5) Schools within the Buffalo City Metro District: **Ngwenyathi High, Sikhulile High, Kusile High, Sinethemba High and Khulani High School** with the topic **"SUPPORTING GRADE 12 PHYSICAL SCIENCES TEACHERS IN IMPROVING THEIR PCK OF THE TOPIC WORK AND ENERGY IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA"** as part of your study towards the Ph.D Student in Science Education qualification at Rhodes University.

This permission is granted provided that you make proper arrangements with the affected schools and to ensure that tuition time is not disrupted.

We wish you well in your endeavours.

Yours faithfully

V.N. MABECE

DISTRICT DIRECTOR- BCMED

growth

NDP

Appendix C: An Example of a Permission Letter (School A)

The Principal: **Kusile High School**
Buffalo City Metropolitan District

15 February 2023

Dear Sir/Madam

Re: Request for permission to conduct educational research with the Physical Science Teacher

I am Alfred Khumbulani Mapfumo (Student number: 10M7590), a part-time Ph.D. student in Science Education at Rhodes University and a Teaching Development Specialist at Walter Sisulu University in East London. I hereby humbly request your permission to conduct my research study with the Physical Sciences teacher at your school.

Your Physical Science teacher, I, and teachers from other selected schools from around Mdantsane will form a Physical Sciences Professional Learning Community (PSPLC). The study is expected to commence in the first quarter of 2023 and ends in the second quarter of 2023. The purpose of this study is to explore working with Physical Sciences teachers to co-develop and enact lessons that combine isiXhosa and English (translanguaging) in the teaching and learning of the problematic Physics concepts of Work and Energy. This approach is intended to make Physical Sciences more accessible the rural and township learners that are learning the subject in a language that they have not yet mastered well enough. This study is well-timed considering that Physical Sciences examination papers in some districts are now bilingual (English & IsiXhosa) and yet the teachers are not capacitated to teach and assess bilingually from their initial teacher education.

This study will be developmental in nature and will involve several face-to-face and online workshops with the participating teachers where curriculum documents, textbooks, and NCS examination diagnostic reports will be analysed with the aim of getting a clear understanding of the concepts and developing teaching strategies that employ pedagogical translanguaging between English and IsiXhosa. Additionally, the teachers would be asked to video record themselves as they teach using lessons developed by the group, and these recordings will be viewed by the PSPLC with the aim of developing each other's teaching strategies.

For further details or for any issues of clarity do not hesitate to contact me via my Email: akmapfumo@gmail.com or my supervisor Prof K.M. Ngcoza, email: kngcoza@ru.ac.za and cellphone, 078 885 2143. Permission to carry out this study has been granted by Rhodes University and the ethics committee can be contacted using the contact details below.

Rhodes University, Research Office, Ethics
Ethics Coordinator: ethics-committee@ru.ac.za
T: +27 (0) 46 603 7335 F: +27 (0) 82 739 4378
Room 220, Main Admin Building, Drostdy Road
Makhanda,
6139

May you kindly complete the reply slip below.

Permission is granted ☑ Permission is not granted ☐

Name: B.L. MYANGIWE Designation: PRINCIPAL

Signature: Date: 02/03/2023

Yours Sincerely

Alfred Khumbulani Mapfumo
(Ph.D. Scholar, Rhodes University)

KUSILE COMPREHENSIVE HIGH
Malimngo Street
Duncan Village, East London 5201
Cell: 073 [illegible]
Date:.....
K:Principal.200200333@ecschools.org.za

Appendix D: Lesson Plan

<table>
<tr><td>Educator</td><td></td><td>Class:</td><td>12</td></tr>
<tr><td>Topic</td><td>Work, Energy, and Power</td><td>Dates:</td><td></td></tr>
<tr><td colspan="2">Prior Knowledge
1. Vector and scalar quantities.
2. Components of vectors/forces
3. Newton’s Laws of Motion</td><td colspan="2">Common Misconceptions
• Work and energy are vectors and allocated signs – misconception, these are scalar quantities.
• Calculating ΔK using the formula $\Delta K = \frac{1}{2}m(v_f - v_i)^2$ instead $\frac{1}{2}(v_f^2 - v_1^2)$
• Defining the work-energy theorem incorrectly viz. the net work done is ‘directly proportional to’ instead of ‘equal to the change in kinetic energy</td></tr>
<tr><td colspan="4">Lesson Outcomes</td></tr>
<tr><td>Lesson Number</td><td colspan="3">By the end of the lesson of the week learners should be able to:</td></tr>
<tr><td>1</td><td colspan="3">1.1 Define the work done on an object by force.
1.2 Classify work as a scalar quantity and is measured in joules (J)
1.3 Give examples of when an applied force does and does not do work on an object.
1.4 Calculate the work done on an object when a force F applied at an angle θ to the direction of motion causes the object to move distance Δx, using W=FΔxcosθ</td></tr>
</table>

2	2.1 Calculate the net work done on an object when two or more forces are applied on a horizontal surface.
	2.2 Calculate the net work done on an object when two or more forces are applied on an inclined surface.
3	3.1 Solve problems involving net work done calculations. 3.2 State the work-energy theorem in words and as an equation. 3.3 Apply work -energy theorem on horizontal planes.
4	4.1 Apply the work-energy theorem to objects on inclined planes (frictionless and rough)

Content	Language Notes:
• Definition of work • Network calculation • Work-energy theorem • Application of work-energy theorem	1. **Displacement** – (Umlinganiselo woshenxiso/wokufuduswa). Umlinganiselo wokusuka kwento endaweni isiya kwenye, ukuqala apho isuka khona ukuya apho iphele khona ngomgca othe ngqo. 2. **Kinetic** - ezinxulumene okanye eziphuma kwintshukumo. 3. **Kinetic Energy** - Amandla into enawo ngenxa yokuba ikwintshukumo. 4. **Gravitational potential energy** – ngamandla agcinekileyo kwinto ngokwendawo ekuyo ngaphezulu komhlaba. 5. **Friction** – Ukukhuhlana phakathi kwezinto ezimbini ezinamatheleneyo (ezidibeneyo).
	6. **Conservation** – ukugcina into ikwimo ebekuyo. 7. **To conserve** - ukugcina into injengoba ibinjalo (ikwimo ebikuyo) ekuqaleni nangona isebenza/isetyenziswa. 8. **Conservative force** – umsebenzi owenziwe ngalamandla uxhomekeke kwisiqalo nesiphelo sendlela ehanjiweyo, hay kumgama wayo.

Teacher Activities: **(Lesson 1)** 1. Factual recall test/question answer session to check on prior content knowledge. 2. Explain the concept of 'work done' with real-life examples. 3. Use code-mixing and code-switching to explain terms such as 'displacement.' 4. Show how to use the work formula in calculations. 5. Comment on and correct learners' presentations 6. Give homework (1) questions. Pg	**Learner Activities** 1. Write test/ answer questions orally. 2. Write their own notes using code-meshing. 3. Practice using the formula for work done in pairs. 4. Share with the class on the board. 5. Do corrections. 6. Note homework questions
(Lesson 2) 1. Review homework 2. Give examples on calculating net work done, using code-mixing 3. Give learners classwork. 4. Check and assist learners as they work on classwork. 5. Give homework (2) questions pg	1. Present answers to the homework 2. Write their own notes using code-meshing 3. Do classwork in pairs. Discussing using both English and IsiXhosa 4. Note down homework questions

(Lesson 3) 1. Review homework 2. Introduce the work – energy theorem. 3. Use translation/glossary for the term 'kinetic energy' 4. Give examples of using the work-nergy theorem on horizontal planes. 5. Comment on and correct learners' presentations 6. Give homework (2) questions	1. Share homework answers on the board. 2. Do corrections. 3. Write their own notes using code-meshing 4. Work through classwork in pairs using both English and IsiXhosa for discussion and English only for the written solutions 5. Share solutions with the class. 6. Note down homework questions
(Lesson 4) 1. Review homework 2. Give examples of application of work-energy theorem on horizontal planes using both English and IsiXhosa 3. Conduct a question-and-answer session in both English and IsiXhosa on concepts covered during the weeks. 4. Gives learners' homework questions	1. Share homework answers on the board. 2. Make their own notes using code-meshing 3. Do corrections. 4. Work through classwork in pairs using English and IsiXhosa for discussing and English on for the written solutions 5. Ask and answer questions orally
Assessment Tasks	**Tools**

1. Homework 1 pg. 2. Homework 2 pg. 3. Homework 3 pg. Homework 4 pg.	All assessments have memos.
Enrichment Learners who deserve the enrichment will be given past examination question papers to practice solving more problems.	
EDUCATOR REFLECTIONS: **What went well:**	

Challenges faced:

Comments on the inclusion of IsiXhosa in both teaching and assessment and learner response to it.

Appendix E: Interview Schedule

Introduction

Thank you for agreeing to participate in this study. I am interviewing you to better understand how you typically teach the topic of Work, Energy, and Power. This interview is part of my study on Exploring how Grade 12 teachers can teach the topic by planning and enacting lessons that are in both English and IsiXhosa. This interview is about your experiences and there are no right or wrong answers to any of my questions, I am interested in your own experiences. Feel free to ask me to clarify where necessary and also be free to ask any relevant questions.

I kindly ask for your permission to record this interview for the purpose of assisting me to write down the important information you are about to share with me without mission anything.

1. In your view, what concepts do you consider as the key concepts that learners must know/remember from earlier grades before they can successfully learn the topic of Work, Energy, and Power?

2. What do consider to be key concepts that make up the topic of Work energy and Power at the Grade 12 level?

3. From your experiences, which of the concepts that you mentioned in questions 1 and 2 do learners typically have problems remembering or comprehending?

4. How do you typically assist learners to understand the concepts that you identified in questions 1 and 2?

5. Please tell me how you use representations (analogies, graphs, pictures etc) in the teaching of this topic?

6. The official language of teaching and learning is English.

    a. Do you use English **only** in your teaching of the topic of Work, Energy, and Power? (YES/NO)

    b. If your answer to (a) is NO, kindly describe your language usage when teaching this topic.

    c. Are there any specific areas or terms within the topic that you find particularly difficult

to teach/explain in English? If there are, please name them.

7. How do you normally handle cases where learners have difficulty comprehending the terms/areas identified in question 6c (if this occurs)?

8. Please comment on the language and the contexts and examples used in the textbooks and other reading materials that learners used.

9. Thank you for sharing your experiences. What else can you tell me about your teaching experiences with this topic that I did not ask.